NR483 DT JANUARY 2024

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

NR483 - JANUARY 2024

CONSOLIDATED JANUARY 2024 EDITION
PARTS A - B - C - D - E

NAVAL SHIPS

BUREAU VERITAS

BUREAU VERITAS
RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

NR483 - JANUARY 2024

This document contains the consolidated January 2024 edition, Part A to Part E.

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These rules are provided within the scope of the Bureau Veritas Marine & Offshore General Conditions, enclosed at the end of Part A of NR467, Rules for the Classification of Steel Ships. The latest version of these General Conditions is available on the Bureau Veritas Marine & Offshore website.

PART A
CLASSIFICATION AND SURVEYS
NR483 A DT R05 JANUARY 2024

PART B
HULL AND STABILITY
NR483 B DT R05 JANUARY 2024

PART C
MACHINERY, SYSTEMS AND FIRE PROTECTION
NR483 C DT R05 JANUARY 2024

PART D
SERVICE NOTATIONS
NR483 D DT R05 JANUARY 2024

PART E
ADDITIONAL CLASS NOTATIONS
NR483 E DT R05 JANUARY 2024

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NR483

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part A
Classification and Surveys

Chapter 1	Principles of Classification and Class Notations
Chapter 2	Assignment, Maintenance, Suspension and Withdrawal of Class
Chapter 3	Scope of Surveys (all ships)
Chapter 4	Scope of Surveys in Respect of the Different Services of Ships
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January 2024

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Part A
Classification and Surveys

CHAPTER 1
PRINCIPLES OF CLASSIFICATION AND CLASS NOTATIONS

Section 1 General Principles of Classification

Section 2 Classification Notations

Section 1 General Principles of Classification

1 Principles of classification

1.1 Purpose of the Rules

1.1.1 The Rules published by the Society give the requirements for the assignment and the maintenance of class for seagoing surface naval ships, in particular frigates.

Class assigned to a ship reflects the discretionary opinion of the Society that the ship, for declared conditions of use and within the relevant time frame, complies with the Rules applicable at the time the service is rendered. Class requirements can be temporarily suspended under emergency conditions (war, terrorist attack,...) declared by the Naval Authority.

Note 1: The general conditions of classification are laid down in the Preamble.

1.1.2 The application criteria of the different parts of the present Rules are the following:

- Part A - Classification and Surveys applies to all ships.
- Part B - Hull and Stability, Part C - Machinery, Systems and Fire Protection, Part D - Service Notations and NR216 - Materials and Welding apply to seagoing ships whose hull is of welded steel construction. Where necessary, the extent of application is more precisely defined in each chapter of these parts of the Rules.
- Part E - Additional Class Notations applies, at the request of the Interested Party, to all ships.

The classification of ships other than those dealt with in the above-mentioned Part B, Part C, Part D, Part E and NR216 is covered by specific Rules published by the Society.

1.2 General definitions

1.2.1 The following general definitions are used in these Rules :

- Society means the Classification Society with which the ship is classed.
- Rules means these Rules for the Classification of Ships and documents issued by the Society serving the same purpose.
- Surveyor means technical staff acting on behalf of the Society to perform tasks in relation to classification and survey duties.
- Survey means an intervention by the Surveyor for assignment or maintenance of class as defined in Part A, Chapter 2, or interventions by the Surveyor within the limits of the tasks delegated by the Naval Authorities.
- Interested Party means a party, other than the Society, having responsibility for the classification of the ship, such as the Owner of the ship and his representatives, or the Shipbuilder, or the Engine Builder, or the Supplier of parts to be tested.
- Navy means the Governmental Body to whom the State or the Defence Department of the State has delegated responsibility for ownership of naval ships. The Navy is responsible for the requirement, procurement and through life support and maintenance of the naval ship.
- Naval Authority means the authority nominated by the Navy responsible for providing regulation associated with procurement and support of the ship. The Naval Authority may also be responsible for identifying appropriate standards, auditing and classification. The Naval Authority could be a Navy department, Statutory Authority or an independent organization with appropriate standing.
- Owner means the party having the responsibility to keep the ship seaworthy, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2.
- Shipbuilder means the party having the responsibility of the construction of the ship and of her classification at the assignment phase.
- Approval means the examination and acceptance by the Society of documents, procedures or other items related to classification, verifying solely their compliance with the relevant Rules requirements, or other referentials where requested.
- Type approval means an approval process for verifying compliance with the Rules of a product, a group of products or a system, and considered by the Society as representative of continuous production.
- Essential service is intended to mean a service necessary for a ship to proceed at sea, be steered or manoeuvred, or undertake activities connected with its operation, and for the safety of life, as far as class is concerned.
- The gross tonnage (GT) is the measure of the overall size of a ship as determined in accordance with the provisions of the 1969 International Convention on Tonnage Measurement of Ships. It is expressed as a figure without units.

1.3 Meaning of classification, scope and limits

1.3.1 The classification consists of:

- the development of Rules, guidance notes and other documents relevant to the ship, structure, material, equipment, machinery and any other item covered by such documents

- the examination of plans and calculations and the surveys, checks and tests intended to ensure that the ship meets the Rules (refer to Ch 2, Sec 1)
- the assignment of class (see Ch 2, Sec 1) and issue of a Certificate of Classification, where the above Rules are met
- the periodical, occasional and class renewal surveys performed to verify that the ship in service meets the conditions for maintenance of class (see Ch 2, Sec 2).

1.3.2 The Rules, surveys performed, reports, certificates and other documents issued by the Society, are in no way intended to replace or alleviate the duties and responsibilities of other parties such as Navy, Naval Authority, Designers, Shipbuilders, Manufacturers, Repairers, Suppliers, Contractors or Sub-contractors, actual or prospective Owners or Operators, Charterers, Brokers, Cargo-owners and Underwriters. The Society cannot therefore assume the obligations arising from these functions, even when the Society is consulted to answer inquiries concerning matters not covered by its Rules, or other documents.

The activities of such parties which fall outside the scope of the classification as set out in the Rules, such as design, engineering, manufacturing, operating alternatives, choice of type and power of machinery and equipment, number and qualification of crew or operating personnel, lines of the ship, trim, hull vibrations, spare parts including their number, location and fastening arrangements, life-saving appliances, and maintenance equipment, remain therefore the responsibility of those parties, even if these matters may be given consideration for classification according to the type of ship or additional class notation assigned.

The classification-related services and documents performed and issued by the Society do not relieve the parties concerned of their responsibilities or other contractual obligations expressed or implied or of any liability whatsoever, nor do they create any right or claim in relation to the Society with regard to such responsibilities, obligations and liabilities. In particular, the Society does not declare the acceptance or commissioning of a ship or any part of it, this being the exclusive responsibility of the Owner.

1.3.3 Unless otherwise specified, the Rules do not deal with structures, pressure vessels, machinery and equipment which are not permanently installed and used solely for operational activities such as dredging or heavy load lifting, workshops or welding equipment, except for their effect on the classification-related matters, as declared by the Interested Party the Naval Authority or the Owner, such as fire protection and ship's general strength.

During periods of construction, modification or repair, the unit is solely under the responsibility of the builder or the repair yard. As an example, the builder or repair yard is to ensure that the construction, modification or repair activities are compatible with the design strength of the ship and that no permanent deformations are sustained.

Note 1: Refer to [3.3] as regards the Owner's responsibility for maintenance and operation of the ship in relation to the maintenance of class.

1.4 Request for services

1.4.1 Requests for interventions by the Society, such as surveys during construction, surveys of ships in service, tests, etc., are in principle to be submitted in writing and signed by the Interested Party. Such request implies that the applicant will abide by all the relevant requirements of the Rules, including its Preamble.

The Society reserves the right to refuse or withdraw the class of any ship for which any applicable requirement of the Rules is not complied with.

1.5 Register of ship

1.5.1 Except when otherwise stated by the Owner, the Ship is published in the Register of Ships. This publication, which is updated by the Society, contains the names of ships which have received the Certificate of Classification, as well as particulars of the class assigned and non classified information concerning each ship.

Referring the additional notations, only these which publication is authorized by the Owner are mentioned in the Register.

2 Rules

2.1 Effective date

2.1.1 The effective date of entry into force of any amendments to the Rules is indicated on the inside front page of each Part of the Rules.

2.1.2 In principle, the applicable Rules for assignment of class to a new ship are those in force at the date when the contract between the Owner and the shipyard is signed.

2.1.3 Special consideration may be given to applying new or modified rule requirements which entered into force subsequent to the date of the contract, at the discretion of the Society and in the following cases:

- when a justified written request is received from the parties applying for classification
- when the keel is not yet laid and more than one year has elapsed since the contract was signed
- where it is intended to use existing previously approved plans for a new contract.

2.1.4 The above procedures for application of the Rules are, in principle, also applicable to existing ships in the case of major conversions and, in the case of alterations, to the altered parts of the ship.

2.1.5 The rule requirements related to assignment, maintenance and withdrawal of the class of ships already in operation, as detailed in Part A, Chapter 2 to Part A, Chapter 5, are applicable from the date of their entry into force.

2.2 Equivalence

2.2.1 The Society may consider the acceptance of alternatives to these Rules, provided that they are deemed to be equivalent to the Rules to the satisfaction of the Society.

2.2.2 Except when the alternative design and arrangements are:

- already approved by the Society on a ship with similar characteristics and operating conditions, or
- based on novel principles and features as indicated in [2.3.1],

a justificative engineering analysis of the alternative design and arrangements is to be submitted to the Society.

2.2.3 The engineering analysis submitted to the Society shall include, as a minimum, the following elements:

a) determination of the ship type and arrangement concerned

b) identification of the rule requirements with which the ship or the arrangement will not comply

c) identification of the potential hazards of the ship or arrangement concerned

d) identification of the relevant alternative standard or regulations, functional requirements and operating conditions

e) detailed technical description of the proposed alternative design and arrangements

f) technical justification or analysis of previous in service experience on ships of similar characteristics and operating conditions showing that the proposed design and arrangements comply with the alternative standard in d).

2.3 Novel features

2.3.1 The Society may consider the classification of ships based on or applying novel design principles or features, to which the Rules are not directly applicable, on the basis of experiments, calculations or other supporting information provided to the Society. The specific limitations may then be indicated on the Certificate of Classification.

2.4 Interpretation

2.4.1 The Society alone is qualified to decide upon the meaning, interpretation and application of the Rules and other classification-related documents. No reference to the Rules or other classification-related documents has any value unless it involves, accompanies or follows the intervention of the Society.

2.5 Disagreement and appeal

2.5.1 Any technical disagreement with the Surveyor in connection with the performance of his duties should be raised by the Interested Party as soon as possible.

The Interested Party may appeal in writing to the Society, which will subsequently consider the matter and announce its decision according to its established procedure.

3 Duties of the Interested Parties

3.1 International and national regulations

3.1.1 The classification of a ship does not absolve the Interested Party from compliance with any requirements issued by the Naval Authority.

3.1.2 When authorized by the Naval Authority concerned, the Society will act on its behalf within the limits of such authorization. In this respect, the Society will take into account the relevant requirements, survey the ship, report and issue or contribute to the issue of the corresponding certificates.

The above surveys do not fall within the scope of the classification of ships, even though their scope may overlap in part and may be carried out concurrently with surveys for assignment or maintenance of class.

3.2 Surveyor's intervention

3.2.1 Except for secrecy or operational restrictions, Surveyors are to be given free access at all times to ships in service which are classed or being classed, shipyards and works, to carry out their interventions within the scope of assignment or maintenance of class, or within the scope of interventions carried out on behalf of the Naval Authority, when so delegated.

3.2.2 Interested Parties are to take the necessary measures for the Surveyors' inspections and testing to be carried out safely. Interested Parties - irrespective of the nature of the service provided by the Surveyors of the Society or others acting on its behalf - assume with respect to such Surveyors all the responsibility of an employer for his workforce such as to meet the provisions of applicable legislation. As a rule, the Surveyor is to be constantly accompanied during surveys by personnel of the Interested Party.

Refer also to Ch 2, Sec 2, [2.5].

3.2.3 The Certificate of Classification and/or other documents issued by the Society remain the property of the Society. All certificates and documents necessary to the Surveyor's interventions are to be made available by the Interested Party to the Surveyor on request.

3.2.4 During the phases of ship design and construction, due consideration should be given to rule requirements in respect of all necessary arrangements for access to spaces and structures with a view to carrying out class surveys. Arrangements of a special nature are to be brought to the attention of the Society.

3.3 Operation and maintenance of ships

3.3.1 The classification of a ship is based on the understanding that the ship is loaded and operated in a proper manner by competent and qualified crew or operating personnel according to the loading, environmental, operating and other criteria on which classification is based.

In particular, it will be assumed that the draught maximum displacement of the ship in operating conditions will not exceed the maximum approved for the classification, that the ship will be properly loaded taking into account both its stability and the stresses imposed on its structures and that cargoes will be properly stowed and suitably secured and that the speed and course of the ship are adapted to the prevailing sea and weather conditions, and that the ship is operated in accordance with the applicable international and national regulations for the prevention and containment of marine pollution.

3.3.2 Any document issued by the Society in relation to its interventions reflects the condition of the ship as found at the time and within the scope of the survey. It is the Owner's responsibility to ensure proper maintenance of the ship until the next survey required by the Rules. It is the duty of the Owner to inform the Surveyor when he boards the ship of any events or circumstances affecting the class.

3.4 Use of measuring equipment and of service suppliers

3.4.1 General

Firms providing services on behalf of the Interested Party, such as measurements, tests and servicing of safety systems and equipment, the results of which may form the basis for the Surveyor's decisions, are subject to the acceptance of the Society, as deemed necessary.

The equipment used during tests and inspections in workshops, shipyards and on board ships, the results of which may form the basis for the Surveyor's decisions, is to be customary for the checks to be performed. Firms are to individually identify and calibrate to a recognized national or international standard each piece of such equipment.

3.4.2 Simple measuring equipment

The Surveyor may accept simple measuring equipment (e.g. rulers, tape measures, weld gauges, micrometers) without individual identification or confirmation of calibration, provided it is of standard commercial design, properly maintained and periodically compared with other similar equipment or test pieces.

3.4.3 Shipboard measuring equipment

The Surveyor may accept measuring equipment fitted on board a ship (e.g. pressure, temperature or rpm gauges and meters) and used in examination of shipboard machinery and/or equipment based either on calibration records or comparison of readings with multiple instruments.

3.4.4 Other equipment

The Surveyor may request evidence that other equipment (e.g. tensile test machines, ultrasonic thickness measurement equipment, etc.) is calibrated to a recognized national or international standard.

3.5 Spare parts

3.5.1 It is the Owner's responsibility to decide whether and which spare parts are to be carried on board.

3.5.2 As spare parts are outside the scope of classification, the Surveyor will not check that they are kept on board, maintained in a satisfactory condition, or suitably protected and lashed.

However, in the case of repairs or replacement, the spare parts used are to meet the requirements of the Rules as far as practicable; refer to Ch 2, Sec 2, [7.3.2].

Section 2 Classification Notations

1 General

1.1 Purpose of the classification notations

1.1.1 The classification notations give the scope according to which the class of the ship has been based and refer to the specific rule requirements which are to be complied with for their assignment. In particular, the classification notations are assigned according to the type, service and navigation of the ship and other criteria which have been provided by the Interested Party, when applying for classification.

The Society may change the classification notations at any time, when the information available shows that the requested or already assigned notations are not suitable for the intended service, navigation and any other criteria taken into account for classification.

Note 1: Reference should be made to Ch 1, Sec 1, [1.3] on the limits of classification and its meaning.

1.1.2 The classification notations assigned to a ship are indicated on the Certificate of Classification.

1.2 Types of notations assigned

1.2.1 The types of classification notations assigned to a ship are the following:

a) main class symbol

b) construction marks

c) service notations with additional service features, as applicable

d) navigation notations

e) additional class notations (optional).

The different classification notations and their conditions of assignment are listed in [2] to [6], according to their types.

1.2.2 As an example, the classification notations assigned to a ship may be as follows (the kind of notation shown in brackets does not form part of the classification notation indicated the Certificate of Classification:

I ✠ HULL • MACH

(main class symbol, construction marks)

frigate

(service notation)

unrestricted navigation

(navigation notation)

✠ AUT-CCS

(additional class notation).

2 Main class symbol

2.1 Main class symbol

2.1.1 The main class symbol expresses the degree of compliance of the ship with the rule requirements as regards its construction and maintenance. There is one main class symbol, which is compulsory for every classed ship.

2.1.2 The main class symbol **I** is assigned to ships built in accordance with the requirements of the Rules or other rules recognized as equivalent, and maintained in a condition considered satisfactory by the Society. The period of class (or interval between class renewal surveys) assigned to a ship is maximum 5 years; see Ch 2, Sec 2, [5].

Except for special cases, class is assigned to a ship only when the hull, propulsion and auxiliary machinery installations, and equipment providing essential services have all been reviewed in relation to the requirements of the Rules.

2.1.3 The class symbol **II** is assigned to ships which do not meet all requirements for class symbol **I**, but are deemed acceptable to be entered into the Register of Ships.

The period of class assigned to class symbol **II** ships is maximum 3 years, see Ch 2, Sec 2, [5].

3 Construction marks

3.1 General

3.1.1 The construction mark identifies the procedure under which the ship and its main equipment or arrangements have been surveyed for initial assignment of the class. The procedures under which the ship is assigned one of the construction marks are detailed in Ch 2, Sec 1.

3.1.2 One of the construction marks defined below is assigned separately to the hull of the ship and its appendages, to the machinery installation, and to some installations for which an additional classification notation (see [6] below) is assigned.

The construction mark is placed before the symbol **HULL** for the hull, before the symbol **MACH** for the machinery installations, and before the additional class notation granted, when such a notation is eligible for a construction mark.

When the same construction mark is assigned to both hull and machinery, the construction mark is assigned globally to the ship without indication **HULL** and **MACH** after the main class symbol.

If the ship has no machinery installations covered by classification, the symbol **MACH** is not granted and the construction mark will be placed before the symbol **HULL**.

3.1.3 The construction marks refer to the original condition of the ship. However, the Society may change the construction mark where the ship is subjected to repairs, conversion or alterations.

3.2 List of construction marks

3.2.1 The mark ✠ is assigned to the relevant part of the ship, when it has been surveyed by the Society during its construction in compliance with the new building procedure detailed in Ch 2, Sec 1, [2.1].

3.2.2 The mark • is assigned to the relevant part of the ship, where the procedure for the assignment of classification is other than those detailed in [3.2.1], but however deemed acceptable.

4 Service notations

4.1 General

4.1.1 The service notations define the type and/or service of the ship which have been considered for its classification, according to the request for classification signed by the Interested Party. At least one service notation is to be assigned to every classed ship.

4.1.2 The assignment of any service notation to a new ship is subject to compliance with general rule requirements laid down in Part B and Part C of the Rules, in NR216 Materials and Welding and, for some service notations, in the additional requirements laid down in Part D.

4.1.3 A ship may be assigned several different service notations. In such case, the specific rule requirements applicable to each service notation are to be complied with. However, if there is any conflict in the application of the requirements applicable to different service notations, the Society reserves the right to apply the most appropriate requirements or to refuse the assignment of one of the requested service notations.

4.1.4 A service notation may be completed by one or more additional service features, giving further precision regarding the type of service of the ship, for which specific rule requirements are applied.

4.1.5 The different service notations which may be assigned to a ship are listed in [4.2] to [4.10].

4.2 Frigate

4.2.1 The service notation **frigate** is assigned to ships designed for world wide operations and used either as centres of command or as a part of a task force or as an independent unit. They may have a variety of roles as air defence, anti submarine, sea defence or shore support.

They typically have displacement of more than 2000 tonnes, a length of more than 90 meters and comply with severe requirements.

The additional requirements of Ch 4, Sec 2 and Part D, Chapter 1 are applicable to these ships.

4.3 Aircraft carrier

4.3.1 The service notation **aircraft carrier** is assigned to ships designed for world wide operations and used either as centres of command or as a part of a task force or as an independent unit. They have the role of supporting aircraft operations at sea, with the capability to launch, recover and accommodate airplanes, unmanned aerial vehicles and helicopters.

They typically have displacement in excess of 20 000 tonnes, a length of more than 170 meters and comply with severe requirements.

The additional requirements of Ch 4, Sec 3 and Part D, Chapter 2 are applicable to these ships.

4.4 Corvette

4.4.1 The service notation **corvette** is assigned to ships designed for worldwide operations and used either as part of a task force or as an independent unit. They may have a variety of roles as anti-air, anti-submarine and sea defence and they generally have a helicopter capability.

They typically have displacement between 1000 and 2500 tonnes, a length between 60 and 90 meters and a maximum speed of more than 25 knots.

The additional requirements of Ch 4, Sec 2 and Part D, Chapter 3 are applicable to these ships.

4.5 Auxiliary naval vessel

4.5.1 The service notation **auxiliary naval vessel** is assigned to ships designed for world wide operations and are intended for underway replenishment vessels and fleet support vessels which carry and may transfer at sea oil, and possibly other solid and liquid supplies, like freshwater, stores, spare parts and ammunition.

The additional requirements of Ch 4, Sec 4 and Part D, Chapter 4, are applicable to these ships.

4.6 Amphibious vessel

4.6.1 The service notation **amphibious vessel** is assigned to ships designed for world wide operations and used either as centres of command, or as a part of a task force, or as an independent unit. They have the role of supporting helicopter and landing craft operations together with the transport of troops and vehicles.

They typically have a displacement in excess of 20 000 tonnes but smaller units can also be considered for this service notation.

The additional requirements of Ch 4, Sec 5 and Part D, Chapter 5 are applicable to these ships.

4.7 Military OPV

4.7.1 The service notation **military OPV** is assigned to ships dedicated to patrol and combat missions, serving as an independent unit, possessing a weapons system and generally having no operational limits based on weather conditions or sea state.

They have a variety of roles such as protection of the Economic Exclusive Zone, defense against terrorist attacks and other surveillance duties. These vessels patrol at either low or high speed.

The additional requirements of Ch 4, Sec 2 and Part D, Chapter 6 are applicable to these ships.

4.8 Landing craft

4.8.1 The service notation **landing craft** is assigned to craft designed for delivering troops and equipment ashore and restricted to vessels that can be docked in an amphibious mothership (length <60m).

They typically have a versatile deck structure to accommodate a range of vehicles and other loads. They are usually equipped with loading / unloading ramps, have structure reinforced for beaching loads and have mooring and towing capability.

The notation **landing craft** is completed by **-MOTHERSHIP (name of mother ship class)** when the mothership is already known and the limits for overall dimensions of the landing craft are mentioned inside the request for classification.

Note 1: Navigation notations to be assigned to landing craft are restricted to **coastal area** or **sheltered area**.

The requirements of Part D, Chapter 7 are applicable to these ships.

4.9 Unmanned Surface Vessel (USV)

4.9.1 The service notation **USV** is assigned to unmanned surface units.

The type of service is to be specified after the service notation.

Example: **USV / minehunter**.

The scope of application and the requirements for the assignment of the service notation **USV** are given in NR681 Unmanned Surface Vessels.

4.10 Special service

4.10.1 The service notation **special service** is assigned to naval ships for which, by reason of their design or mission, the granting of a specific service notation mentioned in Part D is not considered relevant, but where NR483 can nevertheless be applied.

Specific Rules of the Society and in particular the Rules for the Classification of Steel Ships (NR467) may also be applied to these ships.

An additional service feature may be specified after the notation (e.g. **special service - hospital vessel**) to identify the particular service the ship is intended for. The scope and criteria of classification of such units are indicated in a memoranda.

5 Navigation notations

5.1 Navigation notations

5.1.1 Every classed ship is to be assigned one navigation notation as listed in [5.2].

5.1.2 The assignment of a navigation notation, including the reduction of scantlings or specific arrangements for restricted navigation notations, is subject to compliance with the requirements laid down in Part B, Part C and Part D of the Rules and in NR216 Materials and Welding.

5.1.3 The assignment of a navigation notation does not absolve the Interested Party from compliance with any international and national regulations established by the Naval Authority for a ship operating in national waters, or a specific area, or a navigation zone. Neither does it waive the requirements in Ch 1, Sec 1, [3.3.1].

5.2 List of navigation notations

5.2.1 The navigation notation **unrestricted navigation** is assigned to a ship intended to operate in any area and any period of the year.

5.2.2 The navigation notations **coastal area** or **sheltered area** are only assigned to ships with the service notation **landing craft** as defined in [4.8].

The navigation notation **coastal area** is assigned to ships intended to operate only within 20 nautical miles from the shore and with a maximum sailing time of six hours from a place of refuge, including a mother ship, or a safe sheltered anchorage.

The navigation notation **sheltered area** is assigned to ships intended to operate in sheltered waters, i.e. harbours, estuaries, roadsteads, bays, lagoons and generally calm stretches of water and when the wind force does not exceed 6 Beaufort scale.

6 Additional class notations

6.1 General

6.1.1 An additional class notation expresses the classification of additional equipment or specific arrangement, which has been requested by the Owner.

6.1.2 The assignment of such an additional class notation is subject to the compliance with additional rule requirements, which are detailed in Part E of the Rules.

6.1.3 Some additional class notations, due to the importance of relevant equipment or arrangements, are assigned a construction mark, according to the principles given in [3.1.2]. This is indicated in the definition of the relevant additional class notations.

6.1.4 The different additional class notations which may be assigned to a ship are listed in [6.2] to [6.15], according to the category to which they belong. These additional class notations are also listed in alphabetical order in Tab 1.

Additional class notations from other Bureau Veritas Rules, such as NR467 Rules for the Classification of Steel Ships for example, can also be applied to Naval ships subject to specific agreement of the Society on case by case basis.

Table 1 : List of additional class notations

Additional class notation	Reference for definition	Reference in NR483 or to other Rule Notes	Remarks
ALM **(ALM)** **ALM-EN** **ALM-SUBSEA** **ALP** **(ALP)**	[6.15]	NR526	**ALP**, **ALM**, **ALM-EN** and A**LM-SUBSEA** may be completed by **-MR** **(1)**
ARMOUR	[6.2.1]	Pt E, Ch 1, Sec 1	
AUT-QAS	[6.5.2]	Pt E, Ch 4, Sec 1	**(1)**
AUT-PORT	[6.5.3]	Pt E, Ch 4, Sec 2	**(1)**
AUT-IAS	[6.5.4]	Pt E, Ch 4, Sec 3	**(1)**
AVM-APM	[6.4.2]	Pt E, Ch 3, Sec 1	**(1)**
AVM-DPS	[6.4.3]	Pt E, Ch 3, Sec 2	**(1)**

(1) A construction mark is added to this notation.
(2) This notation may be completed by the suffix **-IMO**, **-MIL** (see [6.12.1])

Additional class notation	Reference for definition	Reference in NR483 or to other Rule Notes	Remarks
AVM-IPSx-(V)	[6.4.4]	Pt E, Ch 3, Sec 3	
AWT	[6.10.4]	Part E, Chapter 7	
BWE	[6.10.5]	Part E, Chapter 7	
BWT	[6.10.6]	Part E, Chapter 7	
CBRN **CBRN-AIR BLAST RESISTANCE**	[6.11.1]	Part E, Chapter 8	
CLEANSHIP **CLEANSHIP SUPER ( )**	[6.10.2] [6.10.3]	Part E, Chapter 7	between brackets, at least 3 eligible notations are to be assigned among the following ones: **AWT**, **BWT**, **GWT**, **HVSC**, **NDO -x days**, **NOX-x%**, **OWS-x ppm**, **SOX-x%**
COMF-NOISE	[6.8.2]	Pt E, Ch 6, Sec 2	
COMF-VIB	[6.8.3]	Pt E, Ch 6, Sec 3	
FFS	[6.2.4]	Pt E, Ch 1, Sec 4	
FIRE()	[6.13.3]	Pt E, Ch 10, Sec 3	The additional class notation **FIRE()** is to be completed, between brackets, by one, more or all of the following notations: **F**, **T**, **S**
GWT	[6.10.7]	Part E, Chapter 7	
HELICOPTER	[6.15.2]	Pt E, Ch 11, Sec 2	
INTERNAL CONNECTIVITY	[6.15.4]	NR688	
INWATERSURVEY	[6.15.1]	Pt E, Ch 11, Sec 1	
LSA	[6.13.1]	Pt E, Ch 10, Sec 1	
MANOVR	[6.12.1]	Pt E, Ch 9, Sec 1	**(2)**
MON-HULL	[6.7.2]	Pt E, Ch 5, Sec 1	
MON-SHAFT	[6.7.3]	Pt E, Ch 5, Sec 2	
NDO-x days	[6.10.8]	Part E, Chapter 7	
NOX-x%	[6.10.9]	Part E, Chapter 7	
NSC **NSC()**	[6.15.3]	–	When partial compliance with the Naval Ship Code, the list of the chapters complied with is indicated between brackets
OWS-x ppm	[6.10.10]	Part E, Chapter 7	
REF-STORE	[6.9.1]	Pt E, Ch 11, Sec 3	**(1)**
RS-P	[6.2.3]	Pt E, Ch 1, Sec 3	
SEA-KEEP	[6.12.3]	Pt E, Ch 9, Sec 3	To be completed by notations for the capabilities assessed along with their limiting sea states, amongst the notations listed in Tab 2
SHOCK **SHOCK STRENGTH** **SHOCK EQUIPMENT**	[6.2.2]	Pt E, Ch 1, Sec 2	
SOX-x%	[6.10.11]	Part E, Chapter 7	as an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted
STAR	[6.3.4]	Part E, Chapter 2	This cumulative notation supersedes the notations **STAR-HULL** and **STAR-MACH**, when both are assigned **(1)**
STAR-HULL	[6.3.2]	Pt E, Ch 2, Sec 1	**(1)(2)**
STAR-MACH	[6.3.3]	Pt E, Ch 2, Sec 2	**(1)**
STAR-MACH-PMS	[6.3.3]	Pt E, Ch 2, Sec 2	
SYS-NEQ **SYS-NEQ-1**	[6.6.1]	Pt E, Ch 11, Sec 4	**(1)**
TOW	[6.13.2]	Pt E, Ch 10, Sec 2	
VLS	[6.12.2]	Pt E, Ch 9, Sec 2	Restricted to auxiliary naval vessels

(1) A construction mark is added to this notation.
(2) This notation may be completed by the suffix **-IMO**, **-MIL** (see [6.12.1])

6.2 Military environment

6.2.1 ARMOUR

The additional class notation **ARMOUR** is assigned to ships fitted with a protection by armour, when the requirements of Pt E, Ch 1, Sec 1, [2] to Pt E, Ch 1, Sec 1, [4] are complied with.

The requirements for the assignment and maintenance of this notation are provided in Pt E, Ch 1, Sec 1 and Ch 5, Sec 2, [2] respectively.

According to Ch 1, Sec 1, [1.5.1], this additional class notation is mentioned in the Register only after the Owner has authorized the publication. When this notation is not mentioned in the Register, an attestation is issued by the Society.

6.2.2 SHOCK

The following additional class notations are assigned to ship for which shock-resistance capability measures are taken:

- The additional class notation **SHOCK STRENGTH** is granted to ship for which measures are taken to increase their survivability following threat damage to the structures from an assigned underwater non-contact explosion in compliance with the requirements of Pt E, Ch 1, Sec 2.
- The additional class notation **SHOCK EQUIPMENT** is granted to ship for which a list of specified pieces of equipment have been satisfactorily shock tested and subsequently fulfill the shock resilience criteria specified by the Naval Authority for the applicable design shock level in compliance with the requirements of Pt E, Ch 1, Sec 2.
- The additional class notation **SHOCK** is granted to ship for which hull strength and equipment are in compliance with both notations **SHOCK STRENGTH** and **SHOCK EQUIPMENT**.

6.2.3 Residual strength (RS-P)

The additional class notation **RS-P** is assigned to ships for which the residual hull girder ultimate strength under damage condition is evaluated according to minimum hull damage scenari and rule wave hull girder loads.

The requirements for the assignment of this notation are provided in Pt E, Ch 1, Sec 3.

6.2.4 Flooding fighting systems (FFS)

The additional notation **FFS** is assigned to ship fitted with pumping facilities able to cope with the ingress of a great amount of water resulting from a hull damage or a sea water pipe break.

The requirements for the assignment and maintenance of this notation are given Pt E, Ch 1, Sec 4 and in Ch 5, Sec 2, [3] respectively.

6.3 System of Trace and Analysis of Records (STAR)

6.3.1 General

STAR is a System of Trace and Analysis of Records integrating rational analysis with data and records from ship-in-service concerning planned inspection and ship maintenance.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment of these notations are given in Part E, Chapter 2.

6.3.2 STAR-HULL

The additional class notation **STAR-HULL** is assigned to ships on which an Inspection and Maintenance Plan (IMP) for the hull is implemented.

The notation may be completed by the suffix **NB** when a structural tridimensional analysis has been performed for the hull structures, as defined in Pt B, Ch 7, App 1 or Pt B, Ch 7, App 2 or Pt B, Ch 7, App 3, as applicable, at the new building stage. The suffix **NB** is removed when the ship enters the **STAR-HULL** survey programme through the implementation of the Inspection and Maintenance Plan (IMP).

6.3.3 STAR-MACH

The additional class notation **STAR-MACH** is assigned to ships on which an Inspection and Maintenance Plan (IMP) for the machinery is implemented. This plan is based on a risk analysis review of the installation.

Where only a Planned Maintenance Scheme approved by the Society is implemented, the additional class notation **STAR-MACH-PMS** is assigned.

6.3.4 STAR notation (STAR)

When ships are granted both **STAR-HULL** and **STAR-MACH**, the two separate notations are superseded by the cumulative additional class notation **STAR**.

6.4 Availability of machinery (AVM)

6.4.1 General

The notations dealt with under this heading are relevant to systems and/or arrangements enabling the ship to carry on limited operations when single failure affects propulsion or auxiliary machinery or when an external event such as fire or flooding involving machinery spaces affects the availability of the machinery.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment of these notations are given in Part E, Chapter 3.

6.4.2 AVM-APM (Alternative propulsion mode)

The additional class notation **AVM-APM** is assigned to ships which are fitted with systems and/or arrangements enabling them to maintain operating conditions during the normal service with some limitations in speed, range and comfort, in the case of any single failure of items relative to the propulsion or power generating system.

The limitations in operation and the types of single failure covered by this notation are specified in Pt E, Ch 3, Sec 1.

6.4.3 AVM-DPS (Duplicated propulsion system)

The additional class notation **AVM-DPS** is assigned to ships which are fitted with a duplicated propulsion system enabling them to maintain operating conditions with some limitations in power (but 50% of the main power necessary for nominal speed, booster not included is to be maintained), speed, range and comfort, in the case of any single failure of items relative to the propulsion or power generating system.

The loss of one compartment due to fire or flooding is not considered as a single failure case.

The limitations in operation and the types of failure which are covered by this notation are specified in Pt E, Ch 3, Sec 2.

6.4.4 AVM-IPSx-(V) Independent propulsion system

The additional class notation **AVM-IPSx-(V)** is assigned to ships which are fitted with an independent propulsion system enabling them to maintain operating conditions with some limitations in power (but 50% of the main power is to be maintained), speed, range and comfort, in the case of single failure of items relative to the propulsion or power generating system, where x indicates the number of flooded compartments and V the minimum speed in case of single failure.

The limitations in operation and the types of failure which are covered by this notation are specified in Pt E, Ch 3, Sec 3, [1.2].

Note 1: The loss of one compartment due to fire or flooding is considered as a single failure case.

6.5 Automated machinery systems (AUT)

6.5.1 General

The notations dealt with under this heading are relevant to automated machinery systems installed on board ships.

In compliance with [6.1.3], these notations are assigned a construction mark, as defined in Article [3].

The requirements for the assignment of these notations are given in Part E, Chapter 4.

6.5.2 Unattended machinery space (AUT-QAS)

The additional class notation **AUT-QAS** is assigned to ships which are fitted with automated installations enabling machinery spaces to remain periodically unattended in all sailing conditions including manoeuvring.

6.5.3 Automated operation in port (AUT-PORT)

The additional class notation **AUT-PORT** is assigned to ships which are fitted with automated installations enabling the ship’s operation in port or at anchor without personnel specially assigned for the watch-keeping of the machinery in service.

6.5.4 Integrated machinery system (AUT-IAS)

The additional class notation **AUT-IAS** is assigned to ships fitted with automated installations enabling periodically unattended operation of machinery spaces and additionally with integrated systems for the control and monitoring of platform systems.

6.6 Integrated and digital systems

6.6.1 Centralised navigation equipment (SYS-NEQ)

The additional class notation **SYS-NEQ** is assigned to ships fitted with a centralized navigation control system so laid out and arranged that it enables normal navigation and manoeuvring operation of the ship by two persons in cooperation.

The additional class notation **SYS-NEQ-1** is assigned when, in addition, the installation is so arranged that the navigation and manoeuvring of the ship can be operated under normal conditions by one person for periodical one man watches. This notation includes specific requirements for prevention of accidents caused by the operator’s unfitness.

The requirements for the assignment of these notations are provided in Pt E, Ch 11, Sec 4.

6.7 Monitoring equipment (MON)

6.7.1 General

The notations dealt with under this heading are relevant to hull and tailshaft monitoring equipment installed on board ships.

The requirements for the assignment of these notations are given in Part E, Chapter 5.

6.7.2 Hull stress monitoring (MON-HULL)

The additional class notation **MON-HULL** is assigned to ships which are fitted with equipment continuously monitoring ship's dynamic loads through measurements of motions in waves and stresses/deformations in the hull structure.

The notation may be completed by the suffix **+S** if the measurements are stored for further exploitation by the Owner.

6.7.3 Tailshaft monitoring system (MON-SHAFT)

The additional class notation **MON-SHAFT** is assigned to ships which are fitted with a temperature monitoring system for the tailshaft sterntube aft bearing. The assignment of this notation allows the ship to be granted a reduced scope for complete tailshaft surveys, see Ch 2, Sec 2, [6.6.4].

6.8 Comfort on board (COMF)

6.8.1 General

The notations dealt with under this heading are relevant to the assessment of comfort on board ships with regard to the noise and/or vibration.

The parameters which are taken into consideration for the evaluation of the comfort, such as the level of noise, the level of vibration, is indicated in a memoranda.

The requirements for the assignment and maintenance of these notations are given in Part E, Chapter 6.

6.8.2 Comfort with regard to noise (COMF-NOISE)

The additional class notation **COMF-NOISE** is assigned to ships satisfying levels of noise defined in Pt E, Ch 6, Sec 2. The assessment of noise levels is only carried out through design review and sea trials.

6.8.3 Comfort with regard to vibration (COMF-VIB)

The additional class notation **COMF-VIB** is assigned to ships satisfying levels of vibration defined in Pt E, Ch 6, Sec 3. The assessment of vibration levels is only carried out through design review and sea trials.

6.9 Refrigerating installations

6.9.1 Refrigerating installations for domestic supply (REF-STORE)

The additional class notation **REF-STORE** is assigned to ships fitted with refrigerating plants and spaces exclusively intended for the preservation of ship's domestic supply.

The requirements for the assignment of this notation is given in Pt E, Ch 11, Sec 3.

6.10 Environmental protection

6.10.1 General

The notations dealt with under this heading are assigned to ships fitted with equipment and arrangements enabling them to control and limit the emission of polluting substances in the sea and the air.

The requirements for the assignment of these notations are given in Part E, Chapter 7.

6.10.2 Pollution prevention (CLEANSHIP)

The additional class notation **CLEANSHIP** is assigned to ships so designed and equipped as to control and limit the emission of polluting substances in the sea and the air in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 2.

6.10.3 Pollution prevention (CLEANSHIP SUPER)

The additional class notation **CLEANSHIP SUPER** is assigned to ships so designed and equipped as to control and limit the emission of polluting substances in the sea and the air in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 2.

Note 1: At least 3 eligible notations are to be assigned among the following ones:

AWT, **BWT**, **GWT**, **HVSC**, **NDO-x days**, **NOX-x%**, **OWS-x ppm**, **SOX-x%**.

Example:

CLEANSHIP SUPER (AWT, NOX-80%, SOX-60%)

6.10.4 Advanced Wastewater Treatment (AWT)

The additional class notations **AWT** is assigned to ships fitted with an Advanced Wastewater Treatment plant in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.5 Ballast Water Exchange (BWE)

The additional class notation **BWE** is assigned to ships designed for ballast water exchange complying with the requirements of BWM convention (2004) and in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.6 Ballast Water Treatment (BWT)

The additional class notation **BWT** is assigned to ships fitted with a Ballast Water Treatment plant in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.7 Grey Water Treatment (GWT)

The additional class notation **GWT** is assigned to ships fitted with a treatment installation for grey waters in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.8 No Discharge Operation (NDO-x days)

The additional class notation **NDO-x days** is assigned to ships designed for no discharge operation during x days, in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

Note 1: **x days** is the number of consecutive days the ship is able to operate with the full complement of on-board people, including crew and passengers, without the need for discharging any substances into the sea. This number cannot be less than one day (24 hours).

6.10.9 NOx emissions control (NOX-x%)

The additional class notation **NOX-x%** is assigned to ships for which the average NOx emissions of engines are not to exceed x% of IMO Tier II limit in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.10 High-performance Oily Water Separator (OWS-x ppm)

The additional class notation **OWS-x ppm** is assigned to ships fitted with an oily water separator producing effluents having a hydrocarbon content not exceeding x ppm (parts per million) in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

6.10.11 SOx emissions control (SOX-x%)

The additional class notation **SOX-x%** is assigned to ships for which the oil fuels used within and outside SECAs have a sulphur content not exceeding x% of the relevant IMO limit in accordance with the provisions of Pt E, Ch 7, Sec 1 and Pt E, Ch 7, Sec 3.

Note 1: As an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted.

6.11 Protection against chemical, biological, radiological or nuclear risks (CBRN)

6.11.1 CBRN protection

The additional class notation **CBRN** may be assigned to ships intended for operations in atmospheres contaminated by chemical, biological or nuclear hazardous material and equipped with a citadel with a collective protection system that protects people inside from contamination thanks to its dedicated ventilating system.

The additional class notation **CBRN-AIR BLAST RESISTANCE** may be assigned to ships which, in addition to the above features, have their collective protection system designed to withstand air blast.

The requirements for the assignment and maintenance of these notations are given respectively in Part E, Chapter 8 and in Ch 5, Sec 10.

6.12 Manoeuvring, stability and sea-keeping

6.12.1 Ship manoeuvrability

The additional class notation **MANOVR** may be assigned to ships complying with manoeuvring capability standards.

The above is completed by the following notations according to the specified performance assured:

- **-IMO**, for performance complying with IMO resolution A.751(18)
- -**MIL**, for performance complying with a higher level of manoeuvring standards.

The requirements for the assignment of this notation are given in Pt E, Ch 9, Sec 1.

6.12.2 VLS

The additional notation **VLS** may be assigned to auxiliary naval vessels, the stability of which is in compliance with military criteria, based on the V-lines method with 2 flooded compartments.

The requirements for the assignment of this notation are provided in Pt E, Ch 9, Sec 2.

6.12.3 SEA-KEEP

The confidential additional class notation **SEA-KEEP** is assigned to ships whose specified performance levels are assured up to a certain sea state, according to criteria given in NATO STANAG 4154 Ed. 4.

The **SEA-KEEP** notation is to be completed between brackets, by at least one of the following notations indicating the type of ship capability for which the sea-keeping performance has been evaluated:

- **FLY** for flight operations
- **RAS** for replenishment at sea
- **WEAP** for weapon systems operations
- **CREW** for crew capability
- **BOAT** for small craft operations.

These notations are to be completed, as applicable, by at least one notation detailing the specific capabilities assessed as given in Tab 2.

The notations detailing the specific capabilities assessed are to be completed by a notation **-X(L,M,H)** where **X** specifies the limiting sea state number and **L**, **M** and **H** further specify the degree of severity (Low, Medium, High) of the sea state considered among those characterized by the number, up to and including which the required sea-keeping performance is maintained.

Note 1: for assessment of crew capability, the limiting sea state notation **-X(L,M,H)** is to be added directly to the notation indicating the type of ship capability (e.g. **CREW-2(M)**)

For example, the additional notation **SEA-KEEP(FLY-CTOL-3(H)-FWAH-1(L)**, **RAS-CONREP-2(M))** is assigned to a ship that can satisfy the flight operation limits for “Conventional Take-Off and Landing” in seas up to and including high sea state 3, the flight operation limits for “Fixed Wing Aircraft Handling” in seas up to and including low sea state 1 and the replenishment at sea limits for “Connected replenishment” in seas up to and including medium sea state 2.

The requirements for the assignment of this notation are given in Pt E, Ch 9, Sec 3.

Table 2 : Additional class notations for sea-keeping assessment

Type of ship capability	Specific capability assessed	Notation **(1)**
Flight operations (**FLY**)	Conventional Take-Off and Landing	**-CTOL**
	Fixed Wing Aircraft Handling	**-FWAH**
	Helicopter and short take-off and vertical landing (STOVL) aircraft launch and recovery	**-HELOL**
	Helicopter and short take-off and vertical landing (STOVL) aircraft handling	**-HELOH**
Replenishment at sea (**RAS**)	Connected replenishment	**-CONREP**
	Fuelling at sea	**-FAS**
	Vertical replenishment	**-VERTREP**
Weapon systems operations (**WEAP**)	Radars	**-R**
	Sonar	**-S**
	Trainable missiles	**-TM**
	Vertical launch systems	**-VM**
	Torpedo systems	**-T**
	Support equipment	**-E**
	Guns	**-G**
Crew **(CREW)**	Crew performance	N.A.
Small craft operations (**BOAT**)	Stern and davit (or side) launch and recovery of small craft	**-DECK**
	Stern ramp launch and recovery of small craft	**-RAMP**

(1) To be completed in each case by the limiting sea state notation **-X(L,M,H)** where **X** indicates the limiting sea state number and one of **L**, **M** and **H** is to be specified to indicate the degree of severity (Low, Medium, High) of the limiting sea state.

Note 1: N.A. = Not applicable. In such cases the limiting sea state notation is assigned directly to the notation indicating the type of ship capability.

6.13 Safety equipment and installations

6.13.1 Life saving appliances (LSA)

The additional class notation **LSA** may be assigned to ships the life-saving equipment of which complies with the applicable provisions of Pt E, Ch 10, Sec 1.

Note 1: It is reminded that, except if **LSA** additional class notation is to be granted, life-saving appliances are out of the scope of classification.

6.13.2 Towing

The additional class notation **TOW** is assigned to ships fitted with towing and emergency towing equipment.

The requirements for the assignment and maintenance of this notation are given in Pt E, Ch 10, Sec 2 and Ch 5, Sec 12, [2] respectively.

6.13.3 Enhanced fire protection (FIRE)

The additional class notation **FIRE** may be assigned to ships provided with enhanced fire protection features. It is always completed between brackets by one, or by a combination, of the following notations:

- **F**, for ships equipped with a sprinkler system in accommodation spaces, service spaces and control stations
- **T**, for ships on which the low flame-spread characteristics of surface materials have been assessed taking into account the layer combination
- **S**, for ships on which fire doors located on smoke extraction paths are planned to be kept open.

Examples:

FIRE(F)

FIRE(T, S)

FIRE(F, T, S)

The requirements for the assignment of these notations are given in Pt E, Ch 10, Sec 3.

Note 1: Ships assigned the additional class notation **FIRE** before 1st November 2023, are to be assigned the additional class notation **FIRE(F)** at the first renewal survey held after 1 November 2023, or before upon request from the Owner.

6.14 Lifting appliances

6.14.1 Ships fitted with lifting appliances meeting the requirements of the NR526 "Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units" may be assigned the following additional class notations:

- **ALP** for lifting appliances intended to be used in harbours or similarly sheltered areas
- **ALM** for lifting appliances intended to be used in offshore conditions.

6.14.2 The additional class notations **(ALP)** or **(ALM)** may be assigned by the Society in lieu of the notations **ALP** or **ALM** respectively, when the corresponding lifting appliances meet the requirements of specific National Regulations under the conditions defined in NR526.

6.14.3 The additional class notation **ALM** may be completed by:

- **-EN**, when lifting appliances are in compliance with additional specific safety requirements as defined in NR526
- **-SUBSEA**, when lifting appliances are intended to be used for lifting of subsea equipment in compliance with some specific requirements.

6.14.4 The additional class notations **ALP**, **ALM**, **ALM-EN** and **ALM-SUBSEA** may be completed by **-MR** when, in addition, lifting appliances are intended to be used for lifting of personnel.

6.14.5 The additional class notations **ALP**, **ALM**, **(ALP)**, **(ALM)**, A**LM-EN** and **ALM-SUBSEA** are optional. However, the Society may require the compliance of lifting appliances with the assigning conditions of one of the above mentioned additional class notations for the classification of ships, when the lifting appliance or appliances are of a primary importance to the operation of the ship.

6.14.6 In compliance with [6.1.3], these notations are assigned a construction mark as defined in Article [3].

6.14.7 The requirements for assignment and maintenance of these notations are given in NR526.

6.15 Other additional class notations

6.15.1 In-water survey

The additional class notation **INWATERSURVEY** may be assigned to ships provided with suitable arrangements to facilitate the in-water surveys as provided in Ch 2, Sec 2, [3.4].

The requirements for the assignment of this notation are given in Pt E, Ch 11, Sec 1.

6.15.2 Helicopter deck

The additional class notation **HELICOPTER** may be assigned to ships provided with a helicopter deck when the requirements of Pt E, Ch 11, Sec 2 are complied with.

The requirements for the assignment and maintenance of this notation are given in Pt E, Ch 11, Sec 2 and Ch 5, Sec 13, [2] respectively.

6.15.3 Naval Ship Code (NSC)

The additional class notation **NSC** is assigned to ships complying with the Naval Ship Code published by NATO as ANEP 77 (Allied Naval Engineering Publication).

When only partial compliance is required, the additional class notation **NSC ()** is to be assigned, indicating between brackets the chapters of the Naval Ship Code that are complied with. Chapters detailing the definitions, the use of the NSC and the certification process are deemed to apply automatically and are not needed to be indicated between brackets.

For example, **NSC (II, VI, VII)** means that Chapters II, VI and VII of the Naval Ship Code have been reviewed for assignment of the notation.

The documents to be submitted for review in order to assign additional class notation **NSC** or **NSC ()** are those required by the relevant chapters of the Naval Ship Code.

When the ship is assigned an additional class notation **NSC** or **NSC ()**, a Naval Ship Safety Certificate, indicating the applicable version of the Code, may be issued by the Society on behalf of the Naval Authority, when delegated.

6.15.4 Internal Connectivity

The additional class notation **INTERNAL CONNECTIVITY** may be assigned to ships for which the on-board network infrastructure enables internal connectivity.

The requirements for the assignment and the maintenance of this notation are given in Rule Note NR688 Internal Connectivity.

Note 1: The scope of the notation is limited to a list of Internal Connectivity Areas (ICAs) to be specified by the applicant. This list of ICAs is to be indicated in a memorandum.

7 Other notations

7.1

7.1.1 The Society may also define other notations by means of provisional requirements and guidelines, which may then be published in the form of tentative rules.

8 Explicit request of the Naval Authority

8.1

8.1.1 Some non compulsory requirements of the Rules are applicable only upon explicit request of the Naval Authority.

Same as for the additional class notations, these requirements are to be listed on the request for classification to be applicable.

Example: see Pt C, Ch 1, Sec 6, Tab 5: Value of K_A.

Part A
Classification and Surveys

CHAPTER 2
ASSIGNMENT, MAINTENANCE, SUSPENSION AND WITHDRAWAL OF CLASS

Section 1	Assignment of Class
Section 2	Maintenance of Class
Section 3	Suspension and Withdrawal of Class
Appendix 1	Planned Maintenance Scheme
Appendix 2	CSM and PMS Systems: Surveys Carried out by the Chief Engineer
Appendix 3	Thickness Measurements: Extent, Determination of Locations, Acceptance Criteria

Section 1 Assignment of Class

1 General

1.1 Criteria

1.1.1 Class is assigned to a ship upon a survey, with the associated operations, which is held in order to verify whether it is eligible to be classed on the basis of the Rules of the Society (see Ch 1, Sec 1, [1.3.1]). This may be achieved through:

- the completion of the new building, during which a survey has been performed
- a specific admission to class survey, in cases where a ship is classed by a recognized Classification Society or is not classed at all.

Special consideration will be given to ships transferring class from another recognized Classification Society who have appropriate Military or Navy Ship Rules.

1.2 Confidentiality

1.2.1 The drawing approval activities and the necessary interventions for the class assignment are performed by authorized persons.

The drawings and documents required for the classification of a ship are dealt with according to the level of confidentiality required by the Owner or Naval Authority.

2 New building procedure

2.1 Ships surveyed by the Society during construction

2.1.1 When a ship is surveyed by the Society during construction, it is to comply with those requirements of the Rules which are in force and applicable depending on the class of the ship, taking into account the provisions of Ch 1, Sec 1, [2.1] and Ch 1, Sec 1, [2.5].

2.1.2 The Society:

- approves the plans and documentation submitted as required by the Rules
- proceeds, if required, with the appraisal of the design of materials and equipment used in the construction of the ship and their inspection at works
- carries out surveys or obtains appropriate evidence to satisfy itself that the scantlings and construction meet the rule requirements in relation to the approved drawings
- attends tests and trials provided for in the Rules
- assigns the construction mark ✠; refer to Ch 1, Sec 2, [3.2.1].

2.1.3 The Society defines in specific Rules which materials and equipment used for the construction of ships built under survey are, as a rule, subject to appraisal of their design and to inspection at works, and according to which particulars.

2.1.4 As part of his interventions during the ship's construction, the Surveyor will:

- conduct an overall examination of the parts of the ship covered by the Rules
- examine the construction methods and procedures when required by the Rules
- check selected items covered by the rule requirements
- attend tests and trials where applicable and deemed necessary.

2.1.5 Use of materials, machinery, appliances and items

As a general rule, all materials, machinery, boilers, auxiliary installations, equipment, items etc. (generally referred to as "products") which are covered by the class and used or fitted on board ships surveyed by the Society during construction are to be new and, where intended for essential services as defined in Ch 1, Sec 1, [1.2.1], tested by the Society.

Second hand materials, machinery, appliances and items may be used subject to the specific agreement of the Society and the Owner.

The requirements for the selection of materials to be used in the construction of the various parts of a ship, the characteristics of products to be used for such parts and the checks required for their acceptance are to be as stated in Part C and NR216 Materials and Welding, as applicable, or in other Parts of the Rules or as specified on approved plans. In particular, the testing of products manufactured according to quality assurance procedures approved by the Society and the approval of such procedures are governed by the requirements of NR216 Materials and Welding, Ch 1, Sec 1, [3] of the Rules.

2.1.6 Defects or deficiencies and their repair

The Society may, at any time, reject items found to be defective or contrary to rule requirements or require supplementary inspections and tests and/or modifications, notwithstanding any previous certificates issued.

All repairs are subject to the preliminary agreement of the Society. When the limits of tolerance for defects are specified in the Rules concerned or by the Manufacturer, they are to be taken into account for repairs.

It is incumbent upon the Interested Party to notify the Society of any defects noted during the construction of the ship and/or of any item not complying with the applicable requirements or in any case unsatisfactory. Proposals regarding remedial actions intended to be adopted to eliminate such defects or unsatisfactory items are to be submitted to the Society and, if accepted, carried out to the Surveyor's satisfaction.

2.1.7 Equivalence of Rule testing under certain conditions

Notwithstanding the provisions of [2.1.4], the Society may, at its discretion and subject to conditions and checks deemed appropriate, accept certain materials, appliances or machinery which have not been subjected to rule testing.

2.2 Other cases

2.2.1 When the procedure adopted does not comply with that detailed in [2.1] but the Society deems that it is acceptable for the assignment of class, the construction mark • is assigned in accordance with Ch 1, Sec 2, [3.2.2].

2.3 Documentation

2.3.1 Documentation relevant to the class applied for is to be submitted for the approval of the Society.

2.3.2 The documentation to be submitted is specified in the relevant chapters of the Rules.

The lists of requested plans, documents and other items related to classification are not exhaustive and are intended as guidance for specifying the set of information to be submitted, rather than lists of actual titles. The Society may require that additional information be submitted if deemed necessary for the verification of rule requirements, especially in the case of non-conventional design.

2.3.3 The documentation submitted to the Society is examined in relation to the class applied for in the request for classification.

Note 1: Should the Interested Party subsequently wish to have the class, in particular the service notation or navigation notation, granted to the ship modified, plans and drawings are generally to be re-examined.

2.3.4 A copy of the submitted plans will be returned duly stamped, with remarks related to the compliance with the rule requirements should the need arise.

2.3.5 As a rule, modifications of the approved plans regarding items covered by classification are to be submitted.

2.3.6 Design data to be submitted to the Society are to incorporate all information necessary for the assessment of the design of the ship for the purpose of assignment of class. It is the responsibility of the Interested Party to ascertain that the design data are correct, complete and compatible with the use of the ship.

2.3.7 Design calculations are to be provided, when called for, as supporting documents to the submitted plans.

2.3.8 Design data and calculations are to be adequately referenced. It is the duty of the Interested Party to ascertain that the references used are correct, complete and applicable to the design of the ship.

2.3.9 The submitted plans are to contain all necessary information for checking the compliance with the requirements of the Rules.

2.3.10 In the case of conflicting information, submitted documentation will be considered in the following order of precedence: design data, plans, design calculations.

2.3.11 It is the responsibility of the Interested Party to ascertain that drawings used for the procurement, construction and other works are in accordance with the approved plans.

2.3.12 Upon specific agreement between the Society and the Interested Parties, three-dimensional models may be submitted in place of two-dimensional plans. In this case, the Society may require that additional documentation containing information that cannot be specified in three-dimensional models be submitted.

3 Ships classed after construction

3.1 Class admission process and requirements

3.1.1 The class of the ship will be assigned upon a preliminary review of the documentation listed in [3.1.3] and subsequent satisfactory completion of the surveys, the extent and scope of which are given below.

3.1.2 Surveys

The extent and scope of the admission to class survey is to be not less than those required at the class renewal survey of a ship of the same age and type; in addition all other periodical surveys should be performed together with those inspections which are linked to specific service notations and/or additional class notations and/or special installations the ship is provided with.

Special consideration will be given to ships transferring class from another recognized Classification Society who have appropriate Military or Navy Ship Rules.

3.1.3 Documentation

As a general rule, the documentation to be supplied to the Society is not to be less than the following.

a) Main plans:
   - general arrangement
   - capacity plan
   - loading cases, calculations of still water bending moments, and relevant documents, particulars of loading calculator and instruction booklet as per Society's requirements, according to the case
   - stability documents, if applicable (refer to Part B, Chapter 3).

b) Hull structure plans:
   - midship section
   - profile and deck plan
   - watertight bulkheads
   - rudder and rudder stock
   - shell expansion
   - hatch covers.

c) Machinery plans:
   - engine room general arrangement
   - diagram of fuel- (transfer, service), bilge-, ballast-, lubricating oil-, cooling-, steam- and feed-, general service and starting compressed air piping
   - diagram of fire-fighting systems
   - drawings of boilers and air receivers
   - drawings of shaft line, reduction gear and propeller
   - drawings of steering gear
   - torsion vibration calculations as per conditions laid down in Pt C, Ch 1, Sec 9. Such documents are required only for ships less than 2 years old or for older ships the propelling system of which has been modified during the two years preceding the classification.

d) Electrical installation plans:
   - master plan of power distribution, lighting and emergency power circuits
   - single line diagram of networks and switchboards
   - location and arrangement of electrical equipment in hazardous areas.

Alternative technical data may be accepted by the Society in lieu of specific items of the listed documentation not available at the time of the transfer of class.

3.1.4 Where appropriate within reasonable limits, a proven service record (log book) of satisfactory performance during a period of adequate length may be used as a criterion of equivalence. Special consideration will be given to ships of recent construction.

3.1.5 For installations or equipment covered by additional service and/or class notations, the Society will determine the documentation to be submitted.

3.1.6 In addition, the Society may base its judgement upon documentation such as certificates issued or accepted by the former Classification Society, if any, and certificates issued by the flag Administration or by a recognized organization on its behalf; moreover, other documents and/or plans may be specifically required to be supplied to the Society in individual cases.

4 Date of initial classification

4.1 Definitions

4.1.1 Date of build

For a new building the date of build is the year and month at which the new construction survey process is completed. Where there is a substantial delay between the completion of the construction survey process and the ship commencing active service, the date of commissioning may be also specified.

If modifications are carried out, the date of build remains assigned to the ship. Where a complete replacement or addition of a major portion of the ship (e.g. forward section, after section, main cargo section) is involved, the following applies:

- the date of build associated with each major portion of the ship is indicated on the classification certificate
- survey requirements are based on the date of build associated with each major portion of the ship.

4.1.2 Date of initial classification for new buildings

As a general rule, for new buildings the date of initial classification coincides with the date of issuance of classification certificates which is close to the date of the transfer of property between the Shipbuilder and the Owner.

4.1.3 Date of initial classification for existing ships

In principle, for existing ships the date of initial classification is the date of completion of the admission to class survey.

5 Reassignment of class

5.1 Conditions

5.1.1 At the request of the Owner, a ship which was previously classed with the Society, subsequently withdrawn from class and has not been classed since may have the class reassigned subject to an admission to class survey. If applicable and appropriate, account may be taken of any periodical surveys held in the former period of class with the Society.

Section 2 Maintenance of Class

1 Foreword

1.1 Terminology

1.1.1 Boilers

As the rules do not apply to nuclear propulsion ships, when the word boiler(s) is used in the present chapter, it concerns boilers using fuel or coal.

1.1.2 Expert

The word Surveyor in this chapter means authorized surveyor (see Ch 1, Sec 1, [1.2.1]).

2 General principles of surveys

2.1 Survey types

2.1.1 Classed ships are submitted to surveys for the maintenance of class. These surveys include the class renewal survey, intermediate and annual survey, bottom survey (either survey in dry condition or in-water survey), tailshaft survey, boiler survey, and surveys for the maintenance of additional class notations, where applicable. Such surveys are carried out at the intervals and under the conditions laid down in this Section. In addition to the above periodical surveys, ships are to be submitted to occasional surveys whenever the circumstances so require; refer to [6].

2.1.2 The different types of periodical surveys are summarized in Tab 1. The intervals at which the periodical surveys are carried out are given in the items referred to in the second column of Tab 1. The relevant extent and scope are given in Part A, Chapter 3 and Part A, Chapter 4 for all ships and for service notations, respectively, while surveys related to additional class notations are given in Part A, Chapter 5.

Where there are no specific survey requirements for additional class notations assigned to a ship, equipment and/or arrangements related to these additional class notations are to be examined, as applicable, to the Surveyor's satisfaction at each class renewal survey for the main class.

The surveys are to be carried out in accordance with the relevant requirements in order to confirm that the hull, machinery, equipment and appliances comply with the applicable Rules and will remain in satisfactory condition based on the understanding and assumptions mentioned in Ch 1, Sec 1, [3.3].

Where the conditions for the maintenance of main class, service notations and additional class notations are not complied with, the main class and/or the service notation and/or the additional class notations as appropriate will be suspended and/or withdrawn in accordance with the applicable Rules given in Ch 2, Sec 3.

Note 1: It is understood that requirements for surveys apply to those items that are required according to the Rules or, even if not required, are fitted on board.

Table 1 : List of periodical surveys

Type of survey	Reference in this Section	Reference to scope of survey
Class renewal - hull	[5]	Ch 3, Sec 3 and Part A, Chapter 4 **(1)**
Class renewal - machinery	[5]	Ch 3, Sec 3 and Part A, Chapter 4 **(1)**
Class renewal - additional class notations	[2.1]	Part A, Chapter 5 **(2)**
Annual - hull	[6.2]	Ch 3, Sec 1 and Part A, Chapter 4 **(1)**
Annual - machinery	[6.2]	Ch 3, Sec 1 and Part A, Chapter 4 **(1)**
Annual - additional class notation	[2.1]	Part A, Chapter 5 **(2)**
Intermediate - hull	[6.3]	Ch 3, Sec 2 and Part A, Chapter 4 **(1)**
Intermediate - machinery	[6.3]	Ch 3, Sec 2 and Part A, Chapter 4 **(1)**
Stability and lightweight check	[6.4]	Ch 3, Sec 3, [2]
Bottom - dry condition	[6.5]	Ch 3, Sec 4
Bottom - in water	[6.5]	Ch 3, Sec 4
Tailshaft - complete	[6.6]	Ch 3, Sec 5
Tailshaft - modified	[6.6]	Ch 3, Sec 5
Boiler - complete	[6.7]	Ch 3, Sec 6

(1) As applicable, according to the service notation assigned to the ship
(2) As applicable, according to the additional class notations assigned to the ship.

2.1.3 Unless specified otherwise, any survey other than bottom survey and tailshaft survey may be effected by carrying out partial surveys at different times to be agreed upon with the Society, provided that each partial survey is adequately extensive. The splitting of a survey into partial surveys is to be such as not to impair its effectiveness.

2.2 Change of periodicity, postponement or advance of surveys

2.2.1 The Society reserves the right, after due consideration, to change the periodicity, postpone or advance surveys, taking into account particular circumstances.

2.2.2 When a survey becomes overdue during a voyage, the following applies:

a) In the case of a class renewal survey, the Society may, under exceptional circumstances, grant an extension to allow for completion of this survey provided there is documented agreement to such an extension prior to the expiry date of the Certificate of Classification, adequate arrangements have been made for the attendance of the Surveyor at the first port of call and the Society is satisfied that there is technical justification for such an extension. Such an extension will be granted only until arrival at the first port of call after the expiry date of the Certificate of Classification.

b) In the case of annual and intermediate surveys, no postponement is granted. Such surveys are to be completed within their prescribed windows; see [3.1.3].

c) In the case of all other periodical surveys and recommendations, extension of class may be granted until the arrival of the ship at the port of destination.

2.3 Extension of scope of survey

2.3.1 The Society and/or its Surveyors may extend the scope of the provisions in Part A, Chapter 3 to Part A, Chapter 5, which set forth the technical requirements for surveys, whenever and so far as considered necessary, or modify them in the case of special ships or systems.

2.3.2 The extent of any survey also depends upon the condition of the ship and its equipment. Should the Surveyor have any doubt as to the maintenance or condition of the ship or its equipment, or be advised of any deficiency or damage which may affect the class, then further examination and testing may be conducted as considered necessary.

2.4 General procedure of survey

2.4.1 The general procedure of survey consists in:

- an overall examination of the parts of the ship covered by the rule requirements
- checking selected items covered by the rule requirements
- attending tests and trials where applicable and deemed necessary by the Surveyor.

2.4.2 When a survey results in the identification of significant corrosion, structural defects or damage to hull, machinery and/or any piece of its equipment which, in the opinion of the Surveyor, affect the ship's class, remedial measures are to be implemented before the ship continues in service (see also [3.10]).

Note 1: The Society's survey requirements cannot be considered as a substitute for specification and acceptance of repairs and maintenance, which remain the responsibility of the Owner.

Note 2: During the surveys, the Surveyor does not check that the spare parts are kept on board, maintained in working order and suitably protected and lashed.

2.5 Appointment of another Surveyor

2.5.1 In compliance with the provisions of Ch 1, Sec 1, [2.5.1], should a disagreement arise between the Owner and the Surveyor during a survey, the Society may, at the request of the Owner, designate another Surveyor.

2.6 Alterations or additions to approved systems

2.6.1 When an alteration or addition to an approved system is proposed, documentation is to be submitted and approved by the Society before the work of alteration or addition is commenced.

2.6.2 Where the modifications may affect compliance with the rules, they are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

3 Definitions and procedures related to surveys

3.1 General

3.1.1 Period of class

Period of class means the period starting either from the date of the initial classification, see Ch 2, Sec 1, [4], or from the credited date of the last class renewal survey, and expiring at the limit date assigned for the next class renewal survey.

3.1.2 Anniversary date

Anniversary date means the day of the month of each year in the period of class which corresponds to the expiry date of the period of class.

3.1.3 Survey time window

Survey time window, or more simply window, mean the fixed period during which annual and intermediate surveys are to be carried out.

3.1.4 Overdue surveys

Each periodical survey is assigned a limit date specified by the relevant requirements of the Rules (end of survey interval or end date of window) by which it is to be completed.

A survey becomes overdue when it has not been completed by its limit date.

Examples:

- Anniversary date: 15th April

  The 2000 annual survey can be validly carried out from 16th January 2000 to 15th July 2000. If not completed by 15th July 2000, the annual survey becomes overdue.
- Last bottom survey 20th October 2000 (periodicity 3 years)

  The next bottom survey is to be carried out before 20th April 2003. If not completed by 20th April 2003, the bottom survey becomes overdue.

3.1.5 Recommendations

Any defect and/or deficiency affecting the class and to be dealt with within a specific period of time is indicated as a recommendation. A recommendation is pending until it is cleared. Where it is not cleared by its limit date, the recommendation is overdue.

3.1.6 Memoranda

Those defects and/or deficiencies which do not affect the maintenance of class and which may therefore be cleared at the Owner's convenience and any other information deemed noteworthy for the Society's convenience are indicated as memoranda. Memoranda are not to be regarded as recommendations.

3.1.7 Exceptional circumstances

"Exceptional circumstances" means:

- unavailability of dry-docking facilities, or
- unavailability of repair facilities, or
- unavailability of essential materials, equipment or spare parts, or
- delays incurred by action taken to avoid severe weather conditions.

3.2 Terminology related to hull survey

3.2.1 Ballast tank

A ballast tank is a tank which is used solely for salt water ballast.

3.2.2 Spaces

Spaces are separate compartments such as holds and tanks.

3.2.3 Overall survey

An overall survey is a survey intended to report on the overall condition of the hull structure and determine the extent of additional close-up surveys.

3.2.4 Close-up survey

A close-up survey is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

3.2.5 Transverse section

A transverse section includes all longitudinal members contributing to longitudinal hull girder strength, such as plating, longitudinals and girders at the deck, side shell, bottom, inner bottom, longitudinal bulkheads, and sloped plating in upper and lower side tanks, as well as relevant longitudinals, as applicable for the different ships. For a transversely framed ship, a transverse section includes adjacent frames and their end connections in way of transverse sections.

3.2.6 Representative tanks or spaces

Representative tanks or spaces are those which are expected to reflect the condition of other tanks or spaces of similar type and service and with similar corrosion protection systems. When selecting representative tanks or spaces, account should be taken of the service and repair history on board and identifiable suspect areas.

3.2.7 Substantial corrosion

Substantial corrosion is an extent of corrosion such that assessment of the corrosion pattern indicates a wastage in excess of 75% of allowable margins, but within acceptable limits.

3.2.8 Suspect areas

Suspect areas are locations showing substantial corrosion and/or considered by the Surveyor to be prone to rapid wastage.

3.2.9 Coating

A corrosion prevention system is normally considered either:

- a full hard coating, or
- a full hard coating supplemented by anodes.

Protective coating should usually be epoxy coating or equivalent. Other coating systems may be considered acceptable as alternatives provided that they are applied and maintained in compliance with the Manufacturer's specifications.

Refer to [3.5.7] for access to tanks with soft coating.

3.2.10 Coating condition

Coating condition is defined as follows:

- good: condition with only minor spot rusting
- fair: condition with local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for poor condition
- poor: condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.

3.2.11 Cargo area (oil replenishment ships)

The cargo area is that part of the ship which contains cargo tanks, slop tanks and cargo/ballast pump rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the ship over the above-mentioned spaces.

3.2.12 Cargo area (dry cargo ships)

The cargo area is that part of the ship which includes all cargo holds and adjacent areas including fuel tanks, cofferdams, ballast tanks and void spaces.

3.2.13 Prompt and thorough repair

A “Prompt and Thorough Repair” is a permanent repair completed at the time of survey to the satisfaction of the Surveyor, therein removing the need for the imposition of any associated recommendation. See also [3.10].

3.3 Procedures for thickness measurements

3.3.1 When required as per the scope of surveys defined below, thickness measurements are normally to be carried out under the responsibility of the Owner, in the presence of the Surveyor.

However, the Surveyor may accept thickness measurements not carried out under his supervision.

3.3.2 The thickness measurements are to be carried out by a company authorised by the Society.

The Society reserves the right to limit the scope of authorisation of the Company.

Note 1: The specific Rules of the Society give details about the authorisation.

3.3.3 A thickness measurement report is to be prepared. The report is to give the location of measurements, the thickness measured and the corresponding original thickness. Furthermore, the report is to include the date when the measurements were carried out, the type of measuring equipment, the names and the qualification of the operators and their signatures.

The report is validated by the Surveyor.

3.4 Agreement for in-water survey

3.4.1 The in-water surveys referred to in the Rules are to be carried out by a certified company accepted by the Society and authorized.

Note 1: Rule Note NR533 gives details about the certification.

3.4.2 On the Owner request, a survey program based on close-up in-water hull surveys can be applied with the Society agreement.

For the program application, an on-board person with appropriated professional qualification has to be responsible of the program management.

The surveys of the hull elements and components covered by the program can be performed by on-board divers who have been given by the Society an authorization note, after receiving an appropriated training.

3.5 Conditions for surveys

3.5.1 The Owner is to provide the necessary facilities for the safe execution of the surveys, as per Ch 1, Sec 1, [3.2.2].

3.5.2 For their internal examination, tanks and spaces are to be safe for access, i.e. gas freed, ventilated, etc.

Tanks and spaces are to be sufficiently illuminated, clean and free from water, scale, dirt, oil residues, etc. to reveal significant corrosion, deformation, fractures, damage or other structural deterioration.

3.5.3 A tank entry permit is to be issued prior to entering the tank. Adequate ventilation is to be maintained during the survey, and the required ventilation is to be specified on the entry permit. If the tanks are connected by a common venting system or an IG system, the tank inspected is to be isolated to prevent a transfer of gas from other tanks.

3.5.4 A communication system is to be arranged between the survey party in the tank and the responsible officer on deck.

3.5.5 Rescue and safety equipment such as explosimetre, breathing apparatus, resuscitators, smoke masks, rescue lines, stretcher, etc. is to be provided at the tank hatch, or, if more than one tank is being surveyed, at a central location on deck.

3.5.6 Surveys of tanks by means of boats or rafts may only be undertaken at the discretion of the Surveyor. In such case, the following additional conditions apply:

- a safety meeting is to be held prior to entering the tank, and applicable safety procedures and responsibilities are to be discussed to ensure that the survey is carried out under controlled conditions, in particular concerning the movement of the surface of the water in the tank
- the surface of the water in the tank should be calm (under all foreseeable conditions the expected rise of water within the tank should not exceed 0,25 m) and the water level either stationary or falling. On no account is the level of the water to be rising while the boat is in use
- the tank is to contain clean ballast water only. Even a thin sheen of oil on the water is not acceptable
- at no time should the water be allowed within one metre of the deepest under-deck web face flat so that the survey team is not isolated from a direct escape route to the tank hatch. Filling to levels above the deck transverses should be contemplated only if a deck access manhole is fitted in the bay being examined, so that an escape route for the survey party is available at all times
- only rough duty, inflatable life boats, having residual buoyancy and stability even if one chamber is ruptured, are to be used
- the work-boat is to be tethered to the access ladder and an additional person stationed down the access ladder with a clear view of the work-boat
- all personnel in the compartment are to be provided with personal flotation devices.

3.5.7 When examination of associated structure is required, the following applies:

- ceilings in holds and floors in the engine room are to be lifted to the necessary extent for examination of the structure
- cement or other protective sheathing is to be removed when there is any doubt as to the condition of the plating underneath or when adherence to plating is not tight
- in the case of solid ballast spaces, the solid ballast is to be partially removed for examination of the condition of the structure in way. Should doubts arise, the Surveyor may require more extensive removal of the solid ballast
- where soft coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft coating is to be removed.

3.6 Access to structures

3.6.1 For overall survey, means are to be provided to enable the Surveyor to examine the structure in a safe and practical way.

3.6.2 For close-up survey, one or more of the following means for access, acceptable to the Surveyor, is to be provided:

- permanent staging and passages through structures
- temporary staging and passages through structures
- hydraulic arm vehicles such as conventional cherry pickers, lifts and movable platforms
- portable ladders
- boats or rafts
- other equivalent means.

3.7 Equipment for surveys

3.7.1 One or more of the following fracture detection methods may be required if deemed necessary by the Surveyor:

- radiography (X or γ rays)
- ultrasonic test
- magnetic particle test
- dye penetrant test.

3.8 Surveys at sea and anchorage

3.8.1 Surveys at sea or at anchorage may be accepted provided the Surveyor is given the necessary assistance by the personnel on board. Precautions and procedures for carrying out the survey are to be in accordance with [3.5], [3.6] and [3.7].

3.9 Repairs and maintenance during voyage

3.9.1 Where repairs to hull, machinery or other equipment, which affect or may affect the class, are to be carried out by a riding crew during a voyage, they are to be planned in advance. A complete repair procedure including the extent of proposed repair and the need for the Surveyor's attendance during the voyage is to be submitted to the Society for approval sufficiently in advance. Failure to notify the Society in advance of the repairs may result in the suspension of class of the ship.

3.9.2 The above is not intended to include maintenance to and overhaul of the hull, machinery and equipment in accordance with the Manufacturer's recommended procedures and established marine practice, which does not require the Society's agreement. However, any repair resulting from such maintenance and overhauls which affects or may affect the class is to be noted in the ship's log and submitted to the attending Surveyor for use in determining further survey requirements.

3.10 Repairs

3.10.1 Any damage in association with wastage over the allowable limits (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly (see [3.2.13]) repaired.

Areas to be considered include:

- side shell frames, their end attachments or adjacent shell plating
- deck structure and deck plating
- bottom structure and bottom plating
- watertight or oiltight bulkheads, or
- hatch covers or hatch coamings.

3.10.2 For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

4 Certificate of Classification: issue, validity, endorsement and renewal

4.1 Issue of Certificate of Classification

4.1.1 A Certificate of Classification, bearing the class notations assigned to the ship and an expiry date, is issued to any classed ship.

4.1.2 A Provisional Certificate of Classification may serve as a Certificate of Classification in some cases, such as after an admission to class survey, after a class renewal survey, or when the Society deems it necessary.

4.1.3 The Certificate of Classification is to be made available to the Society's Surveyors upon request.

4.1.4 Issuance of the first Certificate of Classification is notified to the Classification Committee for its advice.

4.2 Validity of Certificate of Classification, maintenance of class

4.2.1 According to Ch 1, Sec 1, [2.4], the Society alone is qualified to confirm the class of the ship and the validity of its Certificate of Classification.

4.2.2 During the class period, a Certificate of Classification is valid when it is not expired.

The class is maintained during a certain period or at a given date, when during the said period or at such date the conditions for suspension or withdrawal of class are not met.

4.2.3 At the request of the Owner, a statement confirming the maintenance of class may be issued by the Society based on the information in its records for that ship at the time.

This statement is issued on the assumption that the Owner has complied with the Rules, in particular with [7].

Should any information which would have prevented the Society from issuing the statement and which was not available at the time subsequently come to light, the statement may be cancelled.

Attention is drawn to Ch 2, Sec 3, [1.2], whereby the Society, upon becoming aware of a breach of the Rules, is empowered to suspend class from the date of the breach, which may be prior to the date of the statement.

4.2.4 According to the same conditions as in [4.2.3], a statement declaring that the class is maintained "clean and free from recommendation" may be issued by the Society when there is no pending recommendation at that date.

4.2.5 Classification-related documents and information are liable to be invalidated by the Society whenever their object is found to differ from that on which they were based or to be contrary to the applicable requirements. The Owner is liable for any damage which may be caused to any third party from improper use of such documents and information.

4.3 Endorsement of Certificate of Classification

4.3.1 Text of endorsement

When surveys are satisfactorily carried out, the Certificate of Classification is generally endorsed accordingly.

Each endorsement normally consists of sections for the description of:

- the surveys held
- the imposed, deleted and postponed recommendations (including the assigned limit date as applicable)
- the unchanged existing recommendations (given for information only).

Where applicable, memoranda are also endorsed in the Certificate of Classification.

4.3.2 Possible modifications to endorsements

The Society reserves the right to modify the endorsements made by Surveyors.

4.4 Status of surveys and recommendations

4.4.1 Information given in the Certificate of Classification, associated endorsements, Rules and specific documents enables the Owner to identify the status of surveys and recommendations.

4.4.2 The omission of such information does not absolve the Owner from ensuring that surveys are held by the limit dates and pending recommendations are cleared to avoid any inconvenience which is liable to result from the suspension or withdrawal of class; see Ch 2, Sec 3.

5 Class renewal survey

5.1 General principles

5.1.1 Class renewal surveys are to be carried out at five-year (class symbol **I**) or three-year (class symbol **II**) intervals.

5.1.2 For surveys completed within three months before the limit date of the class renewal survey, the next period of class will start from this limit date. For surveys completed more than three months before the limit date, the period of class will start from the survey completion date.

In cases where the vessel has been laid up or has been out of service for a considerable period because of a major repair or modification and the Owner elects to carry out only the overdue surveys, the next period of class will start from the expiry date of the renewal survey. If the Owner elects to carry out the next due renewal survey, the period of class will start from the survey completion date.

5.1.3 A new period of class is assigned to the ship after the satisfactory completion of the class renewal survey, and a new Certificate of Classification is issued for the new period of class.

5.1.4 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces is not acceptable.

5.2 Normal system

5.2.1 When the normal system is applied to ships with a 5 year period of class, the class renewal survey may be commenced at the fourth annual survey and continued during the following year with a view to completion by its due date. In this case the survey may be carried out by partial surveys at different times. The number of checks to be performed at each partial survey and the interval between partial surveys are to be agreed by the Society. In general, the first partial survey should include a significant number of thickness measurements, where required by the Rules.

5.2.2 A class renewal survey may be commenced before the fourth annual survey at the request of the Owner. In this case, the survey is to be completed within fifteen months. The conditions for the execution of partial surveys are the same as those referred to in [5.2.1].

5.3 Continuous survey system

5.3.1 The request by the Owner for admission to the continuous survey system will be considered by the Society and agreement depends on the type and age of hull and machinery. This system may apply to the class renewal survey of hull, machinery or other installations such as refrigerating installations covered by an additional class notation.

5.3.2 The continuous survey system is not applicable to the class renewal survey of the hull of ships over 20 years old. However, consideration may be given, at the discretion of the Society, to the applicability of the continuous survey system to the class renewal survey of the hull of ships over 20 years old.

5.3.3 When the continuous survey system is applied, appropriate notations are entered in the Certificate of Classification and the Register of Ships.

5.3.4 Ships subject to the continuous survey system are provided with lists of items to be surveyed under this system; these lists are attached to the Certificate of Classification.

5.3.5 For items inspected under the continuous survey system, the following requirements generally apply:

a) the interval between two consecutive surveys of each item is not to exceed five years
b) the items are to be surveyed in rotation, so far as practicable ensuring that approximately equivalent portions are examined each year
c) the Society may credit for continuous survey results of inspections carried out before the admission to the continuous survey scheme
d) each item is to be surveyed at one time, as far as practicable; the Society may, however, allow possible repair work to be carried out within a certain period.

5.3.6 For ships under continuous survey, items not included in the continuous survey cycle are to be inspected according to the provisions given in [5.2].

5.3.7 Upon application by the Owner, the Society may agree, subject to certain conditions, that some items of machinery which are included in the continuous survey cycle are examined by the Chief Engineer where the Society is not represented. The Chief Engineer is to be certified for this purpose by the Society and his examination is to be followed by a confirmatory survey carried out by a Surveyor. The conditions for the application of this procedure are given in Ch 2, App 2.

5.3.8 The continuous survey system does not supersede the annual surveys and other periodical and occasional surveys.

5.3.9 A general examination of the ship, as detailed in Ch 3, Sec 1 for annual surveys, is to be carried out at the end of the period of class.

5.3.10 For laid-up ships, specific requirements given in [9.1] apply.

5.3.11 The continuous survey system may be discontinued at any time at the discretion of the Society, or at the request of the Owner, and a specific arrangement devised.

5.4 Planned maintenance scheme (PMS) for machinery

5.4.1 A planned maintenance scheme may be considered as an alternative to the continuous survey system for machinery and is limited to components and systems covered by it. When such a system approved by the Society is implemented, a survey scheme other than those normally adopted and with intervals different from those of the continuous survey system as detailed in [5.3] may be accepted.

5.4.2 The conditions for approval of the planned maintenance scheme, the determination of survey item intervals and the general scope of surveys are detailed in Ch 2, App 1.

5.4.3 When the planned maintenance scheme is applied, appropriate notations are entered on the Certificate of Classification and in the Register of Ships.

5.4.4 The planned maintenance scheme does not supersede the annual surveys and other periodical and occasional surveys.

5.4.5 A general examination of the machinery, as detailed in Ch 3, Sec 1 for annual surveys, is to be carried out at the end of the period of class.

5.4.6 The planned maintenance scheme may be discontinued at any time at the discretion of the Society, or at the request of the Owner, and a specific arrangement devised.

5.5 STAR-MACH survey system

5.5.1 When the additional class notation **STAR-MACH** is assigned, the class renewal survey covering machinery installation and other arrangement covered by the notation is replaced by the survey system described in Pt E, Ch 2, Sec 2 for the maintenance of this notation.

5.5.2 When the survey system linked to **STAR-MACH** notation is applied, appropriate notations are entered on the Certificate of Classification and in the Register of Ships.

5.5.3 This survey system does not supersede the annual surveys and other periodical and occasional surveys.

5.5.4 A general examination of the installation covered by the notation, as detailed in Ch 3, Sec 1 for annual surveys, is to be carried out at the end of the period of class.

6 Other periodical surveys

6.1 General

6.1.1 The different types of periodical surveys are summarized in Tab 1.

6.2 Annual surveys

6.2.1 Annual surveys are to be carried out within three months before or after each anniversary date.

6.3 Intermediate surveys

6.3.1 An intermediate survey, where applicable, is to be carried out within the window from three months before the second to three months after the third anniversary date.

6.3.2 The intermediate survey is applicable at any period of class to ships which are five years old and over.

6.3.3 The intermediate survey is not applicable to ships with class symbol **II**.

6.3.4 Concurrent crediting to both Intermediate Survey and Class Renewal Survey for surveys and thickness measurements of spaces is not acceptable.

6.4 Ship lightweight and stability check

6.4.1 The ship lightweight and stability check aim to verify the that the ship is in conformity with respect to the state defined by the design drawings.

The checking is performed through a verification of the light ship mass, of the hull girder deformation in still water and of the stability.

6.4.2 The verification of the light ship mass is performed through a displacement measurement as defined in Pt B, Ch 3, App 1.

6.4.3 The verification of the hull girder deformation is performed through a measurement of the global vertical hull girder deformation by the way of reading aft, forward and midship draught marks or a method defined in agreement between the Owner and the Society.

This measurement is performed in still water and generally at the same time than the ship lightweight check.

6.4.4 The verification of the stability is performed through the determination of the initial righting lever arm by a stability check as defined in Pt B, Ch 3, App 1.

6.5 Bottom survey

6.5.1 Bottom survey means the examination of the outside of the ship’s bottom and related items. This examination may be carried out with the ship either in dry dock (or on a slipway) or afloat: in the former case the survey will be referred to as dry-docking survey, while in the latter case as in-water survey.

6.5.2 The Owner is to notify the Society whenever the outside of the ship’s bottom and related items can be examined in dry dock or on a slipway.

6.5.3 For ships classed with the class symbol **I**, there are to be two examinations of the outside of the ship’s bottom and related items in each period of class of five years.

In all cases, the interval between any two such examinations is not to exceed 36 months.

An extension of examination of the ship's bottom of three months beyond the due date can be granted in exceptional circumstances, as defined in [3.1.7].

6.5.4 For ships under the normal survey system, one of the bottom surveys to be performed in each period of class is to be carried out in conjunction with the class renewal survey and is to be a dry-docking survey.

The Society may allow the bottom survey carried out between class renewal surveys to be replaced by an in-water survey, subject to the provisions of Ch 3, Sec 4. Special consideration is to be given to ships of 15 years of age and over before being permitted to have such in-water examinations.

6.5.5 For ships under the continuous survey system of hull (CSH), one of the bottom surveys to be performed in each period of class is to be carried out in conjunction with the end of class period.

This bottom survey may be an in-water survey, subject to the provisions of Ch 3, Sec 4 and provided that the previous bottom survey performed in the period of class was a dry-docking survey. Special consideration is to be given to ships of 15 years of age and over before being permitted to have such in-water examinations.

6.6 Tailshaft survey

6.6.1 Definition

Tailshaft survey means survey of propeller shafts and tube shafts (hereafter referred to as tailshafts) as well as survey of other propulsion systems.

6.6.2 Tailshaft complete survey

Tailshafts are to be submitted to complete examination at the periodicity specified below and summarized in Fig 1, based on the type of shaft and its design.

a) Where the tailshaft is fitted with continuous liners or equivalent protective coating, or approved oil sealing glands, or made of corrosion-resistant material, the periodicity of complete surveys is:
   - three years for single shafting arrangements
   - four years for multi-shafting arrangements.

b) These periodicities may be increased to five years in the following cases:
   - where the propeller is fitted keyless to the shaft taper, the shaft is protected from sea water, the design details are approved, and a non-destructive examination of the forward part of the aft shaft taper is performed at each survey by an approved crack-detection method
   - where the propeller is fitted to a keyed shaft taper the design details of which comply with the applicable requirements in Pt C, Ch 1, Sec 7, and a non-destructive examination of the after end of the cylindrical part of the shaft (from the after end of the liner, if any), and of about one third of the length of the taper from the large end is performed at each survey by an approved crack-detection method
   - where the propeller is fitted to a solid flange coupling at the aft end of the shaft, the shaft and its fittings are not exposed to corrosion, the design details are approved, and a non-destructive examination of the after flange fillet area of the shaft is performed at each survey by an approved crack-detection method.

c) In all other cases the periodicity of complete surveys is three years.

6.6.3 Tailshaft modified survey

A modified survey of the tailshaft is an alternate way of examination whose scope is given in Ch 3, Sec 5. It may be accepted for tailshafts described in [6.6.2] provided that:

For oil lubricated shafts:

- they are fitted with oil lubricated bearings and approved oil sealing glands
- the shaft and its fittings are not exposed to corrosion
- the design details are approved
- the clearances of the aft bearing are found to be in order
- the oil and the oil sealing arrangements prove effective
- lubricating oil analyses are carried out regularly at intervals not exceeding six months and oil consumption is recorded at the same intervals.

The modified survey is to be carried out five years from the last complete survey with a window period of plus or minus six months.

The next complete survey is to be carried out ten years from the last complete survey.

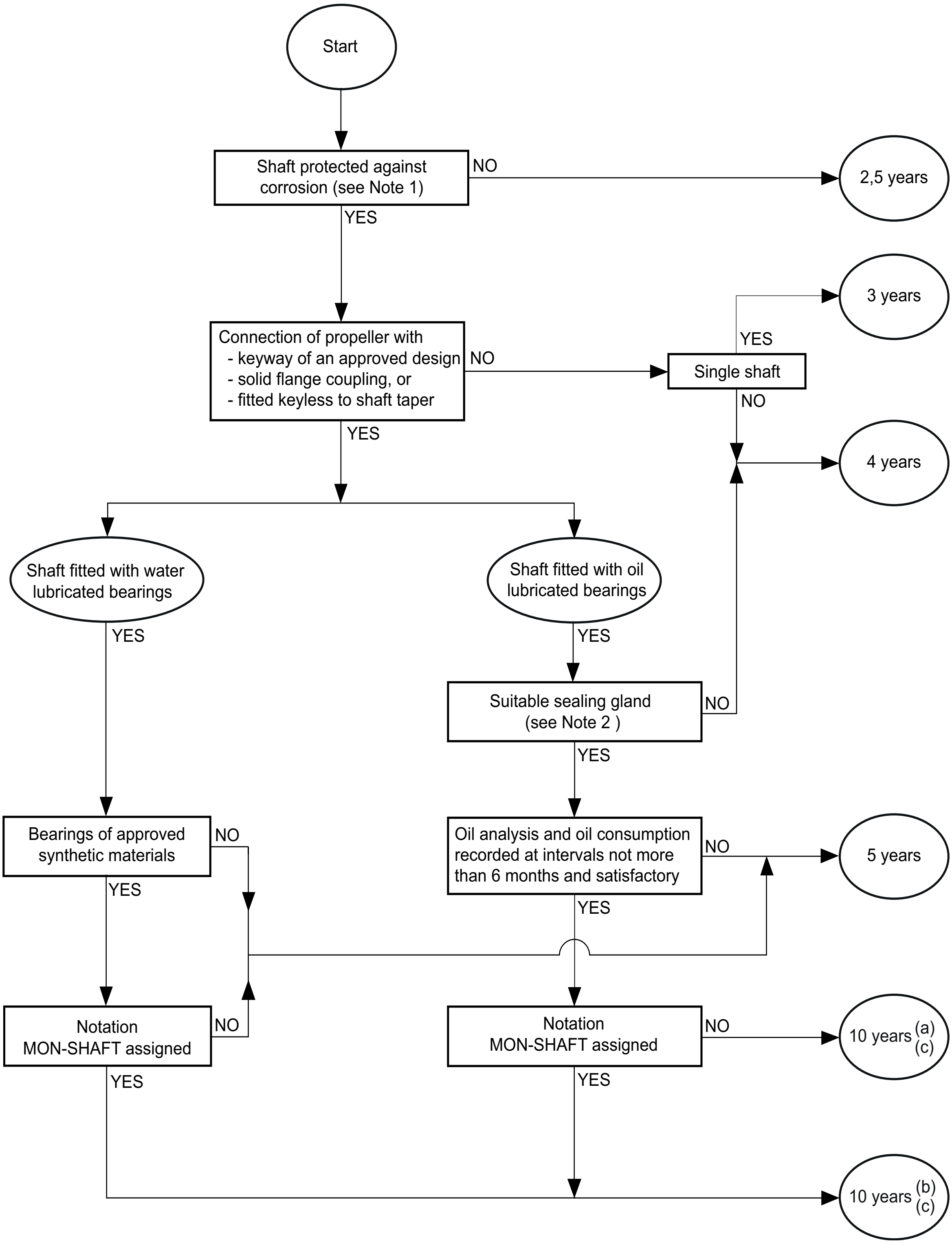
For water lubricated shafts:

- the design details are approved
- the integrity of the coating and the watertightness of its junctions to liners are found to be in order
- the bearings arrangement allows the liners surfaces to be visually checked in way of bearings without shaft removal
- the liners are found to be in order in way of bearings.

The modified survey is to be carried out five years from the last complete survey with a window period of plus or minus six months.

The next complete survey is to be carried out ten years from the last complete survey.

Figure 1 : Periodicity of complete survey of tailshaft



(a) : with shaft withdrawn, subject to modified survey at 5 years plus minus 6 months

(b) : with shaft in place, subject to modified survey at 5 years plus minus 6 months.

(c) : the periodicity cannot exceed the maximum recommended by the designer and manufacturer of the tailshaft and bearing system.

Note 1: Shafts protected against corrosion are those:

- made of corrosion resistant material, or
- fitted with continuous liners or systems considered as equivalent, or
- fitted with oil lubricated bearings and oil sealing glands.

Note 2: Suitable sealing glands are glands which are type approved by the Society with regard to protection of the sterntube against ingress of water.

6.6.4 Tailshaft Monitoring System (MON-SHAFT)

Where, in addition to the conditions stated in [6.6.3] for modified survey, the additional class notation **MON-SHAFT** is assigned, the tailshaft need not be withdrawn at both the complete and modified survey provided that all condition monitoring data is found to be within permissible limits and the remaining requirements for the respective surveys are complied with.

6.6.5 Other propulsion systems

Driving components serving the same purpose as the tailshaft in other propulsion systems, such as directional propellers, vertical axis propellers, water jet units, dynamic positioning systems and thruster assisted mooring systems, are to be submitted to periodical surveys at intervals not exceeding five years.

6.7 Boiler survey

6.7.1 Boilers and thermal oil heaters are to be surveyed twice in every five-year period. The periodicity of the boiler survey is three years (36 months).

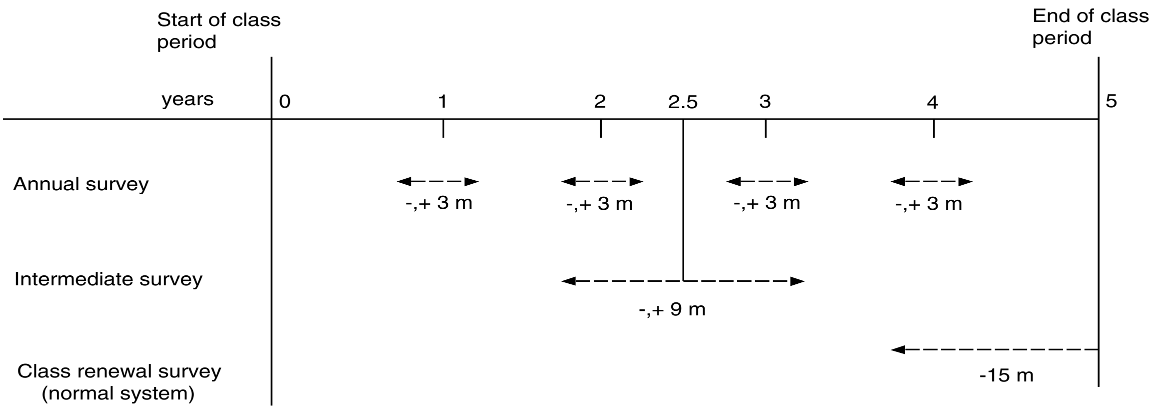
6.7.2 For ships of eight years of age and over fitted with one single boiler supplying steam for main propulsion, the interval between two boiler surveys may be specially considered.

6.7.3 Boilers are also submitted to an external inspection as a part of the annual survey of machinery.

6.8 Links between anniversary dates and annual surveys, intermediate surveys and class renewal surveys

6.8.1 The link between the anniversary dates, the class renewal survey (when carried out according to the normal system), and the annual and intermediate surveys is given in Fig 2.

Figure 2 : Links between anniversary date and annual, intermediate and class renewal surveys



7 Occasional surveys

7.1 General

7.1.1 An occasional survey is any survey which is not a periodical survey. The survey may be defined as an occasional survey of hull, machinery, boilers, refrigerating plants, etc., depending on the part of the ship concerned.

Where defects are found, the Surveyor may extend the scope of the survey as deemed necessary.

7.1.2 Occasional surveys are carried out at the time of, for example:

- updating of classification documents (e.g. change of the Owner, name of the ship, flag)
- damage or suspected damage
- repair or renewal work
- alterations or conversion
- quality system audits
- postponement of surveys or recommendations.

7.2 Damage and repair surveys

7.2.1 In the event of damage which affects or may affect the class of the ship, the Owner is to apply to the Society for a survey. Such application is to be made as soon as possible to enable the Surveyor to ascertain the extent of the damage and necessary repairs, if any.

Note 1: Whenever a ship is fitted with an helicopter platform which is made in aluminium or other low melting metal construction which is not made equivalent to steel, and a fire occurred on the said platform or in close proximity, the platform is to be subject to a structural survey to determine its suitability for further use.

7.2.2 If, after sustaining damage, the ship calls at a port where the Society is not represented, the Owner is to notify the Society forthwith, supply all available information regarding the damage and make arrangements for the ship to be surveyed in the nearest port where the Society is represented.

7.2.3 All repairs to hull, machinery and equipment which may be required in order for a ship to retain its class are to be to the satisfaction of the Surveyor.

During repairs or maintenance work, the Owner is to arrange so that any damage, defects or non-compliance with the rule requirements are reported to the Surveyor during his survey.

7.2.4 Damages and partial or temporary repairs considered acceptable by the Surveyor for a limited period of time are the subject of an appropriate recommendation.

7.2.5 Damages or repairs required by the Surveyor to be re-examined after a certain period of time are the subject of an appropriate recommendation.

7.3 Conversions, alterations and repairs

7.3.1 Conversions, alterations or repairs of/to structures and arrangements affecting the class are to be carried out in accordance with the requirements of the Society and to its satisfaction. Where necessary, documentation is to be submitted to the Society and/or made available to the attending Surveyor.

7.3.2 Materials and equipment used for conversions, alterations or repairs are generally to meet the requirements of the Rules for new ships built under survey; see Ch 2, Sec 1, [2.1.5].

7.4 Quality System audits

7.4.1 The Society reserves the right to carry out occasional surveys in order to conduct audits either as deemed necessary in pursuance of its internal Quality System.

7.4.2 These surveys may also be attended by auditors external to the Society.

7.4.3 The scope of these surveys is determined by the Society.

8 Change of ownership

8.1

8.1.1 In the case of change of ownership, the ship retains its current class with the Society provided that:

- the Society is informed of the change sufficiently in advance to carry out any survey deemed appropriate, and
- the new Owner signs the appropriate request, involving acceptance of the Society's general conditions and Rules. This request covers inter alia the condition of the ship when changing ownership.

Note 1: The ship's class is maintained without prejudice to those provisions in the Rules which are to be enforced in cases likely to cause suspension or withdrawal of the class such as particular damages or repairs to the ship of which the Society has not been advised by the former or, as the case may be, new Owner.

Note 2: No information whatsoever related to the class of the ship will be provided or confirmed to any third party, unless the appropriate request for information is duly completed and signed by the party making the request and the authorisation of the current Owner is obtained.

9 Lay-up and re-commissioning

9.1 General principles

9.1.1 A ship put out of commission may be subject to specific requirements for maintenance of class, as specified below, provided that the Owner notifies the Society of the fact.

If the Owner does not notify the Society of the laying-up of the ship or does not implement the lay-up maintenance program, the ship's class will be suspended and/or withdrawn when the due surveys are not carried out by their limit dates in accordance with the applicable requirements given in Ch 2, Sec 3.

9.1.2 The lay-up maintenance program provides for a "laying-up survey" to be performed at the beginning of lay-up and subsequent "annual lay-up condition surveys" to be performed in lieu of the normal annual surveys which are no longer required to be carried out as long as the ship remains laid-up. The minimum content of the lay-up maintenance program as well as the scope of these surveys are given in Ch 3, App 1. The other periodical surveys which become overdue during the lay-up period may be postponed until the re-commissioning of the ship.

9.1.3 Where the ship has an approved lay-up maintenance program and its period of class expires, the period of class is extended until it is re-commissioned, subject to the satisfactory completion of the annual lay-up condition surveys as described in [9.1.2].

9.1.4 The periodical surveys carried out during the lay-up period may be credited, either wholly or in part, at the discretion of the Society, having particular regard to their extent and dates. These surveys will be taken into account for the determination of the extent of surveys required for the re-commissioning of the ship and/or the expiry dates of the next periodical surveys of the same type.

9.1.5 When a ship is re-commissioned, the Owner is to notify the Society and make provisions for the ship to be submitted to the following surveys:

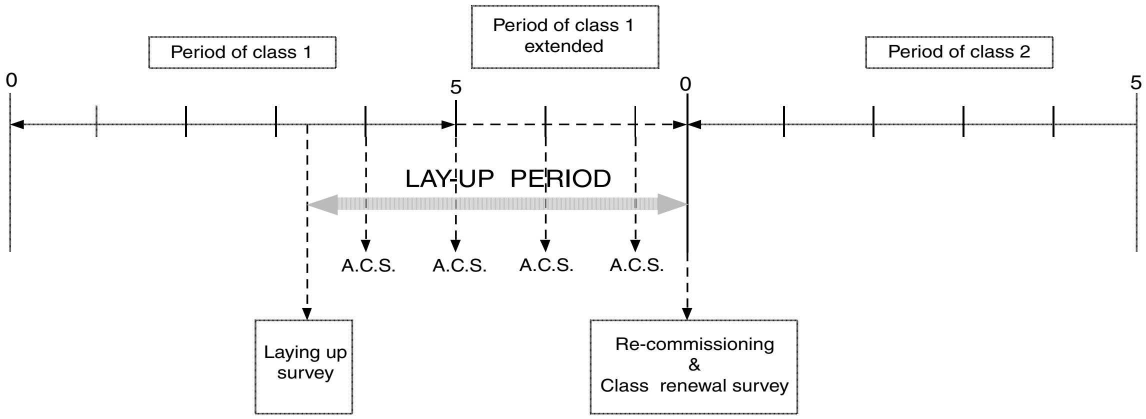
- an occasional survey prior to re-commissioning, the scope of which depends on the duration of the lay-up period
- all periodical surveys which have been postponed in accordance with [9.1.2], taking into account the provisions of [9.1.4].

9.1.6 Where the previous period of class expired before the re-commissioning and was extended as stated in [9.1.3], in addition to the provisions of [9.1.5] a complete class renewal survey is to be carried out prior to re-commissioning. Those items which have been surveyed in compliance with the class renewal survey requirements during the 15 months preceding the re-commissioning may be credited. A new period of class is assigned from the completion of this class renewal survey.

9.1.7 The principles of intervals or limit dates for surveys to be carried out during the lay-up period, as stated in [9.1.1] to [9.1.6], are summarized in Fig 3.

9.1.8 The scope of the laying-up survey and annual lay-up condition surveys are described in detail in Ch 3, App 1.

Figure 3 : Survey scheme of a case of a lay-up going beyond the expiry date of the period of class



Note 1: A.C.S. means annual lay-up condition survey.

Section 3 Suspension and Withdrawal of Class

1 General

1.1 Discontinuance of class

1.1.1 Terminology

The class may be discontinued either temporarily or permanently. In the former case it is referred to as “suspension” of class, in the latter case as “withdrawal” of class. In both these cases, the class is invalidated in all respects. In the case of withdrawal, a specific notation is entered in the supplement to the Register of Ships, until the ship is deleted from the Register.

1.2 Suspension of class

1.2.1 Military operations

When a ship is engaged in a particular operation, such as for example an operation considered with combat risks, the normal requirements for surveys are no more applicable, within the condition that the Owner notified this fact to the Society. During the notified period, the class is suspended.

At the end of the notified period the class is reinstated once the due, during the suspension period, items and/or surveys have been dealt with. The endorsement on the Certificate of Classification has to confirm that all concerned surveys have been performed and mention the period of the suspension of class.

Information given in the Certificate of Classification, associated endorsements, Rules and specific documents enables the Owner to identify the status of surveys and recommendations.

It is the Owner responsibility to verify that the ship parts not covered by the classification are in a satisfactory working state.

1.2.2 The class may be suspended either automatically or following the decision of the Society, or on the Owner request (see [1.2.1]). In any event, the ship will be considered as not retaining its class from the date of suspension until the date when class is reinstated.

1.2.3 The class may be automatically suspended when one or more of the following circumstances occur:

- when a ship is not operated in compliance with the rule requirements, such as in cases of services or conditions not covered by the service notation, or trade outside the navigation restrictions for which the class was assigned
- when a ship has the draught marks placed on the sides in a position higher than that assigned, or, in cases of ships where draught marks are not assigned, the draught is greater than that assigned
- when the Owner fails to inform the Society in order to submit the ship to a survey after defects or damages affecting the class have been detected
- when repairs, alterations or conversions affecting the class are carried out either without requesting the attendance of the Society or not to the satisfaction of the Surveyor. For voyage repairs, reference is to be made to Ch 2, Sec 2, [3.9]
- in case a freeboard has been assigned to the ship, when a ships proceeds to sea with less freeboard than that assigned.

Suspension of class with respect to the above cases will remain in effect until such time as the cause giving rise to suspension has been removed. Moreover, the Society may require any additional surveys deemed necessary taking into account the condition of the ship and the cause of the suspension.

1.2.4 In addition, the class is automatically suspended:

- when the class renewal survey has not been completed by its limit date or within the time granted for the completion of the survey, unless the ship is under attendance by the Society’s Surveyors with a view to completion prior to resuming trading, and unless a specific action plan has been agreed for completion of the survey
- when the annual or intermediate surveys have not been completed by the end of the corresponding survey time window (see Ch 2, Sec 2, [3.1.3]) unless a specific action plan has been agreed for completion of the survey. Continuous survey item(s) due or overdue at the time of the annual surveys is (are) to be dealt with unless a postponement is granted by agreement with the Society, and unless a specific action plan has been agreed for completion of the survey.

Suspension of class with respect to the above cases will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.2.5 In addition to the circumstances for which automatic suspension may apply, the class of a ship may also be suspended following the decision of the Society:

- when a recommendation is not dealt with within the time limit specified, unless it is postponed before the limit date by agreement with the Society
- when one or more surveys are not held by their limit dates (see Ch 2, Sec 2, [3.1.4]) or the dates stipulated by the Society also taking into account any extensions granted in accordance with the provisions of Part A
- when, due to reported defects, the Society considers that a ship is not entitled to retain its class even on a temporary basis (pending necessary repairs or renewals, etc.)
- when the ship has not been maintained in proper condition, as set forth in Ch 1, Sec 1, [3.3.1]
- in other circumstances which the Society will consider on their merits (e.g. in the event of non-payment of fees or where the Owner fails to subject the ship to the occasional survey as per the requirement in Ch 2, Sec 2, [7.2.1]).

Suspension of class decided by the Society takes effect from the date when the conditions for suspension of class are met and will remain in effect until such time as the class is reinstated once the due items and/or surveys have been dealt with.

1.3 Withdrawal of class

1.3.1 The Society will withdraw the class of a ship after consultation of the Classification Committee in the following cases:

- at the request of the Owner
- when the causes that have given rise to a suspension currently in effect have not been removed after due notification of suspension to the Owner
- when the ship is reported as a constructive total loss
- when the ship is lost
- when the ship is reported scrapped.

Withdrawal of class takes effect from the date on which the circumstances causing such withdrawal occur.

1.3.2 When the withdrawal of class of a ship comes into effect, the Society will:

- forward the Owner written notice
- delete the ship from the Register of Ships
- notify the Naval Authority.

1.4 Suspension/withdrawal of additional class notations

1.4.1 If the survey requirements related to maintenance of additional class notations are not complied with, the suspension or withdrawal may be limited to the notations concerned.

The same procedure may apply to service notations of ships which are assigned with more than one service notation.

1.4.2 The suspension or withdrawal of an additional class notation or a service notation (where a ship is assigned with more than one service notation) generally does not affect the class.

Appendix 1 Planned Maintenance Scheme

1 General

1.1

1.1.1 A Planned Maintenance Scheme (hereafter referred to as PMS) is a survey system for machinery items which may be considered as an alternative to the Continuous Machinery Survey system (hereafter referred to as CMS), as described in Ch 2, Sec 2, [5.3].

1.1.2 This survey scheme is to be approved by the Society before being implemented. When the PMS system is applied, the scope and periodicity of the class renewal survey are tailored for each individual item of machinery and determined on the basis of recommended overhauls stipulated by the manufacturers, documented experience of the operators and, where applicable and fitted, condition monitoring. For instance, within the scope of a PMS system the following cases may occur:

- switchboard A is surveyed based on the regular expiry date of the class renewal survey
- lubricating oil pump B is surveyed based on CMS
- diesel engine C is surveyed based on running hours
- turbo pump D is surveyed based on condition monitoring.

1.1.3 However, the survey intervals for items surveyed under the PMS system should not exceed those specified for the CMS. For certain components or items of machinery, the survey intervals based on the CMS system need not be taken into consideration, provided that an approved condition monitoring system is in effect for these parts.

1.1.4 When the condition monitoring of machinery and components included in the approved PMS shows that their condition and performance are within the allowable limits, no overhaul is necessary, unless specified by the Manufacturer.

1.1.5 On board the ship there is to be a person responsible for the management of the PMS for the purpose of which he is to possess the appropriate professional qualifications. This person is usually the Chief Engineer; however, another person designated by the Owner may be accepted by the Society provided that his qualifications are considered equivalent to those of the Chief Engineer.

The surveys of machinery items and components covered by the PMS may be carried out by personnel on board who have been issued a statement of authorisation, under the conditions and limits given in Ch 2, App 2.

Items surveyed by the authorised person will be subject to the confirmatory survey as detailed in Ch 2, App 2.

1.1.6 The conditions and procedures for the approval of a PMS are indicated in Article [2].

2 Conditions and procedures for the approval of the system

2.1 General

2.1.1 The PMS is to be approved by the Society. To this end the Owner is to make a formal request to the Society and provide the documentation and information specified in [2.2], combined in a manual describing the proposed scheme and including sample copies of the different documents to be used during the implementation of the scheme.

2.1.2 When using computerised systems, access for the purpose of updating the maintenance documentation and the maintenance programmes is only granted to the person responsible for the PMS or another person authorised by him.

The computerised systems are to include a back-up procedure, which is to be activated at regular intervals.

The functional application of these systems is to be approved by the Society.

2.2 Documentation

2.2.1 The documentation to be submitted is the manual mentioned above, which is to include:

a) a description of the scheme and its application on board as well as the proposed organisation chart identifying the areas of responsibility and the people responsible for the PMS on board
b) the list of items of machinery and components to be considered for classification in the PMS, distinguishing for each the principle of survey periodicity used as indicated in [1.1.2]
c) the procedure for the identification of the items listed in b), which is to be compatible with the identification system adopted by the Society
d) the scope and time schedule of the maintenance procedures for each item listed in b), including acceptable limit conditions of the parameters to be monitored based on the manufacturers' recommendations or recognised standards and laid down in appropriate preventive maintenance sheets

e) the original reference data, monitored on board, for machinery undergoing maintenance based on condition monitoring

f) the list and specifications of the condition monitoring equipment, including the maintenance and condition monitoring methods to be used, the time intervals for maintenance and monitoring of each item and acceptable limit conditions

g) the document flow and pertinent filing procedure.

2.3 Information on board

2.3.1 The following information is to be available on board:

a) all the documentation listed in [2.2], duly updated

b) the maintenance instructions for each item of machinery, as applicable (supplied by the manufacturer or by the shipyard)

c) the condition monitoring data of the machinery, including all data since the last dismantling and the original reference data

d) reference documentation (trend investigation procedures etc.)

e) the records of maintenance performed, including conditions found, repairs carried out, spare parts fitted

f) the list of personnel on board in charge of the PMS management.

2.4 Annual report

2.4.1 An annual report covering the year's service is to be supplied to the Society. It is to include the following information:

- the list of items of machinery and components (item b) in [2.2.1]) and the procedure for their identification
- the preventive maintenance sheets
- the condition monitoring data, including all data since the last dismantling and the original reference data of the machinery checked through condition monitoring
- any changes to the other documentation in [2.2].

All the documentation is to be signed by the person responsible mentioned in [1.1.5].

3 Implementation of the system

3.1

3.1.1 When the documentation submitted has been approved and the PMS system has been implemented on board and used for a sufficient period (which is not to exceed one year) so that all personnel become familiar with it, a survey is to be carried out in order to start the system and make it officially operational. The scope of this survey, referred to as Implementation Survey, is given in [5.1.1].

3.1.2 Upon the successful outcome of the Implementation Survey, the PMS is considered approved. The relevant annex to the Certificate of Classification of the ship is updated and the survey notation PMS is entered in the Register of Ships.

4 Retention and withdrawal of the system

4.1

4.1.1 The PMS system is retained throughout the class period provided that:

- an annual report covering the year's service is supplied to the Society in accordance with [2.4]
- an annual audit in accordance with [5.2] is satisfactorily completed
- any change to the approved PMS is submitted to the Society for agreement and approval.

4.1.2 The survey arrangement for machinery according to the PMS may be withdrawn by the Society if the PMS is not satisfactorily operated on account of either the maintenance records or the general condition of the machinery or the failure to observe the agreed intervals between overhauls.

4.1.3 The Owner may discontinue the PMS at any time by informing the Society in writing. In this case, the items which have been inspected under the PMS since the last annual audit will be credited for class at the discretion of the attending Surveyor.

4.1.4 In the case of sale or change of management of the ship, the approval of the PMS will be reconsidered.

5 Surveys

5.1 Implementation survey

5.1.1 The implementation survey is to be carried out by a Surveyor of the Society, as stated in [3.1.1], within one year from the date of the documentation approval.

5.1.2 The scope of this survey is to verify that:

- the PMS is implemented in accordance with the approved documentation and is suitable for the type and complexity of the components and systems on board
- the documentation required for the annual audit is produced by the PMS
- the requirements of surveys and testing for retention of class are complied with
- the shipboard personnel are familiar with the PMS procedures.

Upon the successful outcome of the survey confirming the proper implementation of the PMS, the system is considered operational subject to the submission to the Society of a report describing the system.

5.2 Annual audit

5.2.1 Once the PMS system is implemented, the continued compliance with the requirements for checks, overhauls and repairs, where needed, indicated in [2] is to be verified by means of annual audits in order to confirm the validity of the approved survey scheme system.

5.2.2 The annual audit is to be carried out in conjunction with the annual class surveys.

5.2.3 The purpose of this audit is to verify that the scheme is being correctly operated, in particular that all items (to be surveyed in the relevant period) have actually been surveyed in due time. A general examination of the items concerned is carried out.

5.2.4 The maintenance files and functioning records are examined to verify that the machinery has been functioning satisfactorily since the previous survey or audit or, if necessary, that the necessary measures have been taken in response to machinery operating parameters exceeding acceptable tolerances, and that the overhaul intervals have been observed.

5.2.5 Written reports of breakdown or malfunction are to be made available.

5.2.6 The description of the repairs, if any, carried out is to be examined. Any machinery part or component which has been replaced by a spare due to damage is to be retained on board, where possible. On this occasion such replaced parts are to be submitted to the examination of the Surveyor.

5.2.7 Where condition monitoring equipment is in use, functions tests, confirmatory inspections and random check readings are to be carried out as far as practicable and reasonable at the discretion of the Surveyor.

5.2.8 The Surveyor also checks that the personnel on board in charge of the PMS have the appropriate authorisation (see Ch 2, App 2).

5.2.9 A report containing the description of the overhaul and repair activity carried out throughout the period since the preceding audit, and signed by the person responsible, is to be submitted to the attending Surveyor.

5.2.10 If the Surveyor is not satisfied with the results the PMS is achieving, i.e. with the degree of accuracy as regards the maintenance records and/or the general condition of the machinery, he forwards the Society a report recommending the changes to the survey scheme and explaining the reasons for his suggestions.

5.2.11 Upon the satisfactory outcome of this audit, the Surveyor confirms the validity of the PMS, endorses the Certificate of Classification in accordance with Ch 2, Sec 2, [4.3] and decides which items can be credited for class.

5.3 Damage and repairs

5.3.1 Damage to components or items of machinery covered by the PMS which may affect the class is to be reported to the Society. A Surveyor will attend on board, survey the damaged items and, on the basis of the survey results, decide whether recommendations are to be imposed.

5.3.2 All parts of machinery or components which need to undergo substantial repairs are to be surveyed before, during and after the repairs, as deemed appropriate by the Surveyor.

5.3.3 In the case of outstanding recommendations or records of unrepaired damage which may affect the PMS, the relevant items are to be taken out of the PMS until the recommendations have been fulfilled or the repairs carried out.

6 Machinery items surveyed on the basis of condition monitoring

6.1

6.1.1 The extent of condition-based maintenance and associated monitoring equipment to be included in the maintenance scheme is decided by the Owner. The minimum parameters to be checked in order to monitor the condition of the various machinery for which this type of maintenance is accepted are indicated in [6.1.2] to [6.1.5].

6.1.2 For the main diesel engine the parameters to be checked are the following:

- power output
- rotational speed
- indicator diagram (where possible)
- fuel oil temperature and/or viscosity
- charge air pressure
- exhaust gas temperature for each cylinder
- exhaust gas temperature before and after the turbochargers
- temperatures and pressure of engine cooling systems
- temperatures and pressure of engine lubricating oil system
- rotational speed of turbochargers
- vibrations of turbochargers
- results of lubricating oil analysis
- crankshaft deflection readings
- temperature of main bearings.

6.1.3 For the main and auxiliary steam turbines the parameters to be checked are the following:

- turbine bearing vibrations
- power output
- rotational speed
- plant performance data, i.e. steam conditions at the inlet and outlet of each turbine, saturated, superheated and desuperheated steam conditions at the outlet of boilers, condenser vacuum, sea temperature.

6.1.4 For the auxiliary diesel engines the parameters to be checked are the following:

- exhaust gas temperature before and after the turbochargers
- temperatures and pressure of engine cooling systems
- temperatures and pressure of engine lubricating oil system
- rotational speed of turbochargers
- crankshaft deflection readings.

6.1.5 For other auxiliary machinery the parameters to be checked are the following, as applicable:

- inlet and outlet temperatures of cooling systems
- inlet and outlet temperatures of heating systems
- vibrations and performance data of pumps and fans
- differential pressure at filters.

Appendix 2 CSM and PMS Systems: Surveys Carried out by the Chief Engineer

1 Conditions

1.1

1.1.1 The basic conditions for the acknowledgment of surveys carried out by Chief Engineers are specified hereafter. Consideration may be given to other conditions on a case by case basis.

1.1.2 An Owner's attestation, confirming that the Chief Engineer is duly qualified to carry out the inspection of the machinery items when the CSM system or PMS system, as applicable, is implemented on-board ships in accordance with the requirements in [2.1.1] and [2.1.2], is to be made available to the Surveyor on-board.

2 Limits of the interventions

2.1

2.1.1 For ships where the CSM system is implemented, the following items of the class renewal survey for machinery cannot be inspected by the Chief Engineer:

- pressure vessels
- main and auxiliary turbines
- main reduction gears
- crankshafts, with associated main bearings and bottom end connecting rod bearings, of main propulsion internal combustion engines. However, bottom end connecting rod bearings of diesel engines having trunk pistons may be inspected by the Chief Engineer when the complete associated cylinder is inspected in the course of the engine maintenance program
- turbochargers of main propulsion internal combustion engines
- intermediate shafting and associated bearings.

Generally, within a 10-year cycle comprising two consecutive class cycles, all the items surveyed under CSM are to be inspected once by the Society’s Surveyors.

2.1.2 For ships where the PMS system is implemented, all items covered by the system can be surveyed by the Chief Engineer, with the exception of pressure vessels.

2.1.3 In no case may the surveys of tailshafts and boilers, which are items not included in the scope of the class renewal survey, be carried out by the Chief Engineer.

3 Procedure for carrying out surveys

3.1 General

3.1.1 As regards the procedure for carrying out surveys, the Owner is to inform the Chief Engineer that surveys are to be conducted in accordance with the Rules of the Society and, specifically, the requirements for class renewal surveys related to machinery and systems contained in Ch 3, Sec 3, [4].

It is the responsibility of the ship’s Captain and Chief Engineer to decide the date and place for the survey of each component in order to avoid possible accidents (fire included) in the event of damage to the unit(s) remaining in service.

Some guidelines for the Chief Engineer relevant to the dismantling and inspections of main components of the machinery installation are given below.

The items and/or machinery which, as a result of the surveys, are replaced due to wear, damage or defects, are to be kept on board until they are inspected by a Surveyor of the Society.

3.2 Main diesel engines

3.2.1 The following items are to be surveyed as indicated:

- the top and bottom halves of the main bearings are to be removed and inspected, and the clearances are to be taken, recorded and compared with the limits recommended by the engine builder
- the top and bottom halves of crankpin bearings are to be examined, and the clearances are to be taken, recorded and compared with the limits recommended by the engine builder
- crankpins, journals and webs are to be examined for crack detection, mainly at the fillets and in the vicinity of the lubricating oil holes
- crankshaft deflections are to be taken and recorded at regulars intervals, enabling verification of the trend when they are taken in the presence of the Society's Surveyor. This operation is to be effected bearing in mind that during the readings the journals are to be steady on their bearings
- other parts exposed to wear or operating incidents are to be carefully examined and the results recorded. In particular, the wear of liners is to be measured and recorded.

3.3 Auxiliary diesel engines

3.3.1 The survey generally consists of the complete dismantling of the engine and a careful examination of those items most liable to be exposed to wear or operating incidents. In particular:

- crankshaft deflections and wear of cylinder liners are to be measured
- the crankshaft is to be checked by means of dye penetrant in way of fillets and lubricating oil holes
- all top halves of the main bearings together with at least two bottom halves are to be dismantled
- crankcase explosion relief valves, if fitted, are to be checked.

3.4 Reciprocating compressors

3.4.1 The survey is to include:

- the dismantling of pistons and valves for inspection
- the examination and testing of the nest of cooler tubes
- the verification of safety relief valves after reassembling.

3.5 Coolers, condensers, heaters

3.5.1 The survey is to include:

- the dismantling of the covers
- the examination of the nest of tubes
- the testing of the nest of tubes, if necessary.

3.6 Electrical switchboard

3.6.1 The survey is to include:

- the cleaning of the switchboard
- the verification of the connection assemblies, locking device tightening and busbar tightening
- the examination of the condition of the circuit-breakers, switches and fuses
- the verification of the contacts and screens
- the checking of the measuring instruments, which are to be re-calibrated or replaced, if inaccurate
- the insulation resistance test.

3.7 a.c. and d.c. generators

3.7.1 The survey is to include:

- the removal of protection plates and brush carriers
- the cleaning of field coils and armature windings
- the verification of proper contact of brushes, which are to be renewed if excessively worn
- the verification of commutators and sliprings
- the measurement of air gap clearances
- the checking of journals and bearings
- the insulation resistance test.

3.8 Other items (pumps, electric motors, etc.)

3.8.1 The survey is generally to include the complete dismantling for inspection of the main parts exposed to wear or operating incidents, such as bearings, casings, impellers and rotors.

4 Records of surveys carried out

4.1

4.1.1 The surveys carried out by the Chief Engineer are to be recorded in the engine/machinery log-book and a survey report is to be prepared for each item surveyed.

The report is generally to be drawn up in English; however, for ships trading in specific restricted areas the use of the language of the country concerned will be accepted.

The report may be provided in hard copy or using a computerised recording system.

4.1.2 The report is to indicate the following information:

- identification data:
  - name of ship and register number
  - name of Chief Engineer and Owner's attestation
  - date and place (port or voyage leg) of the survey
  - reference of the item in the CSM or PMS list, and description of the item
- inspection conducted:
  - the type of inspection carried out: visual external examination, internal examination after dismantling, overhaul
  - readings performed, when applicable: clearances, measurements, working pressure, or other working parameters of the equipment
  - inspection findings: corrosion, fractures, pieces of equipment worn out, broken or missing
- maintenance and repairs carried out and parts replaced
- results of tests performed after the inspection, such as working test, pressure test.

For sake of completeness, other documentation such as sketches, photos, measurement reports may be attached to the report.

The report is to be signed by the Chief Engineer.

5 Confirmatory survey

5.1

5.1.1 A confirmatory survey, to be carried out by a Surveyor of the Society, is to be requested according to the following principle:

- for ships under the CSM system, within a reasonably short time from the date of the surveys carried out by the Chief Engineer, and, in any case, in the first port which is under the jurisdiction of an Office of the Society
- for ships under the PMS system, at the next annual audit (see Ch 2, App 1, [5.2]).

5.1.2 The Surveyor is to be supplied with a copy of this survey report and also shown the engine log-book.

5.1.3 The Surveyor carries out an external examination of the relevant items and parts replaced and, if applicable, attends running tests. If doubts arise, the Surveyor may request dismantling as deemed necessary.

5.1.4 If the persons on board are authorized to survey the main engine crankshaft and bearings (see [2.1.2]), the Surveyor performs the following:

- check of condition monitoring records (see Ch 2, App 1, [6.1.2])
- check of crankshaft deflection readings
- check of bearing clearances (where possible)
- checks for signs of wiped or broken white metal in the crankcase or filters
- check of the witness marks of shrink fits of crankshafts
- check of the bedplate structure (inside and outside)
- check that the condition of crankpins, journals and associated bearings is duly recorded.

5.1.5 Where the confirmatory survey is performed with an abnormal delay, the inspection is to be more extensive and, if necessary, the due surveys are to be completely repeated.

5.1.6 The date of the execution of the surveys will be assumed to be the date of the confirmatory survey.

6 Suspension of the Chief Engineer's authorization

6.1

6.1.1 Where the condition of the items surveyed by the Chief Engineer as specified in his or her reports does not correspond to the findings of the attending Surveyor, the Society may suspend the Chief Engineer's authorization.

6.1.2 The Society may also suspend the Chief Engineer's authorization in case of doubt on the general maintenance of the machinery installation.

Appendix 3 Thickness Measurements: Extent, Determination of Locations, Acceptance Criteria

1 General

1.1 Aim of the Appendix

1.1.1 Thickness measurements are a major part of surveys to be carried out for the maintenance of class, and the analysis of these measurements is a prominent factor in the determination and extent of the repairs and renewals of the ship's structure.

1.1.2 The Appendix is intended to provide Owners, companies performing thickness measurements and the Society's Surveyors with a uniform means with a view to fulfilling Rule requirements for thickness measurements. In particular, it will enable all the above-mentioned parties to carry out:

- the planning and preparation
- the determination of extent and location, and
- the analysis

of the thickness measurements in cooperation.

1.1.3 This Appendix is also to be used for the thickness measurements of ships assigned the notation **STAR-HULL** (see Ch 5, Sec 3 and Part E, Chapter 2). However, the acceptance criteria for thickness measurements specific to this notation are given in Pt E, Ch 9, Sec 3.

1.2 Scope of the Appendix

1.2.1 Separate Articles below provide the following information:

- references to rule requirements and some additional information on the extent of the thickness measurements to be performed during surveys according to types of ships and related surveys (see Article [2])
- locations of the measurements for the main parts of the ship (see Article [3])
- how to analyse the results of thickness measurements (see Article [4]).

Tables and sketches are also given to detail the above points according to the types of ships.

2 Rule requirements for the extent of measurements

2.1 General

2.1.1 For the maintenance of class, thickness measurements may be required during annual, intermediate and class renewal surveys.

Tab 1 gives the references to the requirements for minimum thickness measurements indicated in Part A, Chapter 3 and Part A, Chapter 4 for each service notation and related to the different types of surveys.

Some additional explanations are also given about the wording used in the Rules as well as the general principles of the required thickness measurements during class renewal surveys.

Table 1 : References to rule requirements related to thickness measurements

SERVICE NOTATION	TYPE OF SURVEY		
	CLASS RENEWAL	INTERMEDIATE	ANNUAL
All service notations	Ch 3, Sec 3, [3.5] and Ch 3, Sec 3, Tab 2: systematic measurements and suspect areas Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 3 as guidance	Ch 3, Sec 2, Tab 1: thickness measurements to be taken if deemed necessary by the Surveyor Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 3 as guidance	Ch 3, Sec 1, [2.1.2]: areas of substantial corrosion identified at previous surveys Where substantial corrosion is found, the extent of thickness measurements may be increased to the Surveyor's satisfaction, using Ch 3, Sec 3, Tab 3 as guidance

2.2 Class renewal survey

2.2.1 The thickness measurements required by the Rules consist of:

- systematic thickness measurements, i.e. measurements of different parts of the structure in order to assess the overall and local strength of the ship
- measurements of suspect areas as defined in Ch 2, Sec 2, [3.2.8]
- additional measurements on areas determined as affected by substantial corrosion as defined in Ch 2, Sec 2, [3.2.7].

3 Number and locations of measurements

3.1 General

3.1.1 Considering the extent of thickness measurements as required by the Rules and indicated in [2], the locations of the points to be measured are given here for the most important items of the structure. Thus the number of points can be estimated.

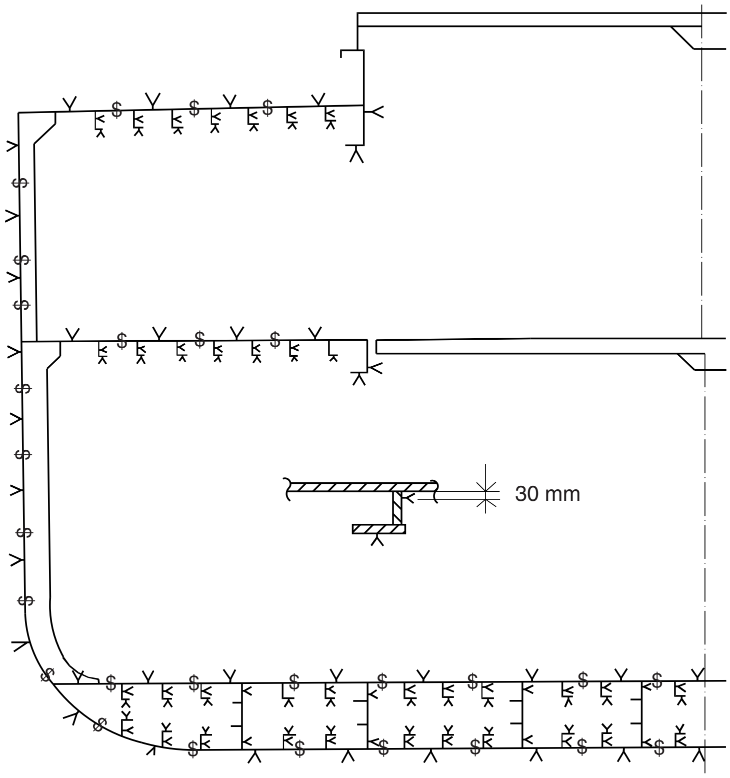
3.2 Locations of points

3.2.1 Tab 2 provides explanations and/or interpretations for the application of those requirements indicated in the Rules which refer to both systematic thickness measurements related to the calculation of global hull girder strength.

Table 2 : Interpretations of rule requirements for the locations and number of points to be measured

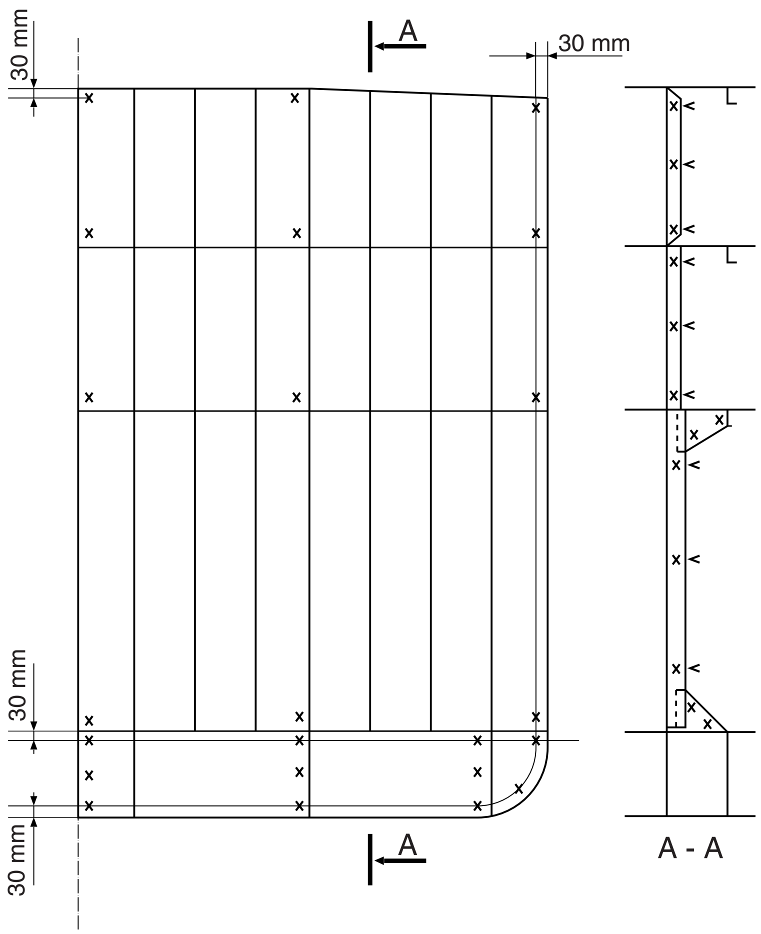
SYSTEMATIC MEASUREMENTS		
ITEM	INTERPRETATION	FIGURE
Selected plates on deck, tank top, bottom, double bottom and wind-and-water	"Selected" means at least a single point on one out of three plates, to be chosen on representative areas of average corrosion	No figure
All deck, tank top and bottom plates and wind-and-water strakes	At least two points on each plate to be taken either at each 1/4 extremity of plate or at representative areas of average corrosion	No figure
Transverse section	Refer to the definition given in Ch 2, Sec 2, [3.2.5]	Fig 1
Bulkheads	"Selected bulkheads" means at least 50% of the bulkheads	Fig 2
Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, 'tweendecks, girders	The internal structural items to be measured in each space internally surveyed are to be at least 10%	Fig 3

Figure 1 : Transverse section of a military ship



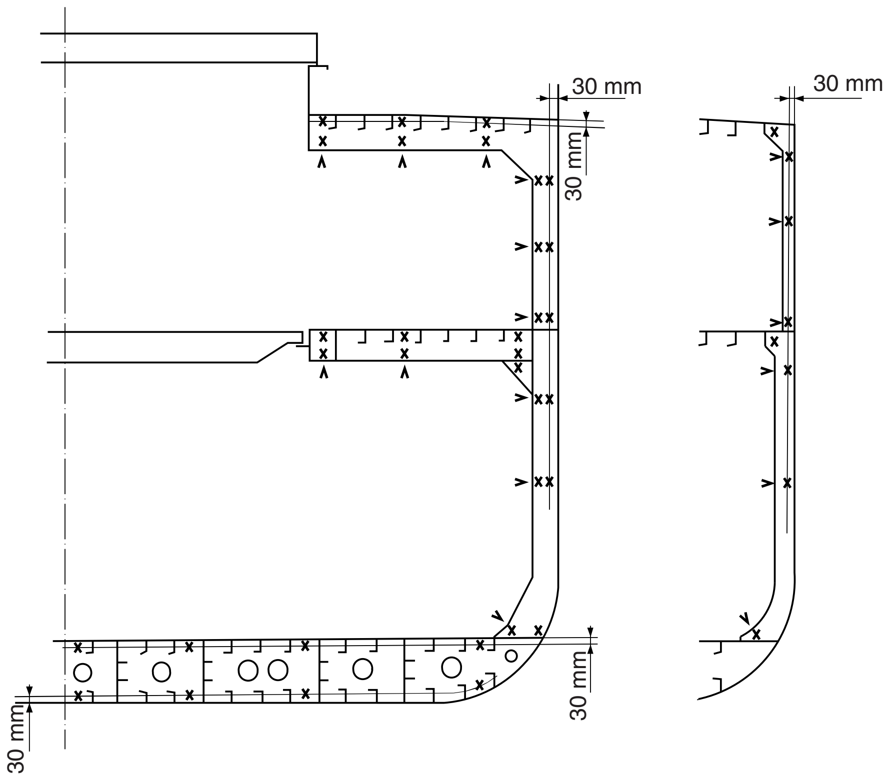
Measurements are to be taken on both port and starboard sides of the selected transverse section

Figure 2 : Locations of measurements on bulkheads of military ships



One stiffener out of three to be measured as per view A - A

Figure 3 : Locations of measurements on selected internal structural elements of military ships



4 Acceptance criteria for thickness measurements

4.1 General

4.1.1 Acceptance criteria stipulate limits of wastage which are to be taken into account for reinforcements, repairs or renewals of steel structure. These limits are generally expressed for each structural item as a maximum percentage of acceptable wastage (W). When the maximum percentage of wastage is indicated, the minimum acceptable thickness (t_{min}) is that resulting from applying this percentage to the rule thickness (t_{rule}), according to the following formula:

$$t_{min} = \left(1 - \frac{W}{100}\right) t_{rule}$$

However, when the rule thickness is not available, the as-built thickness can be used.

Only for criteria related to an item (see [4.3.4] b), the Society may establish a list of renewal thicknesses tailored to the different structural items. In such a case these thicknesses are used in lieu of the minimum thicknesses calculated from the percentage of wastage.

Note 1: In any case, at the request of the Owner, the Society may perform a direct calculation based on the current measurements.

4.1.2 In cases where the ship has some structural elements with reduced wear margins (e.g. due to ship conversion, increase of draught), the minimum acceptable thickness for these elements is to be calculated with reference to the rule scantlings without taking account of any reduction originally agreed.

4.1.3 Decisions on steel renewals are taken by the attending Surveyor applying the criteria given in this Article and based on his judgement and the actual condition of the ship. Should advice be needed to support his decision, the Surveyor may refer to the relevant technical office of the Society.

4.2 Criteria

4.2.1 The acceptance criteria for the minimum thicknesses are divided into:

- criteria on local and global strength, given in [4.3]
- criteria on buckling strength, given in [4.4]
- criteria on pitting, given in [4.5].

4.2.2 Each measured structural item is to be checked against these four criteria, as far as applicable. When the criteria are not met, reinforcements, repairs and renewals are to be carried out as appropriate.

4.3 Local and global strength criteria

4.3.1 Local and global strength criteria are given for the following ship types:

- **military ship**
- **oil replenishment ship**.

These criteria may also be used for other ship types taking into consideration the equivalence or similarity of structural elements and their contribution to local and/or global strength.

4.3.2 For the evaluation of the ship longitudinal strength, it is a prerequisite that fillet welding between longitudinal members and deck, side and bottom plating is maintained effective so as to keep continuity of hull structures.

4.3.3 Each structural item to be assessed is illustrated in a typical transverse section (see Fig 5).

These structural items are also listed in Tab 5 and grouped according to their position and contribution to the local or global strength of the ship.

4.3.4 Each structural item is to be assessed according to four different criteria which vary with regard to the domain under which it is considered, namely:

a) an isolated area, which is meant as a part of a single structural item. This criterion takes into consideration very local aspects such as grooving of a plate or web, or local severe corrosion; however, it is not to be used for pitting for which separate criteria are considered (see [4.5])

b) an item, which is meant as an individual element such as a plate, a stiffener, a web, etc. This criterion takes into consideration the average condition of the item, which is assessed by determining its average thickness using the various measurements taken on the same item

c) a group of items, which is meant as a set of elements of the same nature (plates, longitudinals, girders) contributing either to the longitudinal global strength of the ship in a given zone or to the global strength of other primary transverse elements not contributing to the ship longitudinal strength, e. g. bulkheads, hatch covers, web frames

d) a zone, which is meant as all and only longitudinal elements contributing to the longitudinal strength of the ship; in this regard, the three main zones are defined as deck zone, neutral axis zone and bottom zone. This criterion takes into consideration the average condition of all groups of items belonging to the same zone.

4.3.5 The assessment of the thickness measurements is to be performed using the values given in Tab 5, for each structural element with regard to the four criteria defined above, in the following order:

a) assessment of isolated areas (column 1 in the tables). If the criterion is not met, the wasted part of the item is to be dealt with as necessary.

b) assessment of items (column 2 in the tables). If the criterion is not met, the item is to be dealt with as necessary in the measured areas as far as the average condition of the item concerned is satisfactory. In cases where some items are renewed, the average thicknesses of these items to be considered in the next step are the new thicknesses.

c) assessment of groups of items (column 3 in the tables). If the criterion is not met, a sufficient number of elements are to be renewed in order to obtain an increased average thickness satisfying the considered criterion of the group (generally the elements to be renewed are those most wasted). As an example, for the assessment of the group "deck plates" all deck plates are measured and an average thickness of each of them is estimated. Then the average of all these values is to satisfy the criteria given for this group.

d) assessment of zones (column 4 in the tables). In principle, the criterion of the zone is met when all groups of items belonging to the zone meet their own criteria (see c) above). However, a greater diminution than those given in column 3 may be accepted for one group of items if, considering the other groups of items belonging to the same zone, the overall diminution of the zone does not exceed the criterion given for it in column 4.

   Example: The deck zone consists of two groups of items:

   - deck plating, which has an average diminution of 12% (criterion 10%)
   - deck longitudinals, which has an average diminution of 4% (criterion 10%).

   Even though the deck plating group exceeds its acceptance criterion, the average diminution of the zone, which can be very roughly estimated at 8%, is acceptable and thus the deck plating group can be accepted as it is.

Note 1: This criterion applicable to the zones is based on the general rule that the current hull girder section modulus is not to be less than 90% of the rule section modulus within 0,4L amidships. When the zone criterion is used, the assessment is made on the basis of the original modulus instead of the rule modulus. At the request of the Owner, a direct calculation using the ship's current thicknesses may be performed by the Society in order to accept greater diminutions than those given for this criterion.

4.3.6 These criteria take into consideration two main aspects:

- the overall strength of the hull girder
- the local strength and integrity of the hull structure, such as hatch covers, bulkheads, etc.

4.4 Buckling strength criterion

4.4.1 This criterion is applicable to ships having a length greater than 120 metres.

In addition to the evaluation of structural elements according to [4.3], the structural items contributing to the longitudinal strength of the ship, such as deck and bottom plating, deck and bottom girders, etc., are also to be assessed with regard to their buckling strength. The values shown in Tab 3 are not to be exceeded.

Note 1: The minimum thickness will be specially considered for ships built with excess hull girder section modulus.

4.5 Pitting

4.5.1 The maximum acceptable depth for isolated pits is 35% of the as-built thickness.

4.5.2 For areas with different pitting intensity, the intensity diagrams shown in Fig 4 are to be used to identify the percentage of affected areas.

For areas having a pitting intensity of 50% or more, the maximum average depth of pits is 20% of the as-built thickness. For intermediate values between isolated pits and 50% of affected area, the interpolation between 35% and 20% is made according to Tab 4.

Table 3 : Buckling strength criterion

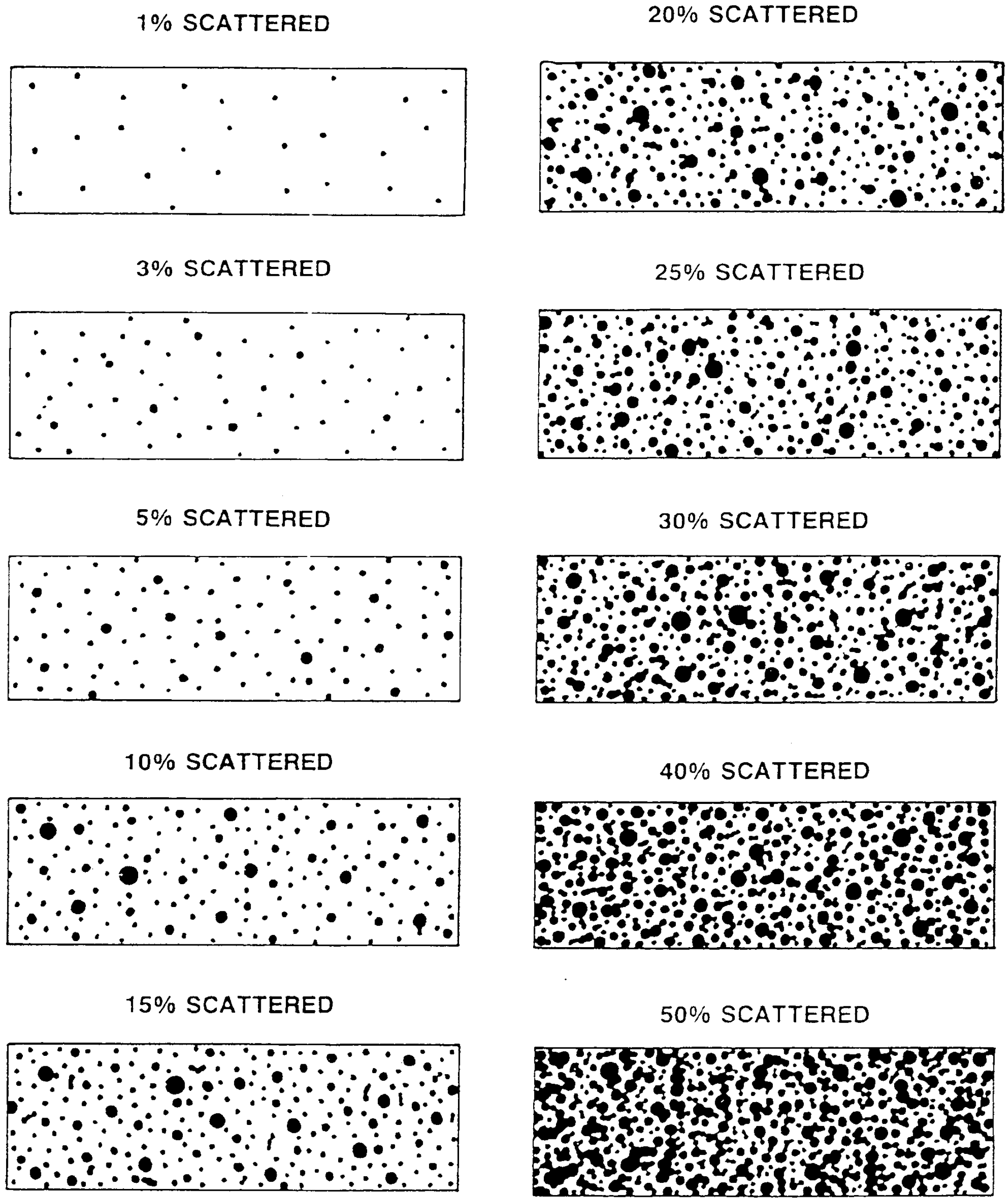
ITEMS		RATIO	MATERIAL (R_{eH})		
			235	315	355 and 390
Bottom and deck plates		s / t	56,0	51,0	49,0
Longitudinals	flat bar web	h_w / t_w	20,0	18,0	17,5
Flanged longitudinals / girders	web	h_w / t_w	56,0	51,0	49,0
Flanged longitudinals / girders	symmetrical flange	b_f / t_f	34,0	30,0	29,0
Flanged longitudinals / girders	asymmetrical flange	b_f / t_f	17,0	15,0	14,5

Symbols:
R_{eH} : Minimum yield stress of the material, in N/mm²;
s : Longitudinal spacing, in mm;
t : Actual plate thickness, in mm;
h_w : Web height, in mm;
t_w : Web thickness, in mm;
b_f : Flange breadth, in mm;
t_f : Flange thickness, in mm;

Table 4 : Pitting intensity and corresponding maximum average depth of pitting

PITTING INTENSITY (%)	MAXIMUM AVERAGE PITTING DEPTH (% of the as-built thickness)
Isolated	35,0
5	33,5
10	32,0
15	30,5
20	29,0
25	27,5
30	26,0
40	23,0
50	20,0

Figure 4 : Pitting intensity diagrams (from 1% to 50% intensity)



4.5.3 In addition, the thickness outside the pits in the area considered is to be assessed according to [4.3] and [4.4].

Note 1: Application of filler material (plastic or epoxy compounds) is recommended as a means to stop or reduce the corrosion process, but it is not considered an acceptable repair for pitting exceeding the maximum allowable wastage limits. Welding repairs may be accepted when performed in accordance with procedures agreed with the Society.

Figure 5 : Military ship: layout of items to be assessed

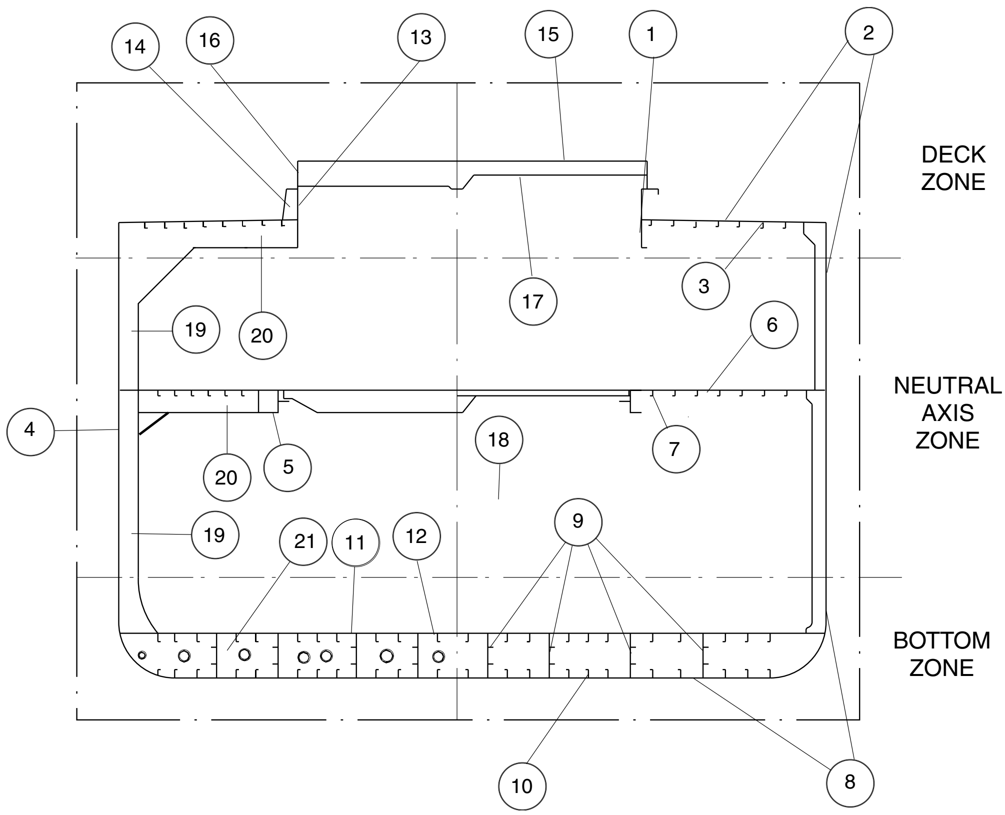


Table 5 : Local and global acceptance criteria for military ships (given in % of wastage)

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
ITEMS CONTRIBUTING TO THE LONGITUDINAL STRENGTH (TRANSVERSE SECTION)					
	DECK ZONE **(1)**	–	–	–	10
1	Hatch coaming underdeck girder web underdeck girder flange	– 25 20	– 20 15	10 – –	– – –
2	Upperdeck plating, deck stringer plates and sheer strakes	30	20	10	–
3	Deck longitudinal-++-s web flange	– 30 25	– 20 15	10 – –	– – –
	NEUTRAL AXIS ZONE **(1)**	–	–	–	15
4	Side shell plating	25	20	15	–
5	‘Tweendeck hatch girder web flange	– 25 20	– 20 15	15 – –	– – –
6	‘Tweendeck plating	30	20	15	–
7	‘Tweendeck longitudinals web flange	– 30 25	– 20 15	15 – –	– – –

(1) Each zone is to be evaluated separately.
(2) If continuous, to be included in item 1.
(3) For deep tank bulkheads, the values “average of item” and “average of group” are to be increased by 5 (%).

Group of items	Description of items	1 Isolated area	2 Item	3 Group	4 Zone
	BOTTOM ZONE **(1)**	–	–	–	10
8	Bilge and bottom strakes and keel plate	25	20	10	–
9	Bottom girders	25	20	10	–
10	Bilge and bottom longitudinals web flange	– 30 25	– 20 15	10 – –	– – –
11	Inner bottom plating	30	20	10	–
12	Inner bottom longitudinals web flange	– 30 25	– 20 15	10 – –	– – –
	OTHER ITEMS				
13	Hatch coaming plating **(2)**	25	20	–	–
14	Hatch coaming brackets	30	25	–	–
15	Hatch cover top plating	25	20	15	–
16	Hatch cover skirt plating	30	20	–	–
17	Hatch cover stiffeners	30	20	–	–
18	Transverse bulkheads **(3)** plating stringer web stringer flange stiffener web stiffener flange brackets	 30 30 25 30 25 30	 20 20 15 20 15 20	 15 – – – – –	 – – – – – –
19	Side frames web flange brackets	 30 25 30	 20 15 20	 – – –	 – – –
20	Deck/'tweendeck frames web flange	 30 25	 20 15	 – –	 – –
21	Floors plating	 30	 20	 –	 –
22	Forward and aft peak bulkheads plating stiffener web stiffener flange	 30 30 25	 20 20 15	 15 – –	 – – –

(1) Each zone is to be evaluated separately.
(2) If continuous, to be included in item 1.
(3) For deep tank bulkheads, the values "average of item" and "average of group" are to be increased by 5 (%).

Part A
Classification and Surveys

CHAPTER 3
SCOPE OF SURVEYS (ALL SHIPS)

Section 1	Annual Survey
Section 2	Intermediate Survey
Section 3	Class Renewal Survey
Section 4	Bottom Survey
Section 5	Tailshaft Survey
Section 6	Boiler Survey
Appendix 1	Class Requirements and Surveys of Laid-up Ships

Section 1 Annual Survey

1 General

1.1

1.1.1 The requirements of this Section apply to annual surveys of all ships. The specific requirements for annual surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

1.1.2 At the time of annual surveys, the ship is to be generally examined. The survey is to include a visual inspection of the hull, equipment and machinery of the ship and some operational tests thereof, so far as necessary and practicable in order to verify that the ship is in a acceptable general condition and is properly maintained. This survey is carried out alongside without dismantling.

1.1.3 Owners are reminded that, in compliance with the requirements in Ch 2, Sec 2, [7.3], any modification to the ship's hull, equipment and machinery affecting its classification is to be made known to the Society.

2 Hull

2.1 Hull and hull equipment

2.1.1 The survey is to include a general external examination and testing, where appropriate, of the following items, as applicable:

- outer shell plating above the waterline, relevant shell doors and accessible parts of the rudder(s)
- plating of main deck and exposed decks, superstructures, with their openings and means of closure
- hatchways and other openings on exposed decks, with their coamings and their means of closure and securing arrangements (for details see [2.2])
- sidescuttles and deadlights, chutes and other openings with their means of closure
- bulwarks, guard rails, freeing ports, gangways and lifelines, ladders
- scuppers and sanitary discharges, valves on discharge lines and their controls
- ventilators, air pipes, overflow pipes and gas vent pipes, with their means of closure and flame screens, where required
- when a freeboard has been assigned to the ship, freeboard marks on the ship's sides
- deck equipment such as lifeboat davit foundations, bollards, fairleads, hawse pipes, etc., masts and associated rigging, including lightning conductors
- windlass and equipment of chain cables or wire ropes for anchors
- watertight bulkheads, their watertight doors and associated local and remote controls, and their watertight penetrations
- main and auxiliary steering arrangements, including their associated equipment and control systems, and manoeuvring gear
- fire divisions and fire doors, dampers in ventilation ducts, means of closure of skylights and other openings
- confirmation that emergency escape routes from accommodation and service spaces are satisfactory
- engine room
- where fitted, helicopter deck and its supporting structure, safety net and arrangements for the prevention of sliding
- availability of loading manual or, where required, electronic loading instrument, including standard test
- availability of approved stability documentation.

Note 1: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested at working nominal pressure where doubts arise.

2.1.2 Suspect areas identified at previous class renewal surveys are to be examined. Areas of substantial corrosion identified at previous class renewal or intermediate surveys are to be subjected to thickness measurements.

2.1.3 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey, see Ch 3, Sec 3, [3.4.2], or the intermediate survey, see Ch 3, Sec 2, Tab 1.

Thickness measurements are to be carried out as considered necessary by the Surveyor.

2.2 Hatch covers and coamings

2.2.1 The Owner or his representative is to declare to the attending Surveyor that no significant changes have been made to the hatch covers, hatch coamings and their securing and sealing devices without prior approval of the Society.

The survey of hatch covers and coamings is to include:

a) when fitted with portable covers, or wooden or steel pontoons, checking of the satisfactory condition of:
   - wooden covers and portable beams, carriers or sockets for the portable beams, and their securing devices
   - steel pontoons
   - tarpaulins
   - cleats, battens and wedges
   - hatch securing bars and their securing devices
   - loading pads/bars and the side plate edge
   - guide plates and chocks
   - compression bars, drainage channels and drain pipes (if any)

b) when fitted with mechanically operated steel covers, checking of the satisfactory condition of:
   - hatch covers
   - tightness devices of longitudinal, transverse and intermediate cross junctions (gaskets, gasket lips, compression bars, drainage channels and, if any, drain pipes)
   - clamping devices, retaining bars, cleating
   - chain or rope pulleys
   - guides
   - guide rails and track wheels
   - stoppers, etc.
   - wires, chains, gypsies, tensioning devices
   - hydraulic system essential to closing and securing
   - safety locks and retaining devices
   - the operation of hatch covers, by means of random examination: stowage and securing in open condition, proper fit, locking and efficiency of sealing in closed position, operational testing of hydraulic and power components, wires, chains and link drives

c) checking of the satisfactory condition of hatch coaming plating and its stiffeners.

3 Machinery and systems

3.1 General machinery installations

3.1.1 The survey of general machinery installations is to cover the following items:

- general examination of machinery and boiler spaces with particular attention to the fire and explosion hazards; confirmation that emergency escape routes are practicable and not blocked
- general examination of the machinery, steam, hydraulic, pneumatic and other systems and their associated fittings, for confirmation of their proper maintenance
- testing of the means of communication and order transmission between the navigating bridge and the machinery control positions and other control stations
- confirmation that the rudder angle indicator on the bridge is in working order
- examination, as far as practicable, of the bilge pumping systems and bilge wells, including operation of the pumps, remote reach rods and level alarms, where fitted
- visual examination of the condition of any expansion joints in sea water systems
- external examination of pressure vessels other than boilers and their appurtenances, including safety devices, foundations, controls, relieving gear, high pressure piping, insulation and gauges.

3.1.2 When the ship is equipped with a refrigerating plant (whether or not covered by an additional class notation), the annual survey is to include the external examination of:

- pressure vessels of the installation to the same extent as indicated in [3.1.1]
- refrigerant piping, as far as practicable
- for refrigerating machinery spaces using ammonia as refrigerant:
  - ventilation system including functional test
  - water-spraying fire-extinguishing system; see [3.4.2] item d)
  - bilge system including functional test
  - electrical equipment, confirming its proper maintenance
  - gas detection system
  - breathing apparatus and protective clothing.

3.1.3 When the ship is equipped with thruster installations, the annual survey is to include:

- an external examination of the machinery installation
- an operating test of the complete installation.

3.2 Boilers

3.2.1 For main and auxiliary boilers, the annual survey consists of an external examination of boilers and their appurtenances, including safety devices, foundations, controls, relieving, high pressure and steam escape piping, insulation and gauges.

3.2.2 For thermal oil heaters, a functional test while in operation is to be carried out, during which the following items are checked:

- the heater for detection of leakages
- the condition of the insulation
- the operation of indication, control and safety devices
- the condition of remote controls for shut-off and discharge valves

A satisfactory analysis of the quality of oil is to be made available to the Surveyor.

3.2.3 For exhaust gas thermal oil heaters, in addition to the requirements of [3.2.2], a visual examination and a tightness testing to the working pressure of the heater tubes are to be carried out.

3.3 Electrical machinery and equipment

3.3.1 The survey of electrical machinery and equipment is to cover the following items:

- general examination, visually and in operation, as feasible, of the electrical installations for power and lighting, in particular main and emergency generators, electric motors, switchboards, switchgears, cables and circuit protective devices, indicators of electrical insulation and automatic starting, where provided, of emergency sources of power
- checking, as far as practicable, the operation of emergency sources of power and, where they are automatic, also including the automatic mode.

3.3.2 The survey is also to cover the bridge control of propulsion machinery, and related arrangements (alarms and safety devices), when fitted.

The survey of an automated installation covered by an additional class notation is detailed in Part A, Chapter 5.

3.3.3 The survey is also to cover the computerized systems through the control of the Software Registry as mentioned in Pt C, Ch 3, Sec 3.This survey shall include:

- checking of modification of software rgistry, in particular the reporting of security checks during software modification inside the Software Registry
- checking that revision of software mentioned in Software Registry corresponds with revision effectively used for at least one computerized system chosen at the satisfaction of the surveyor.
- checking that Software Registry has been updated according to the last ship relevant modifications

3.3.4 For ships where the electrical distribution system includes harmonic filters, the survey is to include:

- Annual measurement, as a minimum, of the harmonic distortion levels of main busbars under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the Surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or by a qualified outside source.
- Verification that records of all above measurements are made available to the Surveyor at each periodical survey.

Note 1: Those requirements apply at any scheduled machinery periodical survey having a due date on or after 1st July 2017 for ships contracted for construction before 1st July 2017.

- For ships contracted for construction on or after 1st July 2017, verification that the facilities used for continuous monitoring of the levels of harmonic distortion experienced on the main busbars as well as alerting the crew when the level of harmonic distortion exceeds the acceptable limits are working properly and review of corresponding records.

3.4 Fire protection, detection and extinction

3.4.1 The survey of fire prevention and other general arrangements is to cover the following items:

- checking that fire control plans are properly posted
- examination and testing, as feasible, of the operation of manual and/or automatic fire doors, where fitted
- checking, as far as practicable, that the remote controls for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in working order
- examination of the closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnel, where applicable
- examination, as far as practicable, and testing, as feasible and at random, of the fire and/or smoke detection systems.

3.4.2 The survey requirements for all types of fire-fighting systems that are usually found on board ships related either to machinery spaces or to cargo areas and/or spaces or to accommodation spaces, irrespective of the service notation assigned, are the following:

a) water fire system
   - examination of the fire main system and confirmation that each fire pump including the emergency fire pump can be operated separately so that the two required powerful jets of water can be produced simultaneously from different hydrants, at any part of the ship whilst the required pressure is maintained in the fire main
   - checking that fire hoses, nozzles, applicators, spanners and international shore connection (where fitted) are in satisfactory working condition and situated at their respective locations

b) fixed gas fire-extinguishing system (CO_2 , Halon or other gas)
   - external examination of gas receivers of the fixed fire-extinguishing systems and their accessories, including the removal of insulation for insulated low pressure gas containers
   - examination of fixed fire-fighting system controls, piping, instructions and marking; checking for evidence of proper maintenance and servicing, including date of last system tests
   - test of the alarm triggered before the gas is released

c) sprinkler system
   - examination of the system, including piping, valves, sprinklers and header tank
   - test of the automatic starting of the pump activated by a pressure drop
   - check of the alarm system while the above test is carried out

d) water-spraying system
   - examination of the system, including piping, nozzles, distribution valves and header tank
   - test of the starting of the pump activated by a pressure drop (applicable only for machinery spaces)

e) fixed foam systems (low or high expansion)
   - examination of the foam system
   - test to confirm that the minimum number of jets of water at the required pressure in the fire main is obtained when the system is in operation
   - checking the supplies of foam concentrate and receiving confirmation that it is periodically tested (not later than three years after manufacture and annually thereafter) by the manufacturer or an agent

f) dry powder system
   - examination of the dry powder system, including the powder release control devices
   - checking the supplies of powder contained in the receivers and that it has maintained its original smoothness
   - checking that the pressure of propelling inert gas contained in the relevant bottles is satisfactory.

3.4.3 As far as other fire-fighting equipment is concerned, it is to be checked that:

- semi-portable and portable fire extinguishers and foam applicators are in their stowed positions, with evidence of proper maintenance and servicing, and detection of any discharged containers
- firemen's outfits are complete and in satisfactory condition.

3.4.4 Where a helideck is fitted, the following is to be checked, as far as appropriate:

- drainage arrangements around the landing area
- fire fighting appliances and arrangements (to be surveyed as per [3.4.2], according to the equipment installed
- overall examination of refuelling systems and hangar facilities for cleanliness and absence of leaks, condition of gutters and drainage arrangement.

Section 2 Intermediate Survey

1 General

1.1 Application

1.1.1 The requirements of this Section apply to intermediate surveys of all ships. The specific requirements for intermediate surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

1.1.2 The intermediate survey is to include examination and checks on a sufficiently extensive part of the structure to show that the structures of the ship are in satisfactory condition so that the ship is expected to operate until the end of the current period of class, provided that the ship is properly maintained and other surveys for maintenance of class are duly carried out during this period.

2 Hull

2.1 Surveys and testings

2.1.1 The requirements given in Tab 1 for the survey and testing of salt water ballast tanks are to be complied with.

Table 1 : Intermediate survey of hull (all ships)

ITEM	Age of ship (in years at time of intermediate survey)	
	5 < age ≤ 10	10 > age
SALT WATER BALLAST SPACES	Representative spaces internally examined Thickness measurements, if considered necessary by the Surveyor See **(1) (2) (3)**	All spaces internally examined Thickness measurements, if considered necessary by the Surveyor Tightness of inner bottom plating of cargo holds in way of double bottom salt water ballast tanks checked See **(1) (3)**

(1) If no visible structural defects are present, the examination is limited to verifying that the protective coating remains efficient.
(2) Where the protective coating is found to be in poor condition, as defined in Ch 2, Sec 2, [3.2.10], where a soft coating has been applied or where a protective coating has never been applied, i.e.neither at the time of construction nor thereafter, the examination is to be extended to other ballast spaces of the same type.
(3) For salt water ballast spaces other than double bottom tanks, where a protective coating is found to be in poor condition, as defined in Ch 2, Sec 2, [3.2.10], and is not renewed, where soft coating has been applied or where a protective coating has never been applied, i.e.neither at the time of construction nor thereafter, maintenance of class is to be subject to the spaces in question being internally examined at annual surveys. The Society may consider waiving such internal examination at annual surveys of tanks protected with soft coating, whose size is 12 m^3 or less.
For salt water ballast double bottom tanks, where such breakdown of coating is found and is not renewed, where soft coating has been applied or where a protective coating has never been applied, i.e. neither at the time of construction nor thereafter, maintenance of class may be subject to the tanks in question being internally examined at annual intervals.
Note 1: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested should doubts arise.

Section 3 Class Renewal Survey

1 General

1.1

1.1.1 The requirements of this Section apply to class renewal surveys of all ships. The specific requirements for class renewal surveys related to service notations and additional class notations assigned to ships are addressed in Part A, Chapter 4 and Part A, Chapter 5, respectively.

1.1.2 The class renewal survey is to include sufficiently extensive examination and checks to show that the structures, main and auxiliary machinery, systems, equipment and various arrangements of the ship are in satisfactory condition or restored to such condition as to allow the ship to operate for the new period of class to be assigned, provided that the ship is properly maintained and other surveys for maintenance of class are duly carried out during this period.

The examinations of the hull are to be supplemented by thickness measurements and testing as deemed necessary, to ensure that the structural integrity remains effective and sufficient to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration.

1.1.3 The Owner is to provide the necessary facilities to enable this class renewal survey. The conditions for survey as detailed in Ch 2, Sec 2, [3.5] to Ch 2, Sec 2, [3.7] are to be met.

1.1.4 When the ship is under the continuous survey system for hull or machinery, the scope of the class renewal survey as described in this Section is carried out on a continuous basis over the period of class according to the procedure laid down in Ch 2, Sec 2, [5.3].

When the machinery installation is surveyed under the Planned Maintenance System, a specific program of survey replaces the scope of the class renewal survey of machinery and systems as laid down in [4], according to the procedure laid down in Ch 2, Sec 2, [5.4].

When the additional class notation **STAR-MACH** is assigned, a specific program of survey replaces the scope of the class renewal survey of the installations covered by the notation, as specified in Pt E, Ch 2, Sec 2.

1.1.5 Upon completion of the class renewal survey, or at the end of the period of class (if the relevant part of the ship is surveyed under the continuous survey system), a general examination of the ship having the same scope as that of an annual survey, as detailed in Ch 3, Sec 1, is to be carried out.

2 Stability and ship lightweight

2.1 Ship lightweight check

2.1.1 A light ship mass check has to be performed as indicated in Ch 2, Sec 2, [6.4.2].

2.2 Hull girder deflection

2.2.1 A measurement of the hull girder vertical deformation has to be performed, at each visit, as indicated in Ch 2, Sec 2, [6.4.3].

2.3 Stability check

2.3.1 A ship stability check may be required as indicated in Ch 2, Sec 2, [6.4.4] when the results of the lightship check shows a significant difference with the previous one.

3 Hull and hull equipment

3.1 Bottom survey in dry condition

3.1.1 A bottom survey in dry condition is to be carried out, as detailed in Ch 3, Sec 4, [2], and in addition the requirements given in [3.1.3] to [3.1.5] are to be complied with.

3.1.2 For ships of unusual characteristics or engaged on special services, means of underwater inspection equivalent to the bottom survey in dry condition may be considered as an alternative by the Society, particularly when a suitable high resistance paint is applied to the underwater portion of the hull or an approved system of impressed current for external cathodic protection is fitted.

3.1.3 Anchors, windlass(es) and chain cables are to be ranged and examined, and the required complement and condition are to be checked. When the ship is more than 5 years old, chain cables are to be gauged.

Any length of chain cable which is found to be damaged or excessively worn is to be renewed.

3.1.4 Sea valves and cocks are to be opened up for internal examination.

3.1.5 Thickness measurements of the outer shell plating, as and if required within the scope of the related class renewal survey, are to be carried out (refer to [3.5]).

3.2 Decks, hatch covers and equipment

3.2.1 Decks are to be examined, particular attention being given to the areas where stress concentration or increased corrosion are likely to develop, such as hatch corners and other discontinuities of structure.

Deck erections such as hatch coamings, deckhouses and superstructures are to be examined.

The sheathing of wood-sheathed steel decks may be removed, at the Surveyor's discretion, in the case of doubt as to the condition of plating underneath.

Due attention is to be given to the examination in way of end and side openings and related shell and inner doors.

3.2.2 The survey of hatch covers and coamings is to include:

- checking of the satisfactory operation of all mechanically operated hatch covers: stowage and securing in open condition, proper fit, locking and efficiency of sealing in closed position, operational testing of hydraulic and power components, wires, chains and link drives
- checking of the effectiveness of sealing arrangements of all hatch covers by means of hose testing or equivalent
- thickness measurements of coaming and attached stiffeners, hatch cover plating and stiffeners (see Tab 2).

3.2.3 The survey of hull equipment is to cover the following points:

- windlass and chain stoppers, with disassembly as deemed necessary to verify the condition of the equipment and control and safety devices, hawse pipes
- steering arrangements, including steering gear, control and indication devices, operational tests and disassembly as deemed necessary; in the case of chain and rod gears, chains, rods, sheaves, pins and rollers are to be examined for wear
- connection of masts and standing rigging to the hull structure as well as condition of structure underneath.

3.2.4 Piping systems outside tanks and compartments are to be visually examined and pressure tested as necessary, as per the requirements laid down for the class renewal survey of machinery and systems; see [4.5].

3.3 Dry compartments

3.3.1 'Tweendecks, cofferdams, pipe tunnels and duct keels, void spaces and other dry compartments which are integral to the hull structure are to be internally examined, ascertaining the condition of the structure, bilges and drain wells, sounding, venting, pumping and drainage arrangements.

The number of compartments to be examined is fixed at 5% of the total, with a minimum of five. They are to be selected on a rotational basis from one class renewal survey to the other.

3.3.2 Machinery and boiler spaces, pump rooms and other spaces containing machinery are to be internally examined, ascertaining the condition of the structure. Particular attention is to be given to tank tops, shell plating in way of tank tops, brackets connecting side shell frames and tank tops, and bulkheads in way of tank tops and bilge wells. Where wastage is evident or suspected, thickness measurements are to be carried out, and renewals or repairs effected when wastage exceeds allowable limits.

Piping systems inside these spaces are to be dealt with according to [4.5].

3.3.3 Chain lockers are to be internally examined, while the anchor chains are ranged as required for the bottom survey in dry condition (see [3.1.3]). The pumping arrangement of the chain lockers is to be tested.

3.4 Tanks

3.4.1 The type and number of tanks to be internally examined at each class renewal survey are detailed in Tab 1, according to the age of the ship.

This internal examination is to ascertain the condition of the structure, bilges and drain wells, sounding, venting, pumping and drainage arrangements, including piping systems and their fittings. Due attention is to be given to plating or double plates below the lower end of sounding and suction pipes.

Where the inner surface of the tanks is covered with cement or other compositions, the removal of coverings may be waived provided they are examined, found sound and adhering satisfactorily to the steel structures.

Note 1: For examination of independent (non-structural) tanks, refer to [4.5.9].

Note 2: Due attention is also to be given to fuel oil piping passing through ballast tanks, which is to be pressure tested when the ship is more than 12 years old.

3.4.2 For salt water ballast spaces other than double bottom tanks, where a protective coating is found to be in poor condition, as defined in Ch 2, Sec 2, [3.2.10] and is not renewed, where soft coating has been applied or where a protective coating has never been applied, i.e. neither at the time of construction nor thereafter, maintenance of class is to be subject to the spaces in question being internally examined at annual surveys. The Society may consider waiving such internal examination at annual surveys of tanks protected with soft coating, whose size is 12 m^3 or less.

For salt water ballast double bottom tanks, where such breakdown of coating is found and is not renewed, where soft coating has been applied or where a protective coating has never been applied, i.e.neither at the time of construction nor thereafter, maintenance of class may be subject to the tanks in question being internally examined at annual intervals.

3.4.3 Double bottom tanks, peak tanks, wing tanks, deep tanks and other integral or independent tanks which are intended to contain sea water or fresh water are to be filled to overflow level, for testing.

Table 1 : Requirements for internal examination of structural tanks at class renewal survey

Type and use of structural tanks	Age of ship (in years at time of class renewal survey)			
	age ≤ 5	5 < age ≤ 10	10 < age ≤15	age > 15
Peaks (all use)	all	all	all	all
Salt water ballast tanks (all types)	all	all	all	all
Fresh water tanks	none	one	half	all
Fuel oil - diesel oil tanks	none	one	two	half **(1)**
Lubricating oil tanks	none	none	one	half **(1)**

(1) Half of the tanks considered are to be internally examined every 5 years (tanks not internally examined may be examined externally from accessible boundaries); at the next class renewal survey the tanks not inspected at the previous survey are to be internally examined, and so on alternatively, so that each tank is internally examined every second class renewal survey.
Note 1: Independent non-structural tanks are to be surveyed according to [4.5.9].
Note 2: The extent of the survey of tanks dedicated to liquids other than those indicated in this table will be considered by the Society on a case-by-case basis according to the nature of the liquids.

Table 2 : Requirements for thickness measurements at class renewal survey

<table>
<tr><th colspan="4">Age of ship (in years at time of class renewal survey)</th></tr>
<tr><th>age ≤ 5</th><th>5 < age ≤ 10</th><th>10 < age ≤15</th><th>age > 15</th></tr>
<tr><td>Suspect areas</td><td>Suspect areas</td><td>Suspect areas</td><td>Suspect areas</td></tr>
<tr><td></td><td>Within the cargo length area or 0,5 L amidships:
- selected deck plates
- 1 transverse section
- selected bottom plates
- selected wind and water strakes</td><td>Within the 0,5 L amidships:
- each deck plate
- 2 transverse sections
- selected tank top plates
- selected bottom plates
- all wind and water strakes</td><td>Within 0,5 L amidships:
- each deck plate
- 3 transverse sections (3)
- each tank top plate
- each bottom plate
- all wind and water strakes</td></tr>
<tr><td></td><td></td><td colspan="2">Outside the cargo length area or 0,5 L amidships:
- selected deck plates
- selected wind and water strakes
- selected bottom plates</td></tr>
<tr><td></td><td colspan="2">Collision bulkhead, forward machinery space bulkhead, aft peak bulkhead (1) (2)</td><td>All transverse and longitudinal bulkheads (1) (2)</td></tr>
<tr><td></td><td colspan="3">In engine room:
- sea chests
- sea water manifold</td></tr>
<tr><td></td><td></td><td>Selected cargo hold bulkheads (transverse and longitudinal) (1)</td><td>All cargo hold bulkheads (transverse and longitudinal) (1)</td></tr>
<tr><td></td><td></td><td colspan="2">Selected internal structure such as floors and longitudinals, transverse frames, web frames, deck beams, tweendecks, girders, etc.
Measurements may be increased if the Surveyor deems it necessary</td></tr>
</table>

(1) Including plates and stiffeners.
(2) Measurements may be waived or reduced after satisfactory visual examination, when such bulkheads form the boundaries of dry (void) spaces.
(3) The number of transverse sections may be reduced at the Surveyor's discretion for ships of length under 90 m.

3.4.4 Tanks which are intended to contain liquids other than water such as fuel oil tanks are to be filled to the top of the tank, for testing.

3.4.5 Other testing procedures, in particular those specified in Pt B, Ch 11, Sec 3, [2] for the initial survey during construction, may be accepted.

For integral tanks which are intended to contain liquid cargoes such as edible oil, the Surveyor may waive the requirement specified in [3.4.4] subject to a satisfactory internal examination.

3.5 Thickness measurements

3.5.1 Thickness measurements are to be carried out according to the procedure detailed in Ch 2, Sec 2, [3.3].

The extent of thickness measurements is detailed in Tab 2, according to the age of the ship.

3.5.2 When the structure is coated and the coating is found to be in good condition, as defined in Ch 2, Sec 2, [3.2.10], the Surveyor may, at his discretion, accept a reduced program of thickness measurements in the corresponding areas. Other effective protective arrangements may also be considered.

3.5.3 When thickness measurements indicate substantial corrosion, the number of thickness measurements is to be increased to determine the extent of substantial corrosion. Tab 3 may be used as guidance for additional thickness measurements.

Table 3 : Guidance for additional thickness measurements in way of substantial corrosion areas

Structural member	Extent of measurements	Pattern of measurements
Plating	Suspect area and adjacent plates	5 point pattern over 1 square metre
Stiffeners	Suspect area	3 measurements each in line across web and flange

4 Machinery and systems

4.1 General

4.1.1 The survey items listed below are to be covered to the satisfaction of the Surveyor. However, other survey alternatives deemed equivalent by the Surveyor in relation to the characteristics and general condition of the ship concerned may also be accepted.

Note 1: Attention is drawn to the requirement Ch 2, Sec 2, [3.5.1] regarding safe execution of surveys, in particular as regards health hazards related to asbestos.

4.2 Main and auxiliary engines and turbines

4.2.1 General

Depending on the type of machinery, the following parts are to be opened up as necessary for inspection. Parts and components are to be pressure tested as appropriate or as deemed necessary by the Surveyor. A working test is also to be carried out, including testing of alarms and safety devices.

4.2.2 Internal combustion engines

a) Columns and entablature
b) Cylinders with their liners, cylinder covers (together with valves and valve gear), pistons with their rods, crossheads, slippers and guides (or gudgeon pins), connecting rods (with their top and bottom end bearings), control gear, driven scavenge pumps, driven air compressors, driven fuel pumps, supercharging blowers, fuel injection pumps, turning gear, etc.
c) Crankshafts (together with their main bearings)
d) Reverse gear, reduction gear and clutches, if fitted.

4.2.3 Steam turbines

a) Condensers and their cooling water and condensate extraction pumps
b) Casings and rotors (including their blading), impulse wheels (including guide blading and diaphragms), nozzles and nozzle boxes, journals and bearings, dummy pistons, labyrinths, external glands, etc.
c) Shafts, including their flexible couplings.

Where the propulsion steam turbines are of a well-known type, and fitted with rotor position indicators and vibration indicators of an approved type, as well as measuring equipment of steam pressure at proper locations along the steam flow, and the arrangements for change-over in the event of emergency operation of the plant are readily operable, the first class renewal survey may be limited to the examination of rotor bearings, thrust bearings and flexible couplings, provided the Surveyor is satisfied from operation service records and power trials subsequent to the survey, that the turbine plant is in good working condition.

4.2.4 Gas turbines

a) Casings, rotors and disks, impellers and blading of all turbines and compressors, combustion chambers, burners, heat exchangers, gas piping, compressed air piping with fittings, starting and reverse arrangements

b) Shafts and their flexible couplings.

4.2.5 Electric propulsion

Where the propulsion machinery consists of an electrical system, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined and the insulation resistance to earth tested. Due attention is to be given to windings, commutations and sliprings. The operation of protective gear and alarm devices is to be checked, as far as practicable. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly.

4.2.6 Thruster installations

When the ship is equipped with thruster installations, the class renewal survey is also to include:

- an examination of the machinery and electrical installation, as applicable
- an external examination of the propulsive part of the installation to be carried out at the dry dock survey due as part of the class renewal survey. During this examination other checks such as clearance readings, tightness of hub and blade sealing for controllable pitch propellers are to be verified. Locking arrangements for bolts, if fitted, are to be checked. Results of lubricating oil analysis to detect possible deterioration of internal gears and bearings or the presence of water are to be confirmed as acceptable. The Manufacturer's requirements may be taken into account. Dismantling of the assembly for the examination of internal parts may be required if the foregoing checks are not satisfactory
- a running test of the system under operating conditions.

4.3 Reduction gears, main thrust and intermediate shaft(s)

4.3.1 Reduction gears complete with all wheels, pinions, shafts, couplings, bearings and gear teeth, including incorporated clutch arrangements, are to be opened up, as deemed necessary by the Surveyor, for visual inspection. For complicated assemblies, gears and roller bearings may be inspected without dismantling.

4.3.2 All shafts, thrust blocks and bearings are to be examined.

4.4 Pumps and other machinery items

4.4.1 General

The items listed in [4.4.2] are to be opened up, as deemed necessary by the Surveyor, for visual inspection. Their parts and components are to be pressure tested as appropriate and considered necessary by the Surveyor. A working test is also to be carried out, including testing of alarms and safety devices if deemed necessary by the Surveyor.

4.4.2 Items to be surveyed

a) Air compressors with their intercoolers, filters and/or oil separators and safety devices

b) Heat exchangers, ventilation fans for boilers and other equipment used for essential services

c) Piston pumps and centrifugal pumps for sea water, bilge and salt water ballast

d) Screw pumps, gear pumps and centrifugal pumps other than those listed in item c) above (opening up is not required).

4.5 Systems in machinery spaces

4.5.1 Valves, cocks and strainers of the bilge and ballast systems are to be opened up, as deemed necessary by the Surveyor, for visual inspection, and, together with the piping and safety devices, examined and tested under working conditions.

4.5.2 The fuel oil, lubricating oil, hydraulic oil, thermal oil, and feed and cooling water systems, together with pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. Safety devices for the foregoing items are to be examined.

4.5.3 The compressed air system together with its valves, fittings and safety devices is to be examined, as considered necessary by the Surveyor.

4.5.4 Compressed air receivers and other pressure vessels for essential services are to be cleaned internally and examined internally and externally. Their fittings, valves and safety devices are to be opened up, as deemed necessary by the Surveyor, for visual inspection and pressure tested as appropriate.

4.5.5 Steel pipes for superheated steam having a temperature of the steam at the superheater outlet exceeding 450°C are to be examined and tested in accordance with [4.5.7] to [4.5.8] at each class renewal survey.

4.5.6 Steel pipes for saturated steam or superheated steam having a temperature of the steam at the superheater outlet not exceeding 450°C are to be examined and tested in accordance with [4.5.7] to [4.5.8] at each class renewal survey for ships over 5 years of age. When the ship is 5 years of age or less, the inspection may be limited to a check of the satisfactory general condition of pipes.

4.5.7 The examination and hydrostatic test of steel pipes for main steam machinery, and steel pipes for auxiliary steam machinery having internal diameter 75 mm and over, are to be carried out on a number of pipes selected by the Surveyor after the lagging in way is removed.

4.5.8 Representative pipe lengths connected with bolted flanges are to be internally and externally examined, and hydrostatically tested to 1,1 times the working pressure at ambient temperature. Bolts and butt-welded joints between flanges and pipes are to be submitted to a non-destructive test for crack detection.

4.5.9 Non-structural tanks located in machinery spaces are to be externally examined; the relevant fittings, with particular regard to the remote control shut-off valves under hydrostatic head, are to be externally examined to check the efficiency of manoeuvres and the absence of cracks or leakage.

4.5.10 When the ship is equipped with a refrigerating plant (whether or not covered by an additional class notation), the class renewal survey is to include:

- examination and test at the design pressure of the parts of the plant under pressure
- for refrigerating machinery spaces using ammonia as refrigerant:
  - examination and test of the water-spraying fire-extinguishing system to the same extent as indicated in [4.8.3] item d)
  - examination of valves and pumps of the bilge system to the same extent as indicated in [4.4]
  - examination and test of the electrical equipment to the same extent as indicated in [4.6.11]
  - test of the gas detection system.

4.6 Electrical equipment and installations

4.6.1 An electrical insulation resistance test is to be performed on the electrical equipment and cables. If needed, for the purpose of this test, the installation may be subdivided or equipment which may be damaged disconnected.

4.6.2 The following minimum values, when performing the insulation test, are to be considered:

- for main and emergency switchboards, feeder circuit breakers being open, busbar circuit closed, measuring and monitoring instruments disconnected, the resistance of insulation measured across each insulated busbar and the hull, and across insulated busbars, should not be less than 1 megohm
- for generators, the equipment and circuits normally connected between the generator and the first circuit breaker being connected, the resistance of insulation (preferably at working temperature whenever possible), in ohms, is to be greater than 1 000 times the rated voltage, in volts. If appropriate, the Surveyor checks also that the insulation resistance of generators separate exciter gear is not less than 250 000 ohms
- the insulation resistance of the entire electrical system is to be checked with all circuit breakers and protective devices closed, except for generators; in general, the resistance should not be less than 100 000 ohms. However, the variation of the resistance with time is to be checked, comparing the current figure with previous readings. If the insulation resistance was to drop suddenly or be insufficient, the defective circuits are to be traced, disconnecting the circuits as much as necessary.

4.6.3 The prime movers of generators are to be surveyed in accordance with [4.2] and their governors tested. All generators are to be presented for inspection, clean and with covers opened and examined under working conditions.

4.6.4 Main and emergency switchboards, section boards and distribution boards are to be cleaned and doors or covers opened for examination of their fittings. The condition of overcurrent protective devices and fuses is to be checked. Circuit-breakers of generators are to be tested, as far as practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily. The tightening of busbar connections is to be checked.

4.6.5 Electrical cables and cable runs are to be examined at random, in particular in places where deterioration is likely to occur; terminal boxes of essential services are also to be subjected to a random check.

4.6.6 The motors and starters concerning essential services together with associated control and switchgear are to be examined and, if considered necessary by the Surveyor, checked, as far as practicable, under working conditions.

4.6.7 Navigation light indicators are to be tested under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

4.6.8 The emergency sources of electrical power, their automatic arrangements and associated circuits are to be tested.

4.6.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

4.6.10 The visible condition of electrical equipment and installations is also to be checked as regards precautions against shock, fire and other hazards of electrical origin.

4.6.11 A general examination of the electrical equipment in areas where there may be flammable gas or vapour and/or combustible dust is to be carried out to ensure that the integrity of the electrical equipment of a safety type has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust-protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in satisfactory condition. The proper condition of bonding straps for the control of static electricity is to be checked. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

Note 1: Owners are reminded that maintenance, repairs or renewal of certified electrical equipment of a safe type remains their responsibility or that of their representatives.

4.6.12 The survey is also to cover the computerized systems through the control of the Software Registry as mentioned in Pt C, Ch 3, Sec 3. This survey shall include :

- checking of modification of software registry, in particular the reporting of security checks during software modification inside the Software Registry
- checking that revision of each piece of software mentioned in Software Registry corresponds with revision effectively used for any listed computerized system.
- checking that Software Registry has been updated according to the last ship relevant modifications.

4.6.13 For ships where the electrical distribution system includes harmonic filters, the survey is to include:

- annual measurement, as a minimum, of the harmonic distortion levels of main busbars under seagoing conditions as close to the periodical machinery survey as possible so as to give a clear representation of the condition of the entire plant to the surveyor. Harmonic distortion readings are to be carried out when the greatest amount of distortion is indicated by the measuring equipment. An entry showing which equipment was running and/or filters in service is to be recorded in the log so this can be replicated for the next periodical survey. Harmonic distortion levels are also to be measured following any modification to the ship's electrical distribution system or associated consumers by suitably trained ship's personnel or by a qualified outside source.
- verification that records of all above measurements are made available to the surveyor at each periodical survey.

Note 1: Those requirements apply at any scheduled machinery periodical survey having a due date on or after 1st July 2017 for ships contracted for construction before 1st July 2017.

- for ships contracted for construction on or after 1st July 2017, verification that the facilities used for continuous monitoring of the levels of harmonic distortion experienced on the main busbars as well as alerting the crew when the level of harmonic distortion exceeds the acceptable limits are working properly and review of corresponding records.

4.7 Controls, commands

4.7.1 Where remote and/or automatic controls-commands, not covered by an additional class notation related to automated installation, are fitted for essential machinery, they are to be tested to demonstrate that they are in satisfactory condition.

4.8 Fire protection, detection and extinction

4.8.1 The Owner or his representative is to declare to the attending Surveyor that no significant changes have been made to the arrangement of structural fire protection.

Note 1: Attention is drawn to the provisions of Ch 1, Sec 1, [3.1.1] regarding compliance with any additional and/or more stringent requirements issued by the Naval Authority.

4.8.2 The class renewal survey of fire prevention arrangements is to cover the following items.

a) Visible parts of items forming part of structural fire protection arrangements in accommodation spaces and in machinery spaces such as bulkheads, decks, doors, stairways, crew and service lift trunks, and light and air trunks are to be examined, due attention being given to their integrity and that of the insulating material.
b) The operation of manual/automatic fire doors, where fitted, is to be checked.
c) Remote controls for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, remote controls for stopping fans in accommodation spaces and means of cutting off power to the galley are to be tested.
d) Closing arrangements of ventilators, funnel annular spaces, skylights, doorways and tunnels, where applicable, are to be tested.
e) Fire and/or smoke detection and alarm systems are to be tested.

4.8.3 The survey requirements for all types of fire-fighting systems that are usually found on board ships related either to machinery spaces or to cargo areas and/or spaces or to accommodation spaces, irrespective of the service notation assigned, are the following:

a) water fire system
    - the associated pumps are to be opened up and examined at the Surveyor’s discretion
    - the fire main is to be hydrostatically tested to the working pressure at the Surveyor’s discretion

b) fixed gas fire-extinguishing system (CO_2 , Halon or other gas)

Receivers of gas of the fixed fire-extinguishing systems are to be externally examined together with all stationary fittings and devices. In addition, the following applies:

- the total loss of CO_2 is not to exceed 10% of the installed quantity, 5% for Halon
- after being repaired or discharged, containers are to be subjected to a hydrostatic test
- hydrostatic testing of high pressure CO_2 containers is to be carried out at intervals not exceeding 10 years; the number of the tested containers is to be not less than 10% of the total number
- low pressure gas containers are to be internally inspected if the content has been released and the container is older than five years; depending upon the result of the internal examination, the Surveyor may require the container to be hydrostatically tested.

It is to be checked that the distribution pipework is proved clear

c) sprinkler system

- the associated pumps are to be opened up and examined at the Surveyor's discretion

d) water spraying system

- the associated pumps are to be opened up and examined at the Surveyor's discretion
- a working test is to be carried out as far as reasonable and appropriate

e) fixed foam systems (low or high expansion)

- the associated pumps are to be opened up and examined at the Surveyor's discretion

f) dry powder system

- it is to be verified that the propelling inert gas bottles have been hydrostatically tested. The same applies to bottles disembarked for refilling or embarked for replacement.

4.8.4 As far as other fire-fighting equipment is concerned, the following items are to be hydrostatically tested:

- any CO_2 bottles of extinguishers
- shells of foam extinguishers
- shells of powder extinguishers
- air or gas bottles associated with fire extinguishers whose shells are not kept under pressure (if internally examined, the test need not be performed).

4.8.5 Where a helideck is fitted, the following is to be checked, as far as appropriate:

- drainage arrangements around the landing area
- fire fighting appliances and arrangements (to be surveyed as per [4.8.3] and [4.8.4], according to the equipment installed)
- other arrangements for helicopter refuelling and hangar facilities (fuel system, ventilation, fire protection and detection).

Section 4 Bottom Survey

1 General

1.1 Conditions

1.1.1 The bottom survey may be carried out in dry condition, such as in dry dock or on a slipway, or through an in-water survey.

The conditions for acceptance of a bottom in-water survey in lieu of a bottom survey in dry condition are laid down in Ch 2, Sec 2, [6.5].

2 Bottom survey in dry condition

2.1 General requirements

2.1.1 When a ship is in dry condition, it is to be placed on blocks of sufficient height to permit the examination of the bottom of the ship.

2.1.2 The outer shell plating is to be visually examined for excessive corrosion, or deterioration due to chafing or contact with the ground or for any undue deformation or buckling. Due attention is to be given to the plating of end structures (stem and sternframe), and to the bilge keel connection to the shell plating.

2.1.3 Sea chests and their gratings, sea connections and overboard discharge valves and cocks and their fastenings to the hull or sea chests are to be examined.

2.1.4 Visible parts of the propeller(s), stern bush(es), propeller shaft boss, brackets and tightness system(s) are to be examined. The clearances of the propeller shaft(s) (or wear down gauge) are to be checked and recorded. For controllable pitch propellers, the Surveyor is to be satisfied with the fastenings and tightness of hub and blade sealing.

Visible parts of other propulsion systems and propellers for steering purposes are also to be examined.

Dismantling is to be carried out, if considered necessary, notably where leakages are detected.

2.1.5 Visible parts of the rudder(s), rudder pintles, rudder stock and couplings as well as the sternframe are to be examined. If considered necessary by the Surveyor, the rudder(s) is (are) to be lifted or the inspection plates removed for the examination of pintles.

The clearances in the rudder bearings and the rudder lowering are to be checked and recorded.

2.2 Bottom survey held within the scope of class renewal survey

2.2.1 The examination and checks detailed in Ch 3, Sec 3, [3.1] are to be carried out as part of the class renewal survey. They are usually carried out during the bottom survey held concurrently with the class renewal survey.

3 Bottom in-water survey

3.1 General

3.1.1 An in-water survey may normally be carried out if the ship has been granted the additional class notation **INWATERSURVEY** as defined in Ch 1, Sec 2, [6.15.1]. Upon application by the Owner and in special circumstances, the Society may also authorise such bottom in-water survey for ships not assigned with the additional class notation **INWATERSURVEY**.

3.1.2 In principle, no outstanding recommendations are to exist requiring repair work to be carried out to the underwater part of the shell plating, the rudder, the propeller or the propeller shaft, unless the Society is satisfied that such repairs may be carried out while the ship is afloat.

3.1.3 The in-water survey is to be carried out with the ship at a suitable draught in sheltered water; the in-water visibility is to be good and the hull below the waterline is to be sufficiently clean to permit proper examination.

3.1.4 The in-water survey is to be carried out under the surveillance of a Surveyor by an in-water survey firm approved as a service supplier by the Society according to Ch 2, Sec 2, [3.4].

The Surveyor is to be satisfied with the methods of orientation of the diver(s) or remotely operated vehicle (ROV) on the plating, which should make use where necessary of permanent markings on the plating at selected points and with the method of pictorial representation. An efficient two-way communication between the Surveyor and the diver(s) is to be provided.

3.1.5 The bottom in-water survey is to provide the information normally obtained from a bottom survey carried out in dry condition, and the scope of the in-water survey is the same as detailed in [2.1], so far as practicable.

3.1.6 If the in-water survey reveals damage or deterioration that requires immediate attention, the Surveyor may require the ship to be drydocked in order for a detailed survey to be undertaken and the necessary repairs carried out.

Section 5 Tailshaft Survey

1 Survey of tailshafts

1.1 General

1.1.1 The different types of surveys to which tailshafts may be subjected and the intervals at which they are to be carried out are given in Ch 2, Sec 2, [6.6]. These surveys are:

- complete survey
- modified survey.

The requirements to be complied with at each survey are listed below.

1.2 Complete survey

1.2.1 The complete survey of tailshafts consists of the following, as applicable:

a) removal of propeller and key, where fitted, and their examination
b) complete withdrawal of shaft to permit the examination of sterntube bearings (outboard or inboard depending on the type of shaft)
c) examination by an appropriate crack detection method of the after end of the cylindrical part of the shaft and forward one third of shaft cone, or the fillet of the flange in the case of a flanged coupling
d) examination of shaft bearing surfaces, liners, joints, threaded end and nut
e) examination of oil sealing glands, if relevant, with the necessary dismantling
f) measurements of clearances and/or weardown (prior to and after the survey) and their recording
g) opening-up of controllable pitch propellers and examination of their working parts and control gear.

1.2.2 Where the notation **MON-SHAFT** has been assigned as specified in Ch 2, Sec 2, [6.6.4], the tailshaft need not be withdrawn at the complete survey and items b) and d) of [1.2.1] need not be covered provided that all condition monitoring data (bearings temperature, consumption and analysis of lubricating oil or water flow, bearings weardown, failure alarms) is found to be within permissible limits and the remaining requirements for the complete survey are complied with.

Where the Surveyor considers that the data presented is not entirely to his satisfaction, the shaft is to be withdrawn.

1.3 Modified survey

1.3.1 A modified survey may be carried out for those tailshafts which fulfil the conditions described in Ch 2, Sec 2, [6.6.3], where the periodicity of this type of survey is also shown.

1.3.2 The modified survey for all types of shafts consists of the following:

a) for oil lubricated tailshaft bearings
    - check of oil sealing glands in place
    - measurements of weardown and their recording
    - examination of the results of sterntube lubricating oil analyses, if relevant, to confirm they have been regularly performed and the recorded parameters are within acceptable limits
    - check of the records of lubricating oil consumption, if relevant, to confirm it is within permissible limits.
b) For sea water lubricated tailshaft bearings:
    - measurements of bearings weardown and clearance
    - external examination of the water pumping and filtering system and confirmation that such equipment operate satisfactorily
    - check of water flow measurements
    - verification of alarms (flow etc.) and interlock system.

1.3.3 In addition, for the different types of shafts, the following is required:

a) for shafts with keyed propeller coupling:
    - removal of propeller and key, and their examination in way of the connection area
    - examination by an appropriate crack detection method of the after end of the cylindrical part of shaft and forward one third of shaft cone

b) for shafts with keyless type propeller coupling:
   - check of the tightness of the propeller hub (propeller hood, fore gland)

c) for shafts with a solid flange coupling at the aft end and variable pitch propeller:
   - check of tightness in way of blade glands and distribution box
   - check of analysis of hydraulic oil
   - working test, as far as practicable, of the blade manoeuvring.

1.3.4 Where the Surveyor considers that the data presented is not entirely to his satisfaction, further dismantling may be required, including withdrawal of the tailshaft.

2 Periodical survey of other propulsion systems

2.1 Rotating and azimuth thrusters

2.1.1 The periodical survey of rotating and azimuth thrusters consists of:

a) removing the propeller(s) in order to examine the following items, as applicable:
   - exposed parts
   - cone and keyway to be checked by an appropriate crack detection method
   - sealing glands
   - threaded end and nut

b) examining the results of a lubricating oil analysis (water content and presence of material particles) to detect possible deterioration of internal gears and bearings

c) examining the orientation device.

If the foregoing checks are not satisfactory, dismantling of the internal parts may be required.

2.2 Vertical axis propellers

2.2.1 The periodical survey of vertical axis propeller systems consists of:

- checking the tightness of the oil glands and the backlash of the gears from outside by action on the blades
- checking the condition of gears and couplings from inside the ship
- examining the results of a lubricating oil analysis (water content and presence of material particles) to detect possible deterioration of internal gears and bearings.

If the foregoing checks are not satisfactory, dismantling of the internal parts may be required.

2.3 Ventilated propellers

2.3.1 When the ship is fitted with ventilated propellers, the survey includes, in addition with the requirements defined in [1.2] and [1.3], the following examinations:

- internal state of the air conducts with respect to free circulation of the air, corrosion and cracks
- air conducts tightness
- tightness of the mechanisms which may commit, in case of leakage, the safety of the tail shaft and of the propeller.

2.4 Pump jet systems

2.4.1 The periodical survey of pump jet systems consists of examining the following parts:

- impeller, shaft and clearances of bearings
- tightness of gland
- water duct
- steering nozzle
- reversing arrangements and control gear.

If the foregoing checks are not satisfactory, further dismantling may be required.

Section 6 Boiler Survey

1 Steam boilers

1.1

1.1.1 Steam boilers, superheaters and economisers are to be examined internally and externally with the periodicity given in Ch 2, Sec 2, [6.7]. To this end, boilers are to be emptied and suitably prepared for the examination, and the water-steam side and fire side are to be cleaned and cleared of soot. Where necessary, the external surfaces are to be made accessible for inspection by removal of insulation and lining.

1.1.2 Subject to the results of this visual examination, the Surveyor may require:

- non-destructive tests for detection of possible defects in critical areas of plating and shells, pipes and stays
- thickness measurements of plating and shells, furnaces, pipes and stays.

If appropriate, a new working pressure may be fixed by the Society.

When situated inside boiler combustion chambers, steam pipes of cylindrical boilers are to be examined at their ends, and if deemed necessary by the Surveyor, a sample pipe is to be removed for examination.

1.1.3 If the internal examination is not carried out for practicable reasons, the parts subject to pressure are to be submitted to a hydraulic test.

The testing pressure is fixed by the Surveyor versus the boiler working pressure and age.

1.1.4 Boiler supports and securing arrangements (fixed and sliding seating, chocks, rolling stays, if any, etc.) are to be examined.

Boiler accessories and mountings (such as valves and studs, water level indicators, safety valves) are to be externally and (as needed) internally examined.

Forced circulation pumps of fired steam generators are, wherever possible, to be opened up.

Fuel supply pipes between pumps and burners, fuel tank valves, pipes and deck control gear are to be examined.

1.1.5 Upon completion of the internal survey, the boiler is to be examined under steam and fuel oil burners and safety devices checked under working conditions.

Safety valves are to be checked for their setting. For auxiliary exhaust gas boilers, if steam cannot be raised at port, it is the Chief Engineer’s responsibility to set the safety valves at sea and record the setting pressure in the log-book.

2 Thermal oil heaters

2.1

2.1.1 Thermal oil heaters are to be internally and externally examined. The heater tubes are to be visually examined, and the tightness of the installation (including flange connections, valves and pumps) is to be checked through a test at the working pressure.

2.1.2 Thermal oil heater supports and securing arrangements are to be examined.

Heater accessories and mountings are to be externally and (as needed) internally examined.

Forced circulation pumps are, wherever possible, to be opened up.

Fuel supply pipes between pumps and burners, fuel tank valves, pipes and deck control gear are to be examined.

2.1.3 The following safety devices and instrumentation are to be examined and tested:

- thermal fluid temperature safety device and control
- thermal fluid flow meter
- device for low thermal fluid level in the expansion tank
- other regulation and safety systems.

2.1.4 Where repairs and/or renewal of components exposed to pressure are performed, a pressure test is to be carried out to 1,5 times the working pressure.

2.1.5 Upon completion of the survey, the thermal oil heater is to be examined under working conditions, with particular attention to safety devices and controls of the plant.

Appendix 1 Class Requirements and Surveys of Laid-up Ships

1 General

1.1

1.1.1 In order to maintain its class during a normal operation period, a ship is to be submitted to the surveys described in Ch 2, Sec 2 at their due dates and to the satisfaction of the Society, and is to be free of overdue surveys and conditions of class during the considered period.

1.1.2 When a ship stops trading and is put out of commission for a certain period, i.e. is laid-up, the normal survey requirements may no longer apply provided that the Owner notifies the Society of this fact. The Owner is also to submit a lay-up maintenance program to the Society for approval.

1.1.3 The lay-up maintenance program includes:

- the safety conditions to be kept throughout the lay-up period
- the measures taken to preserve the maintenance of the ship throughout the lay-up period
- the survey requirements to be complied with for lay-up, maintenance of class in lay-up and re-commissioning.

2 Safety conditions

2.1

2.1.1 Power supply

Adequate power supply is to be supplied, or readily available, all around the clock, either from independent means on board the ship or from shore.

The following safety conditions are to be kept throughout the lay-up period.

2.1.2 Manning

Watch personnel are to be provided. The number of the watch personnel will depend on the size of the ship, the lay-up site and mooring arrangements, the shore assistance available in case of fire, leakage or flooding, the maintenance required to provide adequate preservation. A permanent shore communication installation (radio, telephone) is also to be available.

2.1.3 Fire protection and fire fighting

The following is to be complied with:

- automatic fire alarm systems, where provided, are to be in working order and in operation
- fire-fighting installations are to be tested regularly and readily available
- the fire main is to be readily available and periodically tested under pressure
- ventilation trunks, air inlets and watertight doors are to be kept closed.

2.1.4 Protection against explosion

Cargo spaces and piping systems are to be cleaned and ventilated to prevent gas from forming any pockets.

An inert gas system in operation is recommended for the cargo spaces of oil and chemical tankers.

All flammable materials, sludge, etc. are to be removed from the ship's bilge, tank tops, double bottom tanks, engine room, pump rooms and similar spaces.

Hot work is not be carried out during lay-up, unless special precautionary measures are taken.

2.1.5 Safety equipment

All the equipment usually recommended for the safety of the watch personnel is to be provided, kept in working order and tested regularly.

The usual life-saving equipment such as liferafts, life-buoys, breathing apparatus, oxygen masks and distress signals is to be provided and made accessible.

The requirements of the flag Administration and of the local port authorities of the lay-up site are usually to be applied.

2.1.6 Emergency power

The emergency source of power, emergency generator and/or emergency air compressor are to be kept in working order and tested weekly.

3 Preservation measures for lay-up and maintenance

3.1 General

3.1.1 A lay-up log-book is to be kept on board, in which the maintenance work and tests carried out during the lay-up period are to be entered with the corresponding dates. The nature and frequency of the maintenance, inspections and tests are also to be defined in the lay-up log book.

3.1.2 The following measures for preservation and maintenance during the lay-up period are to be taken by Owners according to the type of ship, hull equipment, machinery installations and the specific cases of lay-up conditions.

3.2 Exposed parts of the hull

3.2.1 Underwater parts of the hull are to be protected against corrosion. It is advisable to provide an impressed current cathodic protection system where the quantity of corrosive waste discharge is particularly high. When such systems are provided they are to be serviced and checked at regular intervals. The condition of sacrificial anodes is to be evaluated at the annual lay-up condition surveys.

3.2.2 The coating of the hull above the waterline, exposed decks, access doors or covers on exposed decks, and hatch covers is to be maintained in satisfactory condition.

All accesses leading to internal spaces are to be kept closed.

All vent pipes and ventilation trunks are to be kept closed.

3.3 Internal spaces

3.3.1 Cargo tanks and cargo holds are to be emptied, cleaned and kept dry.

Ballast tanks are to be kept either full or empty. When ballast spaces are kept filled with sea water, special care is to be taken to keep such spaces topped up and protected against corrosion. When provided, sacrificial anodes are to be renewed when deemed necessary. The topping up is to be regularly verified.

3.3.2 Chain lockers are to be drained, cleaned and kept dry. Coating with bituminous paint is recommended.

3.3.3 Fuel oil and lubricating oil tanks are to be drained regularly.

Lubricating oil analysis is to be performed regularly and the oil renewed when the result is not satisfactory. Prior to being refilled, tanks are to be cleaned.

Empty lubricating oil tanks are to be cleaned and kept dry.

Fresh water or distilled water tanks are to be kept full or empty. Empty tanks are to be cleaned and kept dry. Where cement wash is used as a coating, this is to be examined and repaired prior to filling.

3.3.4 The bilge and tank top in engine rooms are to be cleaned and kept dry.

Hull sea inlet and outlet valves not in use are to be kept closed.

3.4 Deck fittings

3.4.1 The windlass, capstans and winches are to be regularly greased and turned once a week.

All wire cables are to be kept greased.

Visible parts of chains are to be coal-tarred and examined regularly.

Chocks and hawse pipes are to be coated with bituminous paint or equivalent if deemed necessary.

Cargo piping on deck is to be drained, blown through if deemed necessary and kept dry by opening up drains.

Electrical machinery and navigational equipment are to be protected by watertight covers.

3.5 Machinery

3.5.1 Machinery spaces

The air temperature inside the machinery spaces is normally to be kept above 0°C.

Humidity is to be kept as low as possible and within acceptable limits.

3.5.2 Machinery - General

Exposed mechanical parts of machinery are to be greased.

All rotating machinery such as diesel engines, reciprocating engines, pumps, turbines, electric motors and generators are to be turned at regular intervals with a limited number of revolutions (the lubricating oil system should be put in operation or proper priming applied). Units are not to be stopped in the same position as the previous one.

Bearing boxes are to be emptied, cleaned and refilled with new oil.

3.5.3 Main turbines

Turbines are to be kept dry.

All steam inlets are to be sealed.

Expansion arrangements (sliding feet) are to be suitably greased.

Electric heaters are to be put inside the turbines. Heat drying is to be made in open circuit, all valves shut and gland closing devices withdrawn.

Turbines are to be turned weekly, the lubricating oil system being put in service. The shaft line is to be stopped after turning an integer number of revolutions plus one quarter of a revolution.

3.5.4 Reduction gears

For large reduction gears, a fan activating the circulation of hot air in closed circuit with air hoses is to be fitted (intake at lower part of casing and discharge at upper part).

3.5.5 Auxiliary turbine-driven machinery

Stators are to be drained and kept dry.

Shaft sealing glands are to be lubricated.

Lubricating oil is to be analysed and renewed when deemed necessary. Prior to oil renewal, the oil casings are to be cleaned.

Exhaust steam pipes are to be kept dry.

Stuffing boxes are to be dismantled.

Turbines are to be turned weekly an integer number of revolutions plus one quarter of a revolution.

3.5.6 Condensers and heat exchangers

Condensers and heat exchangers are to be drained and kept dry.

Desiccant is to be placed in steam spaces.

Water sides are to be washed with fresh water.

The condition of the zinc anodes is to be periodically checked.

When tubes are fitted with plastic or fibre packing, water sides are to be filled with alkaline distilled water.

When tubes are expanded or fitted with metal packing, water sides are to be provided with desiccants and kept dry.

3.5.7 Auxiliary machinery

Air receivers are to be drained, opened up and cleaned. Pressure relief valves are to be cleaned and slightly lubricated.

Air compressor crankcases are to be drained, cleaned and refilled with clean oil. Cylinders and valves are to be lubricated. Coolers are to be drained and dried. Air drains are to be opened and the system dried.

Air start lines are to be drained and dried.

Hot-wells/return tanks are to be drained and dried.

De-aerators are to be drained and dried.

Feed pumps and extraction pumps are to be drained and dried.

Air ejectors are to be drained and dried.

Main circulation pumps are to be drained and dried.

Evaporators are to be drained, cleaned and dried.

3.5.8 Piping

Pipes not in use are to be drained and kept dry.

3.5.9 Diesel engines

Daily tank fuel oil outlet pipes and all injection equipment are to be filled with filtered gas oil.

Fresh water circuits are to be filled with water mixed with rust inhibitors. Fresh water pH is to be checked monthly.

Oil of hydraulic regulators is to be replaced.

Sea water cooling pipes are to be drained.

Crankcases are to be provided with desiccant.

Starting valves are to be lubricated (internally and externally).

Motor oil is to be sprayed in cylinders and on all external parts liable to corrosion.

Cams and cylinders are to be motor oil sprayed monthly.

Turbo-compressor/charger ball bearings are to be oil sprayed and rotated for an integer number of revolutions plus one quarter of a revolution.

Engine air inlets and exhaust gas pipes are to be sealed.

Scavenge spaces are to be cleaned.

Engines are to be turned weekly.

3.5.10 Shaft lines

Shaft lines are to be coated with grease.

Shaft bearing cooling pipes are to be drained.

For sea water lubricated propeller shafts, the packing gland of the engine room stuffing box is to be tightened.

For oil lubricated sterntubes, lubricating oil is to be analysed and renewed if not satisfactory. The oil level in the tank is to be verified regularly.

Propeller shaft lines are to be rotated an integer number of revolutions plus one quarter of a revolution.

3.6 Electrical installations

3.6.1 Main and secondary switchboards, sub-feeder panels, fuse panels and starters are to be made tight. Desiccant is to be provided.

Contacts of relays, breakers and switch-breakers are to be coated with neutral vaseline.

Bearings of generators are to be cleaned of old grease and protected with new oil or grease.

Carbon brushes are to be lifted off their commutations.

3.6.2 Electrical insulation of each item is to be kept at a minimum 200,000 Ohms and general insulation is to be not less than 50,000 Ohms. Local electric heating may be necessary to improve the level of insulation, particularly in the generators/alternators and large motors.

A insulation resistance test is to be performed regularly.

3.7 Steering gear

3.7.1 Exposed mechanical parts are to be greased or oil sprayed.

For electrical parts the same preservation measures given in [3.6] are to be taken.

It is recommended that the steering gear should be operated monthly.

3.8 Boilers

3.8.1 Smoke sides of boilers are to be swept, washed clean with basic hot water and hot air dried.

3.8.2 Water and steam sides should preferably be preserved using the dry method, keeping the moisture at the lowest possible level, the ideal level being between 30% and 35%. It is advisable to ensure that no residual water remains to cause rapid corrosion. Drum doors are to be kept closed.

In other cases, it is advisable to keep the boilers, superheaters and economisers filled with water having a pH around 10,5. Hydrazine hydrate treatment of the water is preferable to reduce risks of corrosion caused by dissolved oxygen. The water is to be regularly analysed.

3.8.3 Air heaters are to be cleaned and kept dry.

Uptake, shell and fan outlets are to be cleaned and kept closed with watertight hoods.

Burners are to be dismantled, and atomisers greased.

Desiccant is to be provided in furnaces where deemed necessary.

Expansion arrangements (sliding feet) are to be suitably greased.

The internal condition of boilers is to be checked every three months.

3.8.4 Boilers may also be preserved sealed with inert gas (nitrogen), provided that cocks and valves are tight and the installation allows an internal pressure of at least 0,05 bar to be maintained to prevent air penetration. Regular checks of the overpressure are to be carried out and results recorded in the log-book.

3.9 Automated installation

3.9.1 Recommendations for electronic components are the same as those given for electrical installations.

For pneumatic parts the manufacturers' recommendations are to be followed and the system is to be checked regularly.

Pressure, temperature or level sensors are generally not affected by damage when not used. However, when available, the manufacturers' recommendations are to be followed.

4 Lay-up site and mooring arrangements

4.1 General

4.1.1 The choice and suitability of the lay-up site, as well as the type of mooring conditions, the mooring arrangements and their efficiency during the lay-up period remain the responsibility of the Owner.

However, at the Owner's request, the mooring arrangement may be reviewed by the Society.

4.2 Recommendations for the lay-up site

4.2.1 The following recommendations are to be considered by Owners regarding the choice and suitability of the lay-up site.

The site should be:

- sheltered from open sea, strong currents and waves
- not exposed to whirling winds or turbulent tidal waves
- not exposed to moving ice
- clear of corrosive waste waters
- provided with adequate ship/shore communications.

4.3 Recommendations for the mooring arrangements

4.3.1 The following recommendations are to be considered by Owners with respect to the mooring arrangements:

- ground holding should be adequate
- vessels laid-up to buoys or anchored should be moored in such a way as to be prevented from swinging with normal wind and tidal changes
- chain cables should not be subject to cross-contact or twisting and stern anchorage should generally be provided
- laid-up ships should be in ballast condition in order to reduce the effects of wind. Due consideration should be given to the still water bending moment. For guidance, normal ballast draft should be roughly between 30% and 50% of the maximum draft.

4.3.2 Ships should normally be moored singly. However, when several ships are moored together, the following provisions are to be made:

- ships are to be moored bow to stern
- ships are to be of approximately the same size
- the number of ships moored together is, in principle, not to exceed six
- breast-lines are to be of similar elasticity
- fenders are to be provided.

4.4 Review of the mooring arrangements

4.4.1 As indicated in [4.1.1], at the Owners' request, the mooring arrangements may be reviewed by the Society.

4.4.2 The proposal for the mooring arrangements is in such case to be submitted by the Owner and is to include the following information.

a) Mooring site:
   - geographical area (to be specified on a map)
   - characteristics of the sea bottom
   - water depth
   - preferential angular sectors (effects of wind / tide / current) indicated according to statistical studies
   - wave characteristics (amplitude, periods)

b) Geometry of mooring arrangements:
   - ship's position and direction
   - shore anchorage
   - diagram showing mooring equipment (fore and aft)
   - angle between chain cables and ship's centreline

c) Characteristics of mooring equipment:
- maximum holding strength of each anchor
- type of mooring lines (chains, cables, sinkers, etc.)
- length of each section
- weight of each section
- mechanical characteristics of each section (breaking load)
- weight of sinkers.

4.4.3 On completion of the installation, the mooring arrangements are to be surveyed by the Society. When the ship is anchored, the underwater installation is to be inspected by a diver whose report is to be presented to the Society.

4.4.4 It is the responsibility of the Owners to ascertain the efficiency of the mooring arrangements during the lay-up period. The mooring arrangements are to be re-examined at regular intervals (at least each year when the ship is anchored) and when abnormal weather conditions occur at the lay-up site.

5 Surveys

5.1 Laying-up survey

5.1.1 At the beginning of the lay-up period a laying-up survey is to be carried out whose scope is to verify that the safety conditions, preservation measures, lay-up site and mooring arrangements are in accordance with the program agreed by the Society.

5.1.2 Upon satisfactory completion of this survey, an endorsement to confirm that the ship has been placed in lay-up is entered on the Certificate of Classification, which is subsequently to be kept on board.

5.2 Annual lay-up condition survey

5.2.1 As described in Ch 2, Sec 2, [9], an annual lay-up condition survey is to be performed in lieu of the normal annual class surveys. The purpose of this survey is to ascertain that the lay-up maintenance program implemented is continuously complied with.

5.2.2 It is to be checked that the arrangements made for the lay-up are unchanged and that the maintenance work and tests are carried out in accordance with the maintenance manual and recorded in the lay-up log-book.

5.2.3 Upon satisfactory completion of the survey, the Certificate of Classification is endorsed.

5.3 Re-commissioning survey

5.3.1 Owners are to make the necessary arrangements to remove the temporary lay-up installations provided for preservation measures and the protective materials and coatings (oil, grease, inhibitors, desiccants), before the survey is commenced.

It is the Owners' responsibility to verify that the ship parts that are not covered by class are reactivated in satisfactory operational condition.

5.3.2 The scope of the re-commissioning survey is to include:
- a general examination of the hull, deck fittings, safety systems, machinery installations (including boilers whose survey is not due) and steering gear
- all periodical surveys due at the date of re-commissioning or which became overdue during the lay-up period
- dealing with the recommendations due at the date of re-commissioning or which became due during the lay-up period.

5.3.3 For the hull the following is to be carried out:
- examination of shell plating above the waterline, deck plating, hatch covers and coamings
- examination of load line items
- overall survey of all cargo tanks/holds
- overall survey of representative ballast tanks when the lay-up period does not exceed two years
- overall survey of all ballast tanks when the lay-up period is two years and over
- function tests of bilge and ballast systems.

5.3.4 For the deck fittings the following is to be carried out:
- examination of the fire main under working pressure
- where possible, examination of deck piping under working pressure
- function tests of class items
- checking inert gas installation under working condition after inspection of water seal and function test of deck non-return valve and pressure/vacuum valves.

5.3.5 For machinery installations the following is to be checked:

- the analysis of lubricating oil of main engines, auxiliary engines, reduction gears, main thrust bearings and sterntube
- the general condition of crankcase, crankshaft, piston rods and connecting rods of diesel engines
- the crankshaft deflections of diesel engines. In addition when engines have been laid-up for more than two years, one piston is to be disconnected and one liner is to be removed for examination. Dismantling is to be extended if deemed necessary
- the condition of blades of turbines through the inspection doors
- the condition of the water side of condensers and heat exchangers
- the condition of expansion arrangements
- the condition of reduction gears through the inspection doors
- the condition after overhauling of pressure relief devices
- the test of bilge level alarms, when fitted.

5.3.6 The main and emergency electrical installations are to be tested. The parallel shedding of main generators and main switchboard safety devices are to be checked. An insulation resistance test of the electrical installation is to be performed.

5.3.7 For the fire prevention, detection and fire-fighting systems, the following is to be examined and/or tested:

- remote control for quick closing of fuel oil valves, stopping of fuel oil pumps and ventilation systems, closing of fire doors and watertight doors
- fire detectors and alarms
- fire-fighting equipment.

5.3.8 The automated installation is to be checked for proper operation.

5.3.9 When classed, the installations for refrigerated cargo are to be examined under working conditions. Where the lay-up period exceeds two years, representative components of the installation are to be dismantled.

5.3.10 For cargo installations on liquefied gas carriers, the following is to be carried out:

- inspection of the primary barrier in tanks
- for membrane tanks, a global gas test of tanks whose results are to be compared with those obtained at ship's delivery
- testing of gas piping at working pressure using inert gas.

A Surveyor of the Society is to attend the first cooling down and loading of the ship.

5.3.11 For other specific classed installations, the Owners are to submit a survey program to the Society.

5.3.12 On completion of the above surveys, sea trials are to be performed in the presence of a Surveyor of the Society.

The sea trials are to include:

- verification of the satisfactory performance of the deck installations, main propulsion system and essential auxiliaries, including a test of the safety devices
- an anchoring test
- complete tests of steering gear
- full head and full astern tests
- tests of automated machinery systems, where applicable.

5.3.13 Upon satisfactory completion of the surveys, an endorsement to confirm the carrying out of all relevant surveys and the re-commissioning of the ship is entered on the Certificate of Classification.

CHAPTER 4
SCOPE OF SURVEYS IN RESPECT OF THE DIFFERENT SERVICES OF SHIPS

Section 1 General

Section 2 Frigate, Corvette and Military OPV

Section 3 Aircraft Carrier

Section 4 Auxiliary Naval Vessel

Section 5 Amphibious Vessel

Section 1 General

1 General

1.1

1.1.1 The purpose of this Chapter is to give details on the scope of surveys of certain ships which, due to the service notation assigned and related equipment, need specific requirements to be verified for the maintenance of their class.

1.1.2 These specific requirements either are additional to or supersede those stipulated in Part A, Chapter 3, which gives general requirements for surveys applicable to all types of ships: this is indicated in each Section of this Chapter. These surveys are to be carried out at intervals as described in Ch 2, Sec 2, concurrently with the surveys of the same type, i.e. annual, intermediate or class renewal surveys, detailed in Part A, Chapter 3.

1.1.3 Owners are reminded that a general examination of the ship having the same scope of an annual survey is to be carried out at the completion of the class renewal survey, see Ch 3, Sec 3, [1.1.5]. Where specific requirements are given in this Chapter for the class renewal survey, they are additional to the applicable requirements for the annual survey.

2 Service notations subject to additional surveys

2.1

2.1.1 The specific requirements detailed in this Chapter are linked to the service notation(s) assigned to the ship at the request of the Owner. Where a ship has more than one service notation, the specific requirements linked to each one are applicable, insofar as they are not contradictory (in such case, the most stringent requirement will be applied).

2.1.2 Tab 1 indicates which service notations are subject to specific requirements, and in which Section they are specified.

Table 1 : Service notations for which specific requirements are applicable

Service notation assigned	Section applicable	Type of surveys affected by these specific requirements
frigate **corvette** **military OPV**	Ch 4, Sec 2	annual survey class renewal survey
aircraft carrier	Ch 4, Sec 3	annual survey class renewal survey
auxiliary naval vessel	Ch 4, Sec 4	annual survey class renewal survey
amphibious vessel	Ch 4, Sec 5	annual survey class renewal survey

Section 2 Frigate, Corvette and Military OPV

1 General

1.1

1.1.1 The requirements of this Section are applicable after construction to all self-propelled ships which have been assigned one of the following service notations:

- **frigate** as defined in Part D, Chapter 1
- **corvette** as defined in Part D, Chapter 3
- **military OPV** as defined in Part D, Chapter 6.

1.1.2 These requirements are additional to those laid down in Part A, Chapter 3, according to the relevant surveys.

2 Annual survey

2.1 Watertight bulkheads

2.1.1 The survey of watertight bulkheads and arrangements consists of:

- examination, as far as practicable, of collision and watertight bulkheads, and confirmation that their watertight integrity has not been impaired
- checking the diagram provided on the navigation bridge showing the location of the watertight doors and related indicators for their open/closed position
- testing operation of local and remote control (from the navigation bridge) of the watertight doors, and in particular, operation from each side of the bulkhead of audible alarms or visual signals and control handles, as required or fitted
- confirmation of operation of watertight doors in the event of failure of main and emergency sources of power
- confirmation that notices are affixed at appropriate locations.

2.2 Openings in shell plating

2.2.1 The survey consists of:

- examination of the arrangements for closing sidescuttles and their deadlights, as well as scuppers, sanitary discharges and similar openings and other inlets and discharges in the shell plating below the margin line
- confirmation that valves for closing the main and auxiliary sea inlets and discharges in the machinery spaces are readily accessible, and that indicators showing the status of the valves are provided, as required or fitted
- confirmation that gangway access and cargo ports fitted below the margin line may be effectively closed and that the inboard ends of any ash or rubbish chutes are fitted with an effective cover.

2.3 Shell and inner doors

2.3.1 The requirements of this item apply to all shell and inner doors fitted on these ships.

2.3.2 For the scope of survey of shell and inner doors, the following definitions are applicable:

- Securing device:

  a device used to keep the door closed by preventing it from rotating about its hinges
- Supporting device:

  a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure
- Locking device:

  a device that locks a securing device in the closed position.

2.3.3 It is to be checked that the operating procedures for closing the shell and inner doors are kept on board and posted at appropriate places.

When required, the Operating and Maintenance Manual is also to be checked for the verification of its approval and of any modification, reported repairs and proper endorsement by operating personnel.

2.3.4 The structural arrangements as well as welding are to be examined, including:

- plating, primary structure and secondary stiffeners
- hinging arms, hinges and bearings, thrust bearings
- hull and door side supports of securing, supporting and locking devices
- shell plating surrounding the openings and the securing, supporting and locking devices.

Hinge, bearing and thrust bearing clearances are to be measured when no dismantling is necessary for the measurement, or when the function tests detailed below are not satisfactory.

2.3.5 A close visual inspection of securing, supporting and locking devices, including their weld connections, is to be carried out and clearances are to be measured as required.

Non-destructive tests and/or thickness measurements may be required by the Surveyor after visual examination or in cases where cracks or deformations have been found.

2.3.6 A close visual inspection of sealing arrangements (packing material, rubber gaskets, packing retaining bars or channels) is to be carried out. For the tightness hose test, refer to [2.3.8].

2.3.7 The drainage arrangements including bilge wells, drain pipes and non-return valves are to be visually examined. A test of the bilge system between the inner and outer doors and that of the vehicle deck is to be carried out.

2.3.8 Function tests are to be carried out as follows, according to the required and/or existing equipment on board:

a) Doors are to be examined during a complete opening and closing operation; during this operation, the proper working of hinging arms and hinges, proper engagement of the thrust bearings and proper working of devices for locking the door in open position are to be checked

b) Securing, supporting and locking devices are to be examined during a complete opening and closing operation; the following items are to be checked:
   - opening/closing system and securing/locking devices are interlocked in such a way that they can only operate in proper sequence
   - mechanical lock of the securing devices
   - the securing devices remain locked in the event of loss of hydraulic fluid, if they are of hydraulic type

c) Indicators of open/closed position of doors and of securing/locking devices at remote control stations are to be checked; other safety devices such as isolation of securing/locking hydraulic system from other hydraulic systems, access to operating panels, notice plates and warning indicator lights are to be checked

d) A tightness hose test or equivalent of sealing arrangements is to be carried out

e) A working test of the indicator system is to be carried out, including checking of:
   - visual indicators and audible alarms on the navigation bridge and operating panel
   - lamp test function, fail safe performance, power supply for indicator system
   - proper condition of sensors and their protection from water, ice formation and mechanical damage

f) A working test of the water leakage detection system for inner doors and for the area between the bow door and the inner door (as applicable) is to be carried out and the proper function of audible alarms on the navigation bridge and the engine control room panel (as applicable) is to be ascertained

g) The television surveillance system is to be verified with proper indication on the navigation bridge and engine control room monitors

h) Electrical equipment for opening, closing and securing the doors is to be examined.

2.4 Fire protection, detection and extinction

2.4.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the annual survey of all ships in Ch 3, Sec 1, [3.4], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as:

- fire detection systems and alarms
- fixed fire-extinguishing arrangements (gas, water-spraying or foam systems)
- portable fire extinguishers in spaces and at entrances
- ventilation and related safety devices (including remote control on the bridge or on the central safety control room), and
- electrical equipment of a safe type.

2.5 Emergency escapes

2.5.1 It is to be verified that the emergency escape routes including related stairways and ladders, are kept clear.

2.6 Ballast equipment and installation

2.6.1 Piping

The visit includes:

- the examination of the state of the whole ballast piping system
- the examination of seals and space boundary penetrations with respect to cracks and leakages.

2.6.2 Control systems

The visit shall include the following points, as far as the elements exist:

- the examination of the filling measurement systems of the ballast capacities, upper level alarm and associated safety valves to control the overflows
- the confirmation that the pressure gauges installed on the ballast piping are correctly operational.

2.6.3 Ballasting system

The visit includes:

- the examination of all equipment of the ballasting system (pumps, valves and other components)
- the general examination of the ballast system equipment foundations and fixations
- the good working verification of the system, including the local manual means.

3 Class renewal survey

3.1 Stability

3.1.1 A lightweight survey is to be carried out to verify any changes in lightship displacement and in the longitudinal position of the centre of gravity. Where, in comparison with the approved stability information, a deviation exceeding 2% in the lightship displacement or 1% in the position of the longitudinal centre of gravity is found or anticipated, the ship is to be submitted to a new inclining test.

3.2 Lighting

3.2.1 The condition of the Low Location Lighting (LLL) system, where fitted, and its power source(s) is to be verified.

3.3 Shell and inner doors

3.3.1 A close visual inspection of structural arrangements is to be carried out, supplemented by non-destructive tests and/or thickness measurements, as deemed necessary by the Surveyor.

3.3.2 The close visual inspection of securing, supporting and locking devices, as required for the annual survey, is to be supplemented by non-destructive tests and/or thickness measurements.

3.3.3 Clearances of hinges, bearings and thrust bearings are to be measured. Dismantling may be required as deemed necessary by the Surveyor.

3.3.4 Non-return valves of drainage arrangements are to be checked after dismantling.

3.4 Fire protection, detection and extinction

3.4.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the class renewal survey of all ships in Ch 3, Sec 3, [4.8], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as those indicated in [2.4.1].

Section 3 Aircraft Carrier

1 General

1.1

1.1.1 The requirements of this Section are applicable after construction to all self-propelled ships which have been assigned the following service notation:

aircraft carrier

as defined in Part D, Chapter 2.

1.1.2 These requirements are additional to those laid down in Part A, Chapter 3, according to the relevant surveys.

2 Annual survey

2.1 Inner doors

2.1.1 The requirements of this sub-article apply to all inner doors fitted on these ships.

In particular, they apply to hangar doors and aircraft lift doors.

2.1.2 For the scope of survey of inner doors, the following definitions are applicable:

- Securing device:

  a device used to keep the door closed by preventing it from rotating about its hinges
- Supporting device:

  a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure
- Locking device:

  a device that locks a securing device in the closed position.

2.1.3 It is to be checked that the operating procedures for closing the inner doors are kept on board and posted at appropriate places.

When required, the Operating and Maintenance Manual is also to be checked for the verification of its approval and of any modification, reported repairs and proper endorsement by operating personnel.

2.1.4 The structural arrangements as well as welding are to be examined, including:

- plating, primary structure and secondary stiffeners
- hinging arms, hinges and bearings, thrust bearings
- hull and door side supports of securing, supporting and locking devices.

Hinge, bearing and thrust bearing clearances are to be measured when no dismantling is necessary for the measurement, or when the function tests detailed below are not satisfactory.

2.1.5 A close visual inspection of securing, supporting and locking devices, including their weld connections, is to be carried out and clearances are to be measured as required.

Non-destructive tests and/or thickness measurements may be required by the Surveyor after visual examination or in cases where cracks or deformations have been found.

2.1.6 A close visual inspection of sealing arrangements (packing material, rubber gaskets, packing retaining bars or channels) is to be carried out. For the tightness hose test, refer to [2.1.8].

2.1.7 The drainage arrangements including bilge wells, drain pipes and non-return valves are to be visually examined. A test of the bilge system between the inner and outer doors and that of the garage deck is to be carried out.

2.1.8 Function tests are to be carried out as follows, according to the required and/or existing equipment on board:

a) Doors are to be examined during a complete opening and closing operation; during this operation, the proper working of hinging arms and hinges, proper engagement of the thrust bearings and proper working of devices for locking the door in open position are to be checked

b) Securing, supporting and locking devices are to be examined during a complete opening and closing operation; the following items are to be checked:
   - opening/closing system and securing/locking devices are interlocked in such a way that they can only operate in proper sequence
   - mechanical lock of the securing devices
   - the securing devices remain locked in the event of loss of hydraulic fluid, if they are of hydraulic type

c) Indicators of open/closed position of doors and of securing/locking devices at remote control stations are to be checked; other safety devices such as isolation of securing/locking hydraulic system from other hydraulic systems, access to operating panels, notice plates and warning indicator lights are to be checked

d) A tightness hose test or equivalent of sealing arrangements is to be carried out

e) A working test of the indicator system is to be carried out, including checking of:
   - visual indicators and audible alarms on the navigation bridge and operating panel
   - lamp test function, fail safe performance, power supply for indicator system
   - proper condition of sensors and their protection from water, ice formation and mechanical damage

f) A working test of the water leakage detection system for inner doors and for the area between the bow door and the inner door (as applicable) is to be carried out and the proper function of audible alarms on the navigation bridge and the engine control room panel (as applicable) is to be ascertained

g) The television surveillance system is to be verified with proper indication on the navigation bridge and engine control room monitors

h) Electrical equipment for opening, closing and securing the doors is to be examined.

2.2 Internal platforms and ramps

2.2.1 The annual survey of internal movable platforms and ramps (excluding those considered as inner doors and covered in [2.1]) and related equipment consists of:

- a general examination of the installation, particular attention being paid to the condition of steel cables
- confirmation of the proper operation of platforms/ramps and of mechanical stops and locks
- checking, as far as practicable, of the alarms and safety devices.

2.3 Fire protection, detection and extinction

2.3.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the annual survey of all ships in Ch 3, Sec 1, [3.4], attention is to be given to the particular arrangements related to landing and garage spaces, such as:

- fire detection systems and alarms
- fixed fire-extinguishing arrangements (gas, water-spraying or foam systems)
- portable fire extinguishers in spaces and at entrances
- ventilation and related safety devices (including remote control on the bridge or on the central safety control room), and
- electrical equipment of a safe type.

2.4 Emergency escapes

2.4.1 It is to be verified that the emergency escape routes from passenger and crew spaces, including related stairways and ladders, are kept clear.

3 Class renewal survey

3.1 Stability

3.1.1 A lightweight survey is to be carried out to verify any changes in lightship displacement and in the longitudinal position of the centre of gravity. Where, in comparison with the approved stability information, a deviation exceeding 2% in the lightship displacement or 1% in the position of the longitudinal centre of gravity is found or anticipated, the ship is to be submitted to a new inclining test.

3.2 Lighting

3.2.1 The condition of the Low Location Lighting (LLL) system, where fitted, and its power source(s) is to be verified.

3.3 Inner doors

3.3.1 A close visual inspection of structural arrangements is to be carried out, supplemented by non-destructive tests and/or thickness measurements, as deemed necessary by the Surveyor.

3.3.2 The close visual inspection of securing, supporting and locking devices, as required for the annual survey, is to be supplemented by non-destructive tests and/or thickness measurements.

3.3.3 Clearances of hinges, bearings and thrust bearings are to be measured. Dismantling may be required as deemed necessary by the Surveyor.

3.3.4 Non-return valves of drainage arrangements are to be checked after dismantling.

3.4 Internal platforms and ramps

3.4.1 The condition of pulleys, axles, cables and structure of the platforms and ramps is to be checked.

Electric motors and/or hydraulically operated equipment are to be surveyed according to the scope detailed in Ch 3, Sec 3, [4] for the class renewal survey of machinery installations.

3.5 Fire protection, detection and extinction

3.5.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the class renewal survey of all ships in Ch 3, Sec 3, [4.8], attention is to be given to the particular arrangements related to landing and garage spaces, such as those indicated in [2.3.1].

Section 4 Auxiliary Naval Vessel

1 General

1.1 Application

1.1.1 The requirements of this Section apply to self-propelled ships which have been assigned the following service notation:

auxiliary naval vessel

as defined in Part D, Chapter 4.

1.1.2 The requirements for hull surveys apply to the surveys of the hull structure and piping systems in way of cargo tanks, pump rooms, cofferdams, pipe tunnels and void spaces within the cargo area and all ballast tanks. They are additional to the requirements applicable to the remainder of the ship, given in Part A, Chapter 3 according to the relevant surveys.

1.1.3 The requirements contain the minimum extent of examination, thickness measurements and tank testing. When substantial corrosion, as defined in Ch 2, Sec 2, [3.2.7], and/or structural defects are found, the survey is to be extended and is to include additional close-up surveys when necessary.

1.1.4 In all cases the extent of thickness measurements is to be sufficient as to represent the actual average condition.

1.1.5 When, in any survey, thickness measurements are required:

- the procedure detailed in Ch 2, Sec 2, [3.3] is to be applied
- the thickness measurement operator is to attend the survey planning meeting held prior to commencing the survey.

1.1.6 The requirements for machinery surveys apply to surveys of the machinery and equipment in the cargo area or dedicated to cargo service systems and are additional to those given in Part A, Chapter 3 for all ships.

1.2 Documentation on board

1.2.1 The Owner is to obtain, supply and maintain documentation on board as specified in [1.2.2] and [1.2.3], which is to be readily available for examination by the Surveyor. The documentation is to be kept on board for the lifetime of the ship.

1.2.2 A survey report file is to be a part of the documentation on board consisting of:

- reports of structural surveys
- thickness measurement reports.

The survey report file is also to be available in the Owner's management office.

1.2.3 The following additional supporting documentation is to be available on board:

- main structural plans of cargo tanks and ballast tanks
- previous repair history
- cargo and ballast history
- extent of use of inert gas system and tank cleaning procedures
- ship’s personnel reports on:
  - structural deterioration/defects in general
  - leakage in bulkheads and piping systems
  - condition of coatings or corrosion prevention systems, if any
- any other information that may help to identify critical structural areas and/or suspect areas requiring inspection.

1.2.4 Prior to survey, the Surveyor examines the documentation on board and its contents, which are used as a basis for the survey.

1.3 Reporting and evaluation of surveys

1.3.1 The data and information on the structural condition of the ship collected during survey are evaluated for acceptability and structural integrity of the ship's cargo area.

1.3.2 When a survey is split between different survey stations, a report is to be made for each portion of the survey. A list of items examined and/or tested (pressure testing, thickness measurements etc.) and an indication of whether the item has been credited, are to be made available to the next attending Surveyor(s), prior to continuing or completing the survey.

1.3.3 A hull condition evaluation report (summarizing the results of class renewal surveys) is issued by the Society to the Owner, who is to place it on board the ship for reference at future surveys. The hull condition evaluation report is endorsed by the Society.

1.4 Conditions for survey

1.4.1 In order to enable the attending Surveyor(s) to carry out the survey, provisions for proper and safe access are to be agreed between the Owner and the Society.

Details of the means of access are to be provided in the survey planning questionnaire.

In cases where the provisions of safety and required access are judged by the attending Surveyor(s) not to be adequate, the survey of the spaces involved is not to proceed.

1.4.2 The Surveyor(s) are to always be accompanied by at least one responsible person, assigned by the Owner, experienced in tank and enclosed spaces inspection. In addition a back-up team of at least two experienced persons is to be stationed at the hatch opening of the tank or space that is being surveyed. The back-up team is to continuously observe the work in the tank or space and is to keep lifesaving and evacuation equipment ready for use.

1.5 Access to structures

1.5.1 For overall survey, means are to be provided to enable the Surveyor(s) to examine the hull structure in a safe and practical way.

2 Annual survey - Hull items - Liquid cargo area

2.1 Weather decks

2.1.1 The survey is to include:

- examination of cargo tank openings, including gaskets, covers, coamings and screens
- examination of cargo tank pressure/vacuum valves and flame screens
- examination of flame screens on vents to all bunker, oily-ballast and oily slop tanks and void spaces
- examination of cargo, crude oil washing, bunker, ballast and vent piping systems, including remote control valves, safety valves and various safety devices, as well as vent masts and headers
- confirmation that wheelhouse doors and windows, sidescuttles and windows in superstructure and deckhouse ends facing the cargo area are in satisfactory condition.

2.2 Cargo pump rooms and pipe tunnels

2.2.1 The survey is to include:

- examination of all pump room bulkheads and pipe tunnels (if any) for signs of oil leakage or fractures and, in particular, the sealing arrangements of penetrations in these bulkheads
- examination of the condition of all piping systems, in cargo pump rooms and pipe tunnels (if any)
- examination of the bilge and ballast arrangements.

2.3 Ballast tanks

2.3.1 Ballast tanks are to be internally examined when required as a consequence of the results of the class renewal survey or the intermediate survey.

2.3.2 When considered necessary by the Surveyor, or when extensive corrosion exists, thickness measurements are to be carried out and if the results of these thickness measurements indicate that substantial corrosion is found, the extent of thickness measurements is to be increased in accordance with Tab 2 or Tab 3. These extended thickness measurements are to be carried out before the survey is credited as completed. Suspect areas identified at previous surveys are to be examined. Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

2.4 Safe access to tanker bows

2.4.1 The access to bow arrangement is to be examined, as applicable.

3 Annual survey - Hull items - Dry cargo area

3.1 Watertight bulkheads

3.1.1 The survey of watertight bulkheads and arrangements consists of:

- examination, as far as practicable, of collision and watertight bulkheads, and confirmation that their watertight integrity has not been impaired
- checking the diagram provided on the navigation bridge showing the location of the watertight doors and related indicators for their open/closed position
- testing operation of local and remote control (from the navigation bridge) of the watertight doors, and in particular, operation from each side of the bulkhead of audible alarms or visual signals and control handles, as required or fitted
- confirmation of operation of watertight doors in the event of failure of main and emergency sources of power
- confirmation that notices are affixed at appropriate locations.

3.2 Openings in shell plating

3.2.1 The survey consists of:

- examination of the arrangements for closing sidescuttles and their deadlights, as well as scuppers, sanitary discharges and similar openings and other inlets and discharges in the shell plating below the margin line
- confirmation that valves for closing the main and auxiliary sea inlets and discharges in the machinery spaces are readily accessible, and that indicators showing the status of the valves are provided, as required or fitted
- confirmation that gangway access and cargo ports fitted below the margin line may be effectively closed and that the inboard ends of any ash or rubbish chutes are fitted with an effective cover.

3.3 Shell and inner doors

3.3.1 The requirements of this sub-article apply to all shell and inner doors fitted on these ships.

3.3.2 For the scope of survey of shell and inner doors, the following definitions are applicable:

- Securing device:

  a device used to keep the door closed by preventing it from rotating about its hinges
- Supporting device:

  a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship’s structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship’s structure
- Locking device:

  a device that locks a securing device in the closed position.

3.3.3 It is to be checked that the operating procedures for closing the shell and inner doors are kept on board and posted at appropriate places.

When required, the Operating and Maintenance Manual is also to be checked for the verification of its approval and of any modification, reported repairs and proper endorsement by operating personnel.

3.3.4 The structural arrangements as well as welding are to be examined, including:

- plating, primary structure and secondary stiffeners
- hinging arms, hinges and bearings, thrust bearings
- hull and door side supports of securing, supporting and locking devices
- shell plating surrounding the openings and the securing, supporting and locking devices.

Hinge, bearing and thrust bearing clearances are to be measured when no dismantling is necessary for the measurement, or when the function tests detailed below are not satisfactory.

3.3.5 A close visual inspection of securing, supporting and locking devices, including their weld connections, is to be carried out and clearances are to be measured as required.

Non-destructive tests and/or thickness measurements may be required by the Surveyor after visual examination or in cases where cracks or deformations have been found.

3.3.6 A close visual inspection of sealing arrangements (packing material, rubber gaskets, packing retaining bars or channels) is to be carried out. For the tightness hose test, refer to Ch 4, Sec 2, [2.3.8].

3.3.7 The drainage arrangements including bilge wells, drain pipes and non-return valves are to be visually examined. A test of the bilge system between the inner and outer doors and that of the vehicle deck is to be carried out.

3.3.8 Function tests are to be carried out as follows, according to the required and/or existing equipment on board:

a) Doors are to be examined during a complete opening and closing operation; during this operation, the proper working of hinging arms and hinges, proper engagement of the thrust bearings and proper working of devices for locking the door in open position are to be checked

b) Securing, supporting and locking devices are to be examined during a complete opening and closing operation; the following items are to be checked:
   - opening/closing system and securing/locking devices are interlocked in such a way that they can only operate in proper sequence
   - mechanical lock of the securing devices
   - the securing devices remain locked in the event of loss of hydraulic fluid, if they are of hydraulic type

c) Indicators of open/closed position of doors and of securing/locking devices at remote control stations are to be checked; other safety devices such as isolation of securing/locking hydraulic system from other hydraulic systems, access to operating panels, notice plates and warning indicator lights are to be checked

d) A tightness hose test or equivalent of sealing arrangements is to be carried out

e) A working test of the indicator system is to be carried out, including checking of:
   - visual indicators and audible alarms on the navigation bridge and operating panel
   - lamp test function, fail safe performance, power supply for indicator system
   - proper condition of sensors and their protection from water, ice formation and mechanical damage

f) A working test of the water leakage detection system for inner doors and for the area between the bow door and the inner door (as applicable) is to be carried out and the proper function of audible alarms on the navigation bridge and the engine control room panel (as applicable) is to be ascertained

g) The television surveillance system is to be verified with proper indication on the navigation bridge and engine control room monitors

h) Electrical equipment for opening, closing and securing the doors is to be examined.

4 Annual survey - Machinery items - Liquid cargo area

4.1 Cargo area and cargo pump rooms

4.1.1 The Owner or his representative is to declare to the attending Surveyor that no modifications or alterations which might impair safety have been made to the various installations in dangerous zones without prior approval from the Society.

The survey is to include:

- check of the protection of cargo pump room, as applicable, and in particular, check of:
  - temperature sensing devices for bulkheads glands and alarms
  - interlock between lighting and ventilation
  - gas detection system
  - bilge level monitoring devices and alarms
- examination of the emergency lighting in cargo pump rooms
- confirmation that potential sources of ignition in or near the cargo pump rooms, such as loose gear, excessive product in bilge, excessive vapours, combustible materials, etc., are eliminated and that access ladders are in satisfactory condition
- examination, as far as practicable, of cargo, bilge, ballast and stripping pumps for excessive gland seal leakage, verification of proper operation of electrical and mechanical remote operating and shutdown devices and operation of the pump room bilge system, and checking that pump foundations are intact
- confirmation that the ventilation system, including portable equipment, if any, of all spaces in the cargo area (including cargo pump rooms) is operational, ducting is intact, dampers are operational and screens are clean
- confirmation that electrical equipment in dangerous zones, cargo pump rooms and other spaces is in satisfactory condition and has been properly maintained
- confirmation that the remote operation of the cargo pump room bilge system is satisfactory
- examination of the cargo heating system, as appropriate
- examination of the cargo-transfer arrangement and confirmation that the ship's cargo hoses are suitable for their intended purpose and in satisfactory condition
- confirmation that any special arrangement made for bow or stern loading/unloading is in satisfactory condition and test of the means of communication and remote shutdown of the cargo pumps.

4.2 Instrumentation and safety devices

4.2.1 The survey is to include:

- examination of cargo tank gauging devices, high level alarms and valves associated with overflow control
- verification that installed pressure gauges on cargo discharge lines are properly operational
- confirmation that the required gas detection instruments are on board and satisfactory arrangements have been made for the supply of any required vapour detection tubes
- confirmation that devices provided for measuring the temperature of the cargo, if any, operate satisfactorily.

4.3 Fire-fighting systems in cargo area

4.3.1 The survey is to include:

- external examination of piping and cut-out valves of fixed fire-fighting systems related to cargo tanks and cargo pump rooms
- confirmation, as far as practicable and when appropriate, that the remote means for closing the various openings are operable
- examination of the appropriate portable fire-extinguishing equipment for the cargoes to be carried in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4.3]
- examination of fire-fighting systems of any type fitted on board such as deck foam, water-spraying, etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 1, [3.4].

4.4 Inert gas system

4.4.1 The survey is to include:

- external examination of the whole system, to check the condition of all piping, including vent piping above the upper deck in the cargo tank area and overboard discharges through the shell so far as practicable, and associated components to verify, in particular, the absence of signs of corrosion and leakage of gas, water or other liquid from inert gas and water piping systems or from the pressure/vacuum breaking device
- check of proper operation of both inert gas blowers
- check of proper operation of ventilation system required for scrubber room (if any)
- check of deck water seal for automatic water filling and draining
- check of absence of water carry over in the inert gas from the deck water seal and check of the condition of the non-return valve
- check of proper operation of all remotely operated or automatically controlled valves and, in particular, of the flue gas isolating valve located on the inert gas supply main after the blowers
- check of proper operation of the interlocking feature fitted to prevent soot blowers from operating when the inert gas system is working
- check that the gas pressure regulating valve automatically closes when gas blowers are stopped
- check, as far as practicable and using simulated conditions where necessary, of the following alarms and safety devices of the inert gas system:
  - high oxygen content of gas in the inert gas main
  - low gas pressure in the inert gas main
  - low pressure in the supply to the deck water seal
  - high temperature of gas in the inert gas main, including automatic shutdown devices
  - low water pressure to the scrubber, including automatic shutdown devices
  - accuracy of portable and fixed oxygen measuring equipment by means of calibration gases
  - high water level in the scrubber, including automatic shutdown devices
  - failure of the inert gas blowers
  - failure of the power supply to the automatic control system for the gas regulating valve and to the instrumentation for continuous indication and permanent recording of pressure and oxygen content in the inert gas main
  - high pressure of gas in the inert gas main
- check, when practicable, of the proper operation of the inert gas system on completion of the checks listed above.

5 Annual survey - Machinery items - Dry cargo area

5.1 Fire protection, detection and extinction

5.1.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the annual survey of all ships in Ch 3, Sec 1, [3.4], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as:

- fire detection systems and alarms
- fixed fire-extinguishing arrangements (gas, water-spraying or foam systems)
- portable fire extinguishers in spaces and at entrances
- ventilation and related safety devices (including remote control on the bridge or on the central safety control room), and
- electrical equipment of a safe type.

5.2 Emergency escapes

5.2.1 It is to be verified that the emergency escape routes including related stairways and ladders, are kept clear.

5.3 Ballast equipment and installation

5.3.1 Piping

The visit includes:

- the examination of the state of the whole ballast piping system
- the examination of seals and space boundary penetrations with respect to cracks and leakages.

5.3.2 Control systems

The visit shall include the following points, as far as the elements exist:

- the examination of the filling measurement systems of the ballast capacities, upper level alarm and associated safety valves to control the overflows
- the confirmation that the pressure gauges installed on the ballast piping are correctly operational.

5.3.3 Ballasting system

The visit includes:

- the examination of all equipment of the ballasting system (pumps, valves and other components)
- the general examination of the ballast system equipment foundations and fixations
- the good working verification of the system, including the local manual means.

6 Intermediate survey - Hull items

6.1 General

6.1.1 The survey of weather decks is to include:

- examination, as far as applicable, of cargo, crude oil washing, bunker, ballast, steam and vent piping systems as well as vent masts and headers. If upon examination there is any doubt as to the condition of the piping, the piping may be required to be pressure tested, thickness measured or both
- confirmation, if applicable, that cargo pipes are electrically bonded to the hull
- examination of vent line drainage arrangements.

6.2 Ships between 5 and 10 years of age

6.2.1 For single hull oil tankers, all ballast tanks are to be examined.

When considered necessary by the Surveyor, thickness measurements and testing are to be carried out to ensure that the structural integrity remains effective.

6.2.2 For double hull oil tankers, an overall survey of representative salt water ballast tanks selected by the Surveyor is to be carried out.

If such overall survey reveals no visible structural defects, the examination may be limited to a verification that the hard protective coating remains in good condition.

6.2.3 A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurement is to be carried out as deemed necessary by the Surveyor.

6.2.4 In addition to the requirements above, suspect areas identified at previous surveys are to be examined.

6.3 Ships between 10 and 15 years of age

6.3.1 The scope of intermediate survey of ships between 10 and 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [8] with bottom survey in dry condition or bottom in water survey as applicable. However, pressure testing of all cargo and ballast tanks and the requirements for longitudinal strength evaluation of hull girder as required in [8.4.5] are not required unless deemed necessary by the attending Surveyor.

6.4 Ships over 15 years of age

6.4.1 The scope of intermediate survey of ships over 15 years of age is the scope of the preceding class renewal survey of hull, as detailed in [8] with bottom survey in dry condition, except that pressure testing of ballast and cargo tanks and the requirements for longitudinal strength evaluation of hull girder as required in [8.4.5] is not required unless deemed necessary by the Surveyor.

The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and water ballast tanks are to be carried out during the bottom survey in accordance with the applicable requirements for intermediate surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast waterline.

7 Intermediate survey - Machinery items - Liquid cargo area

7.1 Cargo area and cargo pump rooms

7.1.1 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment and fixtures, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

7.1.2 The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship’s personnel.

7.1.3 The satisfactory condition of the cargo heating system is to be verified.

7.2 Inert gas system

7.2.1 The following is to be carried out:

- main parts such as the scrubber, washing machines, blowers, deck water seal and non-return valve are to be opened out as considered necessary and examined
- gas distribution lines and shut-off valves, including soot blower interlocking devices, are to be examined as deemed necessary
- all automatic shutdown devices and alarms are to be examined and tested.

8 Class renewal survey - Hull items - Liquid cargo area

8.1 Survey planning meeting

8.1.1 The establishment of proper preparation and the close co-operation between the attending Surveyor(s) and the Owner's representatives onboard prior to and during the survey are an essential part in the safe and efficient conduct of the survey. During the survey on board, safety meetings are to be held regularly.

8.1.2 Prior to commencement of any part of the renewal and intermediate survey, a survey planning meeting is to be held between the attending Surveyor(s), the Owner's representative in attendance, the thickness measurement company representative, where involved, and the master of the ship or an appropriately qualified representative appointed by the master or Company for the purpose to ascertain that all the arrangements envisaged in the survey programme are in place, so as to ensure the safe and efficient conduct of the survey work to be carried out. See also [1.1.5].

8.1.3 The following is an indicative list of items that are to be addressed in the meeting:

a) schedule of the ship (i.e. the voyage, docking and undocking manoeuvres, periods alongside, cargo and ballast operations, etc.)

b) provisions and arrangements for thickness measurements (i.e. access, cleaning/de-scaling, illumination, ventilation, personal safety)

c) extent of the thickness measurements

d) acceptance criteria (refer to the list of minimum thicknesses)

e) thickness measurements considering the coating condition and suspect areas/areas of substantial corrosion

f) execution of thickness measurements

g) taking representative readings in general and where uneven corrosion/pitting is found

h) mapping of areas of substantial corrosion, and

i) communication between the attending Surveyor(s), the thickness measurement company operator(s) and the Owner's representative(s) concerning findings.

8.2 Scope of survey

8.2.1 In addition to the requirements of annual surveys, the class renewal survey is to include examination, tests and checks of sufficient extent to ensure that the hull and related piping are in satisfactory condition for the new period of class to be assigned, subject to proper maintenance and operation and to periodical surveys being carried out at the due dates.

8.2.2 All cargo tanks, ballast tanks, including double bottom tanks, pump rooms, pipe tunnels, cofferdams and void spaces bounding cargo tanks, decks and outer hull are to be examined, and this examination is to be supplemented by thickness measurement and testing as required in [8.4] and [8.5], to ensure that the structural integrity remains effective. The aim of the examination is to discover substantial corrosion, significant deformation, fractures, damages or other structural deterioration, that may be present.

8.2.3 As indicated in Ch 3, Sec 3, [2.1.1], a bottom survey in dry condition is to be a part of the class renewal survey. The overall and close-up surveys and thickness measurements, as applicable, of the lower portions of the cargo tanks and ballast tanks are to be carried out during this bottom survey in accordance with the applicable requirements for class renewal surveys, if not already performed.

Lower portions of the cargo and ballast tanks are considered to be the parts below light ballast waterline.

8.2.4 Where provided, the condition of the corrosion prevention system of cargo tanks is to be examined.

A ballast tank is to be examined at subsequent annual surveys where:

- a hard protective coating has not been applied from the time of construction, or
- a soft or semi-hard coating has been applied, or
- substantial corrosion is found within the tank, or
- the hard protective coating is found to be in less than good condition and the hard protective coating is not repaired to the satisfaction of the Surveyor.

Thickness measurement is to be carried out as deemed necessary by the Surveyor.

8.3 Overall surveys

8.3.1 Each class renewal survey is to include an overall survey of all tanks and spaces.

8.4 Thickness measurements

8.4.1 The minimum requirements for thickness measurements at class renewal survey are given in Tab 1.

8.4.2 Provisions for extended measurements for areas with substantial corrosion are given in Tab 2 for single hull oil tankers and combination carriers or Tab 3 for double hull oil tankers and as may be additionally specified in the survey program as required in [8.1]. These extended thickness measurements are to be carried out before the survey is credited as completed.

Suspect areas identified at previous surveys are to be examined.

Areas of substantial corrosion identified at previous surveys are to have thickness measurements taken.

The Surveyor may further extend the thickness measurements as deemed necessary.

Table 1 : Thickness measurements at class renewal survey - Auxiliary naval vessels

Age of ship (in years at time of class renewal survey)			
age ≤ 5	5 < age ≤ 10	10 < age ≤ 15	age > 15
Suspect areas	Suspect areas	Suspect areas	Suspect areas
One section of deck plating for the full beam of the ship within the cargo area (in way of a ballast tank, if any, or a cargo tank used primarily for water ballast)	Within the cargo area: • each deck plat • 1 transverse section**(1)**	Within the cargo area: • each deck plate • 2 transverse sections**(1)(2)** • all wind and water strakes	Within the cargo area: • each deck plate • 3 transverse sections**(1)(2)** • each bottom plate
Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey**(3)**	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey**(3)**	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey**(3)**	Measurements, for general assessment and recording of corrosion pattern, of those structural members subject to close-up survey**(3)**
	Selected wind and water strakes outside the cargo area	Selected wind and water strakes outside the cargo area	All wind and water strakes, full length

(1) Transverse sections are to be chosen where the largest reductions are likely to occur or as revealed by deck plating measurements.
(2) At least one section is to be within 0,5 L amidships and, where applicable, in way of a ballast tank.
(3) A close-up survey is a survey where the details of structural components are within the close visual inspection range of the Surveyor, i.e. normally within reach of hand.

Table 2 : Extended thickness measurements at those areas of substantial corrosion - Auxiliary naval vessels

BOTTOM STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom plating	Minimum of 3 bays across tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and webs
Bottom longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
Bottom girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5-point pattern on girder/bulkhead brackets.
Bottom transverse webs	3 webs in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 square metre area. Single measurements on face flat.
Panel stiffening	Where provided	Single measurements

DECK STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Deck plating	2 bands across tank	Minimum of 3 measurements per plate per band
Deck longitudinals	Minimum of 3 longitudinals in each of 2 bays	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
Deck girders and brackets	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across face flat. 5-point pattern on girder/bulkhead brackets.
Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5-point pattern over 2 square metre area. Single measurements on face flat.
Panel stiffening	Where provided	Single measurements

SIDE SHELL AND LONGITUDINAL BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes and strakes in way of stringer platforms	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
All other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Longitudinals on deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
All other longitudinals	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5-point pattern over approximately 2 square metre area, plus single measurements on web frame and cross tie face flats

TRANSVERSE BULKHEADS AND SWASH BULKHEADS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes, and strakes in way of stringer platforms	Plating between pair of stiffeners at 3 locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over 1 metre length
All other strakes	Plating between pair of stiffeners at middle location	Single measurement
Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about 1 square metre of plating
Stiffeners	Minimum of 3 typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span
Brackets	Minimum of 3 at top, middle and bottom of tank	5-point pattern over area of bracket
Deep webs and girders	Measurements at toe of bracket and at centre of span	For web, 5-point pattern over about 1 square metre. 3 measurements across face flat.
Stringer platforms	All stringers with measurements at both ends and middle	5-point pattern over 1 square metre of area plus single measurements near bracket toes and on face flats

8.4.3 When pitting is found on bottom plating and its intensity is 20% or more, thickness measurements are to be extended in order to determine the actual plate thickness out of the pits and the depth of the pits. Where the wastage is in the substantial corrosion range or the average depth of pitting is 1/3 or more of the actual plate thickness, the pitted plate is to be considered as a substantially corroded area.

8.4.4 For areas in tanks where hard protective coatings are found to be in good condition as defined in Ch 2, Sec 2, [3.2.9], the extent of thickness measurements according to Tab 1 may be specially considered.

8.4.5 On oil tankers of 130 m in length and upwards (as defined in the International Convention on Load Lines in force) and more than 10 years of age, the longitudinal strength of the ship's hull girder is to be evaluated in compliance with the requirements of NR467, Pt A, Ch 4, App 1 on the basis of the thickness of the structures measured, renewed or reinforced, as appropriate, during the class renewal survey.

8.5 Tank testing

8.5.1 The requirements for tank testing at class renewal survey are given in Tab 4.

8.5.2 The Surveyor may extend the tank testing as deemed necessary.

8.5.3 Boundaries of ballast tanks are to be tested with a head of liquid to the top of air pipes.

Boundaries of cargo tanks are to be tested to the highest point that liquid will rise under service conditions

For double hull oil tankers, the testing of double bottom tanks and other spaces not designed for the carriage of liquid may be omitted, provided a satisfactory internal examination together with an examination of the tank top is carried out.

Table 3 : Extended thickness measurements at those areas of substantial corrosion - Auxiliary naval vessel with double hull

BOTTOM, INNER BOTTOM AND HOPPER STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Bottom, inner bottom and hopper structure plating	Minimum of 3 bays across double bottom tank, including aft bay Measurements around and under all suction bell mouths	5-point pattern for each panel between longitudinals and floors
Bottom, inner bottom and hopper structure longitudinals	Minimum of 3 longitudinals in each bay where bottom plating measured	3 measurements in line across flange and 3 measurements on vertical web
Bottom girders, including the watertight ones	At fore and aft watertight floors and in centre of tanks	Vertical line of single measurements on girder plating with one measurement between each panel stiffener, or a minimum of 3 measurements
Bottom floors, including the watertight ones	3 floors in bays where bottom plating measured, with measurements at both ends and middle	5-point pattern over 2 square metre area
Hopper structure web frame ring	3 floors in bays where bottom plating measured	5-point pattern over about 1 square metre of plating. Single measurements on flange.
Hopper structure transverse watertight bulkhead or swash bulkhead	• lower 1/3 of bulkhead	5-point pattern over about 1 square metre of plating
	• upper 2/3 of bulkhead	5-point pattern over 2 square metre of plating
	• stiffeners (minimum of 3)	For web, 5-point pattern over span (2 measurements across web at each end and one at centre of span). For flange, single measurements at each end and centre of span.
Panel stiffening	Where provided	Single measurements

DECK STRUCTURE		
Structural member	Extent of measurement	Pattern of measurement
Deck plating	2 transverse bands across tank	Minimum of 3 measurements per plate per band
Deck longitudinals	Every third longitudinal in each of 2 bands with a minimum of one longitudinal	3 measurements in line vertically on webs and 2 measurements on flange (if fitted)
Deck girders and brackets (usually in cargo tanks only)	At fore and aft transverse bulkhead, bracket toes and in centre of tanks	Vertical line of single measurements on web plating with one measurement between each panel stiffener, or a minimum of 3 measurements. 2 measurements across flange. 5-point pattern on girder/bulkhead brackets.
Deck transverse webs	Minimum of 2 webs, with measurements at both ends and middle of span	5-point pattern over 1 square metre area. Single measurements on flange.
Vertical web and transverse bulkhead in wing ballast tank (2 metres from deck)	Minimum of 2 webs, and both transverse bulkheads	5-point pattern over 1 square metre area
Panel stiffening	Where provided	Single measurements

STRUCTURE IN WING BALLAST TANKS		
Structural member	Extent of measurement	Pattern of measurement
Side shell and longitudinal bulkhead plating:		
• upper strake and strakes in way of horizontal girders	Plating between each pair of longitudinals in a minimum of 3 bays (along the tank)	Single measurement
• all other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Side shell and longitudinal bulkhead longitudinals on:		
• upper strake	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
• all other strakes	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Vertical web and transverse bulkheads (excluding deckhead area):		
• strakes in way of horizontal girders	Minimum of 2 webs and both transverse bulkheads	5-point pattern over 2 square metre area
• other strakes	Minimum of 2 webs and both transverse bulkheads	2 measurements between each pair of vertical stiffeners
Horizontal girders	Plating on each girder in a minimum of 3 bays	2 measurements between each pair of longitudinal girder stiffeners
Panel stiffening	Where provided	Single measurements

LONGITUDINAL BULKHEADS IN CARGO TANKS		
Structural member	Extent of measurement	Pattern of measurement
Deckhead and bottom strakes and strakes in way of the horizontal stringers of transverse bulkheads	Plating between each pair of longitudinals in a minimum of 3 bays	Single measurement
All other strakes	Plating between every third pair of longitudinals in same 3 bays	Single measurement
Longitudinals on deckhead and bottom strakes	Each longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
All other longitudinals	Every third longitudinal in same 3 bays	3 measurements across web and 1 measurement on flange
Longitudinal brackets	Minimum of 3 at top, middle and bottom of tank in same 3 bays	5-point pattern over area of bracket
Web frames and cross ties	3 webs with minimum of 3 locations on each web, including in way of cross tie connections	5-point pattern over approximately 2 square metre area of webs, plus single measurements on flanges of web frame and cross ties
Lower end brackets (opposite side of web frame)	Minimum of 3 brackets	5-point pattern over approximately 2 square metre area of brackets, plus single measurements on bracket flanges

TRANSVERSE WATERTIGHT AND SWASH BULKHEADS IN CARGO TANKS		
Structural member	Extent of measurement	Pattern of measurement
Upper and lower stool, where fitted	• Transverse band within 25mm of welded connection to inner bottom/deck plating • Transverse band within 25mm of welded connection to shelf plate	5-point pattern between stiffeners over 1 metre length
Deckhead and bottom strakes, and strakes in way of horizontal stringers	Plating between pair of stiffeners at 3 locations: approximately 1/4, 1/2 and 3/4 width of tank	5-point pattern between stiffeners over 1 metre length
All other strakes	Plating between pair of stiffeners at middle location	Single measurement
Strakes in corrugated bulkheads	Plating for each change of scantling at centre of panel and at flange of fabricated connection	5-point pattern over about 1 square metre of plating
Stiffeners	Minimum of 3 typical stiffeners	For web, 5-point pattern over span between bracket connections (2 measurements across web at each bracket connection and one at centre of span). For flange, single measurements at each bracket toe and at centre of span.
Brackets	Minimum of 3 at top, middle and bottom of tank	5-point pattern over area of bracket
Horizontal stringers	All stringers with measurements at both ends and middle	5-point pattern over 1 square metre of area plus single measurements near bracket toes and on flange

Table 4 : Tank testing at class renewal survey - Auxiliary naval vessels

Age of ship (in years at time of class renewal survey)	
age ≤ 6	age > 6
All ballast tank boundaries	All ballast tank boundaries
Cargo tank boundaries facing ballast tanks, void spaces, pipe tunnels, pump rooms or cofferdams	All cargo tank bulkheads

8.6 Cargo piping, area and pump rooms

8.6.1 Cargo piping on deck and cargo and ballast piping systems within the cargo area are to be examined and operationally tested to working pressure to the attending Surveyor's satisfaction to ensure that their tightness and condition remain satisfactory. Special attention is to be given to any ballast piping in cargo tanks and cargo piping in ballast tanks and void spaces. Surveyors are to be advised on all occasions when this piping, including valves and fittings, is opened during repair periods and can be examined internally.

The Surveyor may require dismantling and/or thickness measurements of piping. A hydraulic test is to be carried out in the event of repair or dismantling or cargo, crude oil washing, or ballast piping, or where doubts arise.

8.6.2 All safety valves on cargo piping and of cargo tanks are to be dismantled for examination, adjusted and, as applicable, resealed.

8.6.3 All cargo pump room boundaries are to be generally examined. All gas-tight shaft sealing devices are to be examined. The bottom of cargo pump rooms is to be presented clean for the examination of stripping devices and gutters.

9 Class renewal survey - Hull items - Dry cargo area

9.1 Stability

9.1.1 A lightweight survey is to be carried out to verify any changes in lightship displacement and in the longitudinal position of the centre of gravity. Where, in comparison with the approved stability information, a deviation exceeding 2% in the lightship displacement or 1% in the position of the longitudinal centre of gravity is found or anticipated, the ship is to be submitted to a new inclining test.

9.2 Shell and inner doors

9.2.1 A close visual inspection of structural arrangements is to be carried out, supplemented by non-destructive tests and/or thickness measurements, as deemed necessary by the Surveyor.

9.2.2 The close visual inspection of securing, supporting and locking devices, as required for the annual survey, is to be supplemented by non-destructive tests and/or thickness measurements.

9.2.3 Clearances of hinges, bearings and thrust bearings are to be measured. Dismantling may be required as deemed necessary by the Surveyor.

9.2.4 Non-return valves of drainage arrangements are to be checked after dismantling.

10 Class renewal survey - Machinery items - Liquid cargo area

10.1 Cargo area and cargo pump rooms

10.1.1 Ballast and stripping pumps are to be internally examined and prime movers checked. A working test is to be carried out, as far as practicable.

Maintenance records of cargo pumps are to be made available to the Surveyor.

10.1.2 The satisfactory condition of the cargo heating system is to be verified and, if deemed necessary by the Surveyor, the system is to be pressure tested.

10.1.3 An operating test of the remote control of pumps and valves and of automatic closing valves is to be carried out.

10.1.4 A general examination of the electrical equipment and cables in dangerous zones such as cargo pump rooms and areas adjacent to cargo tanks is to be carried out for defective and non-certified safe type electrical equipment and fixtures, non-approved lighting and fixtures, and improperly installed or defective or dead-end wiring.

The electrical insulation resistance of the electrical equipment and circuits terminating in or passing through the dangerous zones is to be tested; however, in cases where a proper record of testing is maintained, consideration may be given to accepting recent test readings effected by the ship's personnel.

10.2 Fire-fighting systems in cargo area

10.2.1 The survey is to include the examination of fire-fighting systems of any type fitted on board for the protection of the cargo area, cargo pump room and other dangerous spaces, such as deck foam, water-spraying systems, etc., as applicable in accordance with the relevant requirements given in Ch 3, Sec 3, [4.8].

10.3 Inert gas system

10.3.1 In addition to the inspections required at the intermediate survey, the following is to be carried out:

a) An internal examination of:
   - the inert gas generator, where fitted
   - the scrubber
   - the deck water seal including the non-return valve
   - the pressure/vacuum breaking device
   - the cooling water systems including overboard discharge from the scrubber
   - all valves

b) A test to verify the proper operation of the system upon completion of all survey checks.

11 Class renewal survey - Machinery items - Dry cargo area

11.1 Lighting

11.1.1 The condition of the Low Location Lighting (LLL) system, where fitted, and its power source(s) is to be verified.

11.2 Fire protection, detection and extinction

11.2.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the class renewal survey of all ships in Ch 3, Sec 3, [4.8], attention is to be given to the particular arrangements related to ro-ro cargo spaces, such as those indicated in [5.1.1].

Section 5 Amphibious Vessel

1 General

1.1

1.1.1 The requirements of this Section are applicable after construction to all self-propelled ships which have been assigned the following service notation:

amphibious vessel

as defined in Part D, Chapter 5.

1.1.2 These requirements are additional to those laid down in Part A, Chapter 3, according to the relevant surveys.

2 Annual survey

2.1 Shell and inner doors

2.1.1 The requirements of this sub-article apply to all shell and inner doors fitted on these ships.

2.1.2 For the scope of survey of shell and inner doors, the following definitions are applicable:

- Securing device:
  a device used to keep the door closed by preventing it from rotating about its hinges
- Supporting device:
  a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure
- Locking device:
  a device that locks a securing device in the closed position.

2.1.3 It is to be checked that the operating procedures for closing the shell and inner doors are kept on board and posted at appropriate places.

When required, the Operating and Maintenance Manual is also to be checked for the verification of its approval and of any modification, reported repairs and proper endorsement by operating personnel.

Confirmation is to be obtained that no unapproved changes have been made to the bow, inner, side shell and stern doors since the last survey.

2.1.4 The structural arrangements as well as welding are to be examined, including:

- plating, primary structure and secondary stiffeners
- hinging arms, hinges and bearings, thrust bearings
- hull and door side supports of securing, supporting and locking devices
- shell plating surrounding the openings and the securing, supporting and locking devices.

Clearances of hinges, bearings and thrust bearings are to be taken, where no dismantling is required. Where the function test is not satisfactory, dismantling may be required to measure the clearances. If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pin is to be carried out. Clearances of securing, supporting and locking devices are to be measured, where indicated in the Operation and Maintenance Manual (OMM).

2.1.5 A close-up survey of securing, supporting and locking devices as listed below, including welding, is to be carried out:

- cylinder securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- hinge pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locking hooks, securing pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locking pins, supporting brackets, back-up brackets (where fitted) and their welded connections
- locating and stopper devices and their welded connections.

2.1.6 A close visual inspection of sealing arrangements (packing material, rubber gaskets, packing retaining bars or channels) is to be carried out. For the tightness hose test, refer to [2.1.8].

2.1.7 The drainage arrangements including bilge wells, drain pipes and non-return valves are to be visually examined. A test of the bilge system between the inner and outer doors and that of the vehicle deck is to be carried out.

2.1.8 Function tests are to be carried out as follows, according to the required and/or existing equipment on board:

a) Doors are to be examined during a complete opening and closing operation; during this operation, the proper working of hinging arms and hinges, proper engagement of the thrust bearings and proper working of devices for locking the door in open position are to be checked

b) Securing, supporting and locking devices are to be examined during a complete opening and closing operation; the following items are to be checked:
   - opening/closing system and securing/locking devices are interlocked in such a way that they can only operate in proper sequence
   - mechanical lock of the securing devices
   - the securing devices remain locked in the event of loss of hydraulic fluid, if they are of hydraulic type

c) Indicators of open/closed position of doors and of securing/locking devices at navigation bridge and other remote control stations are to be checked; other safety devices such as isolation of securing/locking hydraulic system from other hydraulic systems, access to operating panels, notice plates and warning indicator lights are to be checked

d) A tightness hose test or equivalent of sealing arrangements is to be carried out

e) A working test of the indicator system is to be carried out, including checking of:
   - visual indicators and audible alarms on the navigation bridge and operating panel
   - lamp test function, fail safe performance, power supply for indicator system
   - proper condition of sensors and their protection from water, ice formation and mechanical damage
   - confirmation that power supply for indicator system is supplied by the emergency source or other secure power supply and is independent of the power supply for operating the doors

f) A working test of the water leakage detection system for inner doors and for the area between the bow door and the inner door (as applicable) is to be carried out and the proper function of audible alarms on the navigation bridge and the engine control room panel (as applicable) is to be ascertained

g) The television surveillance system is to be verified with proper indication on the navigation bridge and engine control room monitors

h) Electrical equipment for opening, closing and securing the doors is to be examined.

2.1.9 Non-destructive tests and/or thickness measurements may be required by the Surveyor after visual examination and function test or in cases where cracks or deformations have been found.

2.2 Internal platforms and ramps

2.2.1 The annual survey of internal movable platforms and ramps (excluding those considered as inner doors and covered in [2.1]) and related equipment consists of:

- a general examination of the installation, particular attention being paid to the condition of steel cables
- confirmation of the proper operation of platforms/ramps and of mechanical stops and locks
- checking, as far as practicable, of the alarms and safety devices.

2.3 Watertight bulkheads

2.3.1 The survey of watertight bulkheads and arrangements consists of:

- examination, as far as practicable, of collision and watertight bulkheads, and confirmation that their watertight integrity has not been impaired
- checking the diagram provided on the navigation bridge showing the location of the watertight doors and related indicators for their open/closed position
- testing operation of local and remote control (from the navigation bridge) of the watertight doors, and in particular, operation from each side of the bulkhead of audible alarms or visual signals and control handles, as required or fitted
- confirmation of operation of watertight doors in the event of failure of main and emergency sources of power
- confirmation that notices are affixed at appropriate locations.

2.4 Openings in shell plating

2.4.1 The survey consists of:

- examination of the arrangements for closing sidescuttles and their deadlights, as well as scuppers, sanitary discharges and similar openings and other inlets and discharges in the shell plating below the margin line
- confirmation that valves for closing the main and auxiliary sea inlets and discharges in the machinery spaces are readily accessible, and that indicators showing the status of the valves are provided, as required or fitted
- confirmation that gangway access and cargo ports fitted below the margin line may be effectively closed and that the inboard ends of any ash or rubbish chutes are fitted with an effective cover.

2.5 Fire protection, detection and extinction

2.5.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the annual survey of all ships in Ch 3, Sec 1, [3.4], attention is to be given to the particular arrangements related to amphibious vessel spaces, such as:

- fire detection systems and alarms
- fixed fire-extinguishing arrangements (gas, water-spraying or foam systems)
- portable fire extinguishers in spaces and at entrances
- ventilation and related safety devices (including remote control on the bridge), and
- electrical equipment of a safe type.

2.6 Means of escape

2.6.1 The condition of means of escape as well as of fire protection, detection and extinction in special category spaces is to be checked.

2.6.2 It is to be verified that the emergency escape routes from passenger and crew spaces, including related stairways and ladders, are kept clear.

3 Class renewal survey

3.1 Lightweight survey

3.1.1 A lightweight survey is to be carried out to verify any changes in lightship displacement and in the longitudinal position of the centre of gravity. Where, in comparison with the approved stability information, a deviation exceeding 2% in the lightship displacement or a deviation of the longitudinal centre of gravity exceeding 1% of the length between perpendiculars is found or anticipated, the ship is to be submitted to a new inclining test.

3.2 Shell and inner doors

3.2.1 The class renewal survey is to include, in addition to the requirements of the annual survey as required in [2], examination, tests and checks of sufficient extent to verify that the bow, inner, side shell and stern doors are in satisfactory condition and considered able to remain in compliance with the applicable requirements, subject to proper maintenance and operation in accordance with the OMM or the manufacturer's recommendations and the periodical surveys being carried out at the due dates for the five-year period until the next class renewal survey.

3.2.2 The examinations of the doors are to be supplemented by thickness measurements and testing to verify compliance with the applicable requirements so that the structural and weathertight integrity remains effective. The aim of the examination is to identify corrosion, significant deformation, fractures, damages or other structural deterioration that may be present.

3.2.3 A close visual inspection of structural arrangements is to be carried out, supplemented by non-destructive tests and/or thickness measurements, as deemed necessary by the Surveyor.

3.2.4 A survey of the items listed in [2.1.4] and [2.1.5], including close-up survey of securing, supporting and locking devices, together with welding, is to be carried out.

Non-destructive testing and thickness measurements are to be carried out on securing, supporting and locking devices, including welding, to the extent considered necessary by the Surveyor. Whenever a crack is found, an examination with NDT is to be carried out in the surrounding area and for similar items, as considered necessary by the Surveyor.

3.2.5 Clearances of hinges, bearings and thrust bearings are to be taken. Unless otherwise specified in the OMM or by the manufacturer's recommendation, the measurement of clearances on amphibious vessels may be limited to representative bearings where dismantling is needed in order to measure the clearances.

If dismantling is carried out, a visual examination of hinge pins and bearings together with NDT of the hinge pins are to be carried out.

3.2.6 Non-return valves of drainage arrangements are to be checked after dismantling.

3.2.7 The maximum thickness diminution of hinging arms, securing, supporting and locking devices is to be treated according to the normal procedure for primary structures, but is not to be more than 15% of the as-built thickness or the maximum corrosion allowance of the Society, whichever is less. Certain designs may be subject to the Society's special consideration.

3.2.8 Checking the effectiveness of sealing arrangements by hose testing or equivalent is to be carried out.

3.3 Internal platforms and ramps

3.3.1 The condition of pulleys, axles, cables and structure of the platforms and ramps is to be checked.

Electric motors and/or hydraulically operated equipment are to be surveyed according to the scope detailed in Ch 3, Sec 3, [4] for the class renewal survey of machinery installations.

3.4 Fire protection, detection and extinction

3.4.1 Within the scope of survey of fire protection, detection and extinction arrangements as required for the class renewal survey of all ships in Ch 3, Sec 3, [4.8], attention is to be given to the particular arrangements related to amphibious vessel spaces, such as those indicated in [2.5.1].

3.5 Means of escape

3.5.1 The condition of means of escape as well as of fire protection, detection and extinction in special category spaces is to be checked.

3.5.2 The condition of the Low Location Lighting (LLL) system, where fitted, and its power source(s) is to be verified.

Part A
Classification and Surveys

CHAPTER 5
SCOPE OF SURVEYS RELATED TO ADDITIONAL CLASS NOTATIONS

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Section 1 General

1 General

1.1

1.1.1 The purpose of this Chapter is to give details on the scope of surveys of specific equipment and systems fitted on board the ship, which are covered by an additional class notation. Unless otherwise specified in Ch 1, Sec 2, [6], the scope of these surveys provides the requirements to be complied with for the maintenance of the relevant additional class notation.

1.1.2 These specific requirements are additional to those laid down in Part A, Chapter 3 and Part A, Chapter 4. These surveys are to be carried out at intervals as described in Ch 2, Sec 2, as far as possible concurrently with the surveys of the same type, i.e. annual, intermediate or class renewal survey.

1.1.3 The equipment and systems are also to be submitted to occasional survey whenever one of the cases indicated in Ch 2, Sec 2, [7] occurs.

1.1.4 Where specific requirements are given for the class renewal survey, they are additional to the requirements for the annual survey, which, in accordance with Ch 3, Sec 3, [1.1.5], is to be carried out at the completion of the class renewal survey.

1.1.5 For the assignment of the additional class notations, ships are to be submitted to an admission to class survey as described in Ch 2, Sec 1, [2] and Ch 2, Sec 1, [3] for new and existing installations, respectively, as applicable.

2 Additional class notations subject to additional surveys

2.1

2.1.1 The specific requirements detailed in this Chapter are linked to the additional class notation(s) assigned to the ship. Where a ship has more than one additional class notation, the specific requirements linked to each additional class notation are applicable as long as they are not contradictory.

2.1.2 Tab 1 indicates which additional class notations are subject to specific requirements, and in which Section they are specified.

Table 1 : Additional class notations for which specific survey requirements are applicable

Additional class notation	Section applicable in this Chapter	Type of surveys affected by these specific requirements	Remarks
Military environment: **ARMOUR** **FFS**	Ch 5, Sec 2	See Remarks	As applicable in accordance with the related Articles in Ch 5, Sec 2
VeriSTAR system: **STAR-HULL** **STAR-MACH**	Ch 5, Sec 3	See Remarks	The scope and periodicity of surveys are stipulated by specific requirements given in Part E, Chapter 2
Availability of machinery: **AVM-APM**, **AVM-DPS**, **AVM-IPSx-(V)**	Ch 5, Sec 4	annual survey class renewal survey	
Automated machinery systems: **AUT-QAS**, **AUT-PORT**, **AUT-IAS**	Ch 5, Sec 5	annual survey class renewal survey	
Integrated ship systems: **SYS-NEQ**, **SYS-NEQ1**	Ch 5, Sec 6	annual survey class renewal survey	
Monitoring equipment: **MON-HULL**, **MON-SHAFT**	Ch 5, Sec 7	annual survey class renewal survey tailshaft survey	
Refrigerating installations: **REF-STORE**	Ch 5, Sec 8	annual survey class renewal survey	
Environmental Protection: **CLEANSHIP**, **CLEANSHIP SUPER** **AWT**, **BWE**, **BWT**, **GWT** **NDO-x days**, **NOX-x%** **OWS-x ppm**, **SOX-x%**	Ch 5, Sec 9	annual survey class renewal survey	

Additional class notation	Section applicable in this Chapter	Type of surveys affected by these specific requirements	Remarks
CBRN protection: **CBRN** **CBRN-AIR BLAST RESISTANCE**	Ch 5, Sec 10	annual surveys class renewal surveys	
Manoeuvrability: **MANOVR**	Ch 5, Sec 11	class renewal surveys	
Towing: **TOW**	Ch 5, Sec 12	annual surveys class renewal surveys	
Helideck: **HELICOPTER**	Ch 5, Sec 13	annual surveys class renewal surveys	

Section 2 Military environment

1 General

1.1 Application

1.1.1 The requirements of this Section apply to self-propelled ships granted with one or more of the following additional class notations:

ARMOUR

FFS

1.1.2 These requirements apply in addition to the requirements given in Part A, Chapter 3 and Part A, Chapter 4 versus the type of surveys.

2 ARMOUR

2.1 Class renewal surveys

2.1.1 Surveys

The survey shall include:

- an examination of the armour components as described in the armouring table
- the confirmation that the armour components are still in place, without external deficiency that can be detected by visual examination.

3 FFS

3.1 Annual survey

3.1.1 The annual survey is to include the following items:

- examination, as far as practicable, of the FFS pumping systems and suctions
- general examination of FFS piping, valves, indicators and remote controls.

3.2 Class renewal survey

3.2.1 The requirements given in [3.1] for annual survey are to be complied with.

3.2.2 In addition, the class renewal survey is to include a functional test of the flooding fighting system. If impractical to conduct, an exemption may be granted for actual pumping if agreed upon by the Naval Authority.

Section 3 VeriSTAR System

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to the **VeriSTAR** system, as described in Ch 1, Sec 2, [6.3]:

STAR-HULL

STAR-MACH

2 STAR-HULL

2.1 Survey scope and periodicity

2.1.1 The scope and periodicity of surveys for the maintenance of the **STAR-HULL** notation are given in Pt E, Ch 2, Sec 1.

3 STAR-MACH

3.1 Survey scope and periodicity

3.1.1 The procedures for the maintenance of the **STAR-MACH** notation are given in Pt E, Ch 2, Sec 2.

Section 4 Availability of Machinery

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to availability of machinery, as described in Ch 1, Sec 2, [6.4]:

AVM-APM

AVM-DPS

AVM-IPSx-(V)

2 Annual survey

2.1

2.1.1 At each annual survey the Owner or his representative is to declare to the attending Surveyor that no modifications have been made to the systems affecting the notations without prior approval by the Society.

3 Class renewal survey

3.1

3.1.1 At each class renewal survey a test is to be conducted in order to ascertain that the systems affecting the notations operate satisfactorily. This test is usually to be carried out at sea.

Section 5 Automated Machinery Systems

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to automated machinery systems, as described in Ch 1, Sec 2, [6.5]:

AUT-QAS

AUT-PORT

AUT-IAS

2 Annual survey

2.1

2.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made without prior approval by the Society.

2.1.2 The annual survey is to include:

- an examination of the engineers' log-book to verify the proper operation of automation systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions or failures which have occurred during the same period
- a general examination of the control systems covered by the notation, including a random check of the proper operation and calibration of main measuring, monitoring, alarm, and automatic shut-off devices
- a check of the fire detectors
- a check of the bilge flooding alarms
- a running test which may be also performed by a spot check method.

3 Class renewal survey

3.1

3.1.1 The requirements given in [2] for annual survey are to be complied with. An additional program of examinations, checks and tests is to be devised in agreement with the Owner and based on the operational data and experience of previous surveys. This program is to include verification of the calibration of instruments and testing of control and safety functions of the machinery. The Owner is to produce evidence that all these checks and tests have been carried out and this will be verified by the Surveyor at random. In addition, the proper operation of the control system of propulsion machinery is to be checked at sea.

Section 6 Integrated Ship Systems

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to integrated ship systems, as described in Ch 1, Sec 2, [6.6.1]:

SYS-NEQ

SYS-NEQ-1

2 Annual survey

2.1

2.1.1 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the relevant installations without the prior approval by the Society.

An examination of the log-books is to be carried out to verify the proper operation of systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions or failures which have occurred during the same period

2.1.2 The annual survey is to include:

a) General:
   - general examination of the bridge layout, with regard to the field of vision, window wipe and wash system, wheelhouse lighting and heating/cooling systems, and arrangements for the safety of navigators

b) Propulsion and steering controls:
   - operational test of the steering gear to confirm the proper operation of the various remote controls from the wheelhouse
   - operational test, as far as practicable, of the propulsion control, including propeller pitch control, where fitted
   - check of the relevant indicators such as rudder angle, ahead/astern position, propeller rpm or pitch

c) Navigation aids:
   - operational test of the satisfactory operating condition of radars
   - operational test of the functions available at quay side of the ARPA and collision avoidance system
   - operational test of the position fixing system
   - operational test of the gyro compass system
   - operational test of the echo sounding device, using appropriate scale of depth
   - operational test of other available alarms (sounding equipment, self-checking device, etc.), as far as practicable

d) Communications:
   - operational test of the whistle control device from the relevant workstation
   - check of the different communication systems (internal communication, VHF radiotelephone installation, NAVTEX)

e) Bridge safety and alarm system (notation **SYS-NEQ-1**)
   - operational test, as far as practicable, of the vigilance system and related alarm/warning transfer system.

3 Class renewal survey

3.1

3.1.1 The requirements given in Article [2] for annual survey are to be complied with. An additional program of examinations, checks and operational tests is to be devised in agreement with the Owner and based on the operational data and experience of previous surveys. This program is to include verification of the calibration of instruments and testing of control and safety functions of the installation. An additional program of random tests of the systems is to be performed during sea trials.

The Owner is to confirm that any modification to the hardware and software is fully documented and properly recorded.

Section 7 Monitoring Equipment

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to hull and tailshaft monitoring equipment, as described in Ch 1, Sec 2, [6.7]:

MON-HULL

MON-SHAFT

2 MON-HULL

2.1 Annual and class renewal survey

2.1.1 The Owner or his representative is to declare to the attending Surveyor that the hull monitoring equipment has been recently calibrated using a reference loading case.

3 MON-SHAFT

3.1 Tailshaft survey

3.1.1 When the records of the tailshaft bearing temperature readings are checked and doubts arise, the Surveyor may require the verification of the accuracy of the gauging devices.

Section 8 Refrigerating Installations

1 General

1.1

1.1.1 The requirements of this Section apply to ships which have been assigned the following additional class notation related to refrigerating installations, as described in Ch 1, Sec 2, [6.9]:

REF-STORE

2 Annual survey

2.1 General

2.1.1 The annual survey of refrigerating installations (plants and spaces) is to be carried out with the installation in running condition and, whenever possible, during unloading operations or without supplies in refrigerated spaces.

2.1.2 The refrigeration installation log-book (or other similar record) is to be made available to the Surveyor for examination of the records since the last survey, and checking any unusual consumption of refrigerant, breakdown or defective items.

2.1.3 Decks, bulkheads or ship sides adjacent to refrigerated spaces are to be checked as far as practicable in order to verify the absence of cold spots.

2.1.4 The Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the installations that could affect the class notations without the prior approval by the Society.

2.2 Refrigerating plant

2.2.1 Refrigerating machines and related accessories, including compressors, condensers, pumps and piping are to be examined externally and in running condition. Insulation of insulated parts is to be checked for possible signs of humidity or wear. The tightness of the system is to be ascertained.

2.2.2 The electrical installation is to be generally examined, and the insulation resistance of the installation is to be checked as deemed necessary by the Surveyor.

2.2.3 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 1, [3.3].

2.3 Refrigerated spaces

2.3.1 Refrigerated spaces are to be generally examined to ascertain the condition of:

- insulation lining; removable panels or covers may be dismantled for examination of insulation, as deemed necessary by the Surveyor
- hatch covers, doors, access panels (including gaskets and securing devices) and dampers of ventilation ducts
- air coils, coolers, fans, air ducts, coolant piping systems and associated equipment; cleanliness of grids
- bilge wells
- protection of fans and other rotating machinery, battens for air circulation within the space.

2.4 Instrumentation and safety devices

2.4.1 Thermometers used for measurement of temperature in refrigerated spaces, air ducts and other elements of the installation are to be examined and checked for their accuracy. The Surveyor may require the calibration of one or more thermometers and one or more automation devices to be checked in his presence or, failing this, a certificate of calibration is to be presented to him.

2.4.2 The following alarm and safety devices are also to be checked, as required or fitted:

- alarm and emergency shutdown devices
- CO_2 detectors, if any
- refrigerant leakage detectors
- access to spaces, with regard to possibilities of escape and prevention of personnel being trapped within spaces.

3 Class renewal survey

3.1 General

3.1.1 The installation is to be surveyed out of operation in order to enable examinations in opened condition of certain items.

3.1.2 After completion of these examinations, the installation is to be checked while cooling down from the ambient temperature to the lowest design temperature for the refrigerated spaces. The plant is to be examined for ability to maintain stable air temperatures and defrosting operation is to be checked.

3.2 Refrigerating plant

3.2.1 The equipment is to be dismantled to a sufficient extent to enable the following examinations:

- reciprocating compressors: examination of cylinders, valves, crankshaft, connecting rods, pistons, bearings and safety devices
- screw compressors, turbo compressors and pumps: parts subject to wear and tear; the equipment may not need to be opened up if log-book records and a running test show proper functioning.

3.2.2 Prime movers of pumps, compressors and fans are to be examined to the same extent as required in Ch 3, Sec 3, [4] for similar equipment for the class renewal survey of machinery.

3.2.3 Condensers and coolers are to be opened up for examination of tube plates, tubes and end covers.

Condensers are to be pressure tested to 1,2 times the rated working pressure.

3.2.4 Insulation of insulated parts (such as piping and pressure vessels) may need to be removed at random, to ascertain the condition of such parts and of the insulation itself.

3.2.5 The electrical installation of the plant is to be examined and insulation tests checked.

3.2.6 If independent from the electrical installation of the ship, the generators supplying electrical power to the refrigerating installation are to be examined to the same extent as described in Ch 3, Sec 3, [4.6].

3.2.7 Sea connections to condenser circulating pumps are to be opened up and piping examined.

3.2.8 Other equipment, such as oil separators on refrigerant systems, filters and dehydrators, are to be examined to the satisfaction of the Surveyor.

3.3 Refrigerated spaces

3.3.1 The lining and insulation in the refrigerated spaces may need to be partly removed for examination of its condition. The condition of the hull part under the insulation is then ascertained, as well as that of girders, meat rails, hooks and coil/cooler supports.

3.3.2 Air coolers and coils are to be examined and pressure tested at the rated working pressure and at 1,2 times such pressure in the case of hydraulic test after repairs.

3.3.3 Air cooler fans are to be examined and their prime movers are to be checked to the same extent as stated in [3.2.2].

3.3.4 The electrical installation in the refrigerated spaces is to be examined and insulation tests checked.

3.3.5 Defrosting and heating systems are to be examined to the satisfaction of the Surveyor.

3.4 Instrumentation and safety devices

3.4.1 Pressure relief valves and safety disks are to be checked. Discharge piping is to be examined with regard to integrity and non-obstructed flow.

Section 9 Environmental Protection

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships which have been assigned one of the following additional class notations related to pollution prevention systems, as described in Ch 1, Sec 2, [6.10]:

- **CLEANSHIP**
- **CLEANSHIP SUPER**
- **AWT**
- **BWE**
- **BWT**
- **GWT**
- **NDO-x days**
- **NOX-x%**
- **OWS-x ppm**
- **SOX-x%**

2 Prevention of sea pollution

2.1 First annual survey

2.1.1 Confirmation of no discharge period

During the first annual survey, the Surveyor collects the results of tests and measurements undertaken by the Shipowner according to Pt E, Ch 7, Sec 3. These results are used to confirm or modify the no discharge numeral appended to the notations **NDO-x days**.

2.1.2 Audit

An on-board audit of the procedures, as required in Part E, Chapter 7, is done by the Surveyor in order to ascertain that the Master and crew are familiar with the ship's on-board procedures for preventing pollution and in order to check that the discharge records mentioned in Part E, Chapter 7 are properly completed.

2.2 Annual survey

2.2.1 General

The survey is to include, as far as practicable:

- confirmation of the installation being in accordance with the plans. If modifications have been made, checking that these modifications are in accordance with approved documentation (for all additional class notations related to pollution prevention systems)
- confirmation that the IOPP certificate is valid (for **CLEANSHIP**, **CLEANSHIP SUPER** and **OWS-x ppm**)
- general examination of the most important components of the sewage treatment plant, the garbage treatment plant, the oil filtering equipment, the incinerators if fitted, the comminuters and grinders, the hazardous wastes recovery unit if fitted (for **CLEANSHIP** and **CLEANSHIP SUPER**)
- general examination of the holding tanks, including examination of a possible corrosion protection of the inside surfaces of the tanks which are to be in good condition (for **CLEANSHIP** and **CLEANSHIP SUPER**)
- verification of the satisfactory condition of the standard discharge connections for oil and wastewater (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT** and **NDO-x days**)
- external examination and operating tests of the equipment and systems as required in Pt E, Ch 7, Sec 2 and Pt E, Ch 7, Sec 3 (for all additional class notations related to pollution prevention systems).
- confirmation that the hazardous wastes are properly stowed as specified in the garbage management plan (for **CLEANSHIP**, **CLEANSHIP SUPER** and **NDO-x days**).

For some pollution prevention system of [1.1.1], the survey is also to include, as far as practicable:

- ascertainment of the correct concentration of the disinfectant in the effluent (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT** and **GWT**)
- ascertainment of possible concentration of other chemicals in the effluent (for **CLEANSHIP**, **CLEANSHIP SUPER**, **AWT** and **GWT**).

2.2.2 Review of records

The following records for the preceding 12 months are to be reviewed as necessary:

- oil record book (for **CLEANSHIP**, **CLEANSHIP SUPER** and **OWS-x ppm**)
- garbage record book (for **CLEANSHIP**, **CLEANSHIP SUPER** and **OWS-x ppm**)
- records of ballast exchanges after international voyages (for **BWE** and **BWT**)
- ballast water record book (for **BWE** and **BWT**)
- sewage and grey water discharge book (for **CLEANSHIP**, **CLEANSHIP SUPER**, **GWT** and **AWT**)
- emissions record (for **CLEANSHIP SUPER**, **NOX-x%** and **SOX-x%**)
- results of the tests on effluents done by the Shipowner according to Pt E, Ch 7, Sec 4, [2.3.1] for any pollution prevention system of Pt E, Ch 7, Sec 4, [1.1.1] (for **AWT**).

2.3 Class renewal survey

2.3.1 The requirements given in [2.2] for annual surveys are to be complied with. In addition, for all additional class notations related to pollution prevention systems, the following is to be carried out:

- demonstration, under working conditions, of the correct functions of the most important components of the sewage treatment plant or AWT plant if fitted, the garbage treatment plant, the oil filtering equipment, the incinerators if fitted, the comminuters and grinders, the hazardous waste recovery unit if fitted
- ascertainment of the correct function of the alarms.

3 Prevention of air pollution

3.1 Annual survey

3.1.1 Ozone depleting substances (CLEANSHIP, CLEANSHIP SUPER)

a) A procedure for annual verification of the system and equipment condition by an authorised organisation is to be settled. The interval of this verification may be extended in case of predictive maintenance scheme approved by the Society.

b) A procedure for weekly verification and maintenance is to be settled enabling to:

- check the tightness of the circuits by satisfactory means (such as weighing or vessel pressure monitoring)
- identify the location of possible leakage
- carry out necessary corrective actions.

Record books tracing all the operations carried out on board the ship according to the procedures mentioned in the NOx Technical Code are to be kept on-board and updated after each intervention. They are to include in particular the following records:

- presence of leak and corrective action
- volume of substance recovered and indication of the storage location
- volume of substance recharged
- volume of substance consumed
- volume of substance disposed.

The survey is to include the following items:

- verification that the above procedures for annual and weekly checking of systems with ozone depleting substances are available on-board
- confirmation that appropriate entries are being made in the record book for ozone depleting substances
- test of the proper operation of the leak detectors and related audible and visual alarms.

c) Review of ozone - depleting substance record book.

3.1.2 NOx emission (CLEANSHIP SUPER, NOX-x%)

- The procedures for demonstrating compliance with NOx emission limits on board are given in the NOx Technical Code.
- During the annual survey, it is to be confirmed that the NOx emission control procedure is available on-board.
- NOx emission records.

3.1.3 SOx emission (CLEANSHIP, CLEANSHIP SUPER, SOX-x%)

Procedures are to be established to detail the maximum sulphur content in the fuel oil purchase orders, and to check the actual content of sulphur at the delivery of bunker.

In the case the actual sulphur content is checked by sampling testing and analysis, procedures are to be carried out in accordance with a recognised standard acceptable to the Society.

The fuel management procedures are to be established and followed as part of the certified ship management system of the ship.

Records on purchase orders and on type of checking carried out, including results, are to be kept on-board.

The survey is to include the following items:

- verification that the above procedures for defining, ordering and checking fuel oils for control of SOx emission are available on-board
- confirmation that fuel oil sulphur content records are available on-board
- emission record (when exhaust gas cleaning is provided (EGC)).

3.1.4 Shipboard incineration (CLEANSHIP, CLEANSHIP SUPER)

The annual survey is to include the following items, when fitted:

- external examination of the incinerators and confirmation that such equipment operates satisfactorily
- test of the alarms, exhaust monitoring devices and emergency stop located outside the compartment.

3.2 Class renewal survey

3.2.1 The requirements given in [3.1] for annual surveys are to be complied with. In addition, the following is to be carried out:

- confirmation of the operation and calibration of the emissions analysers if fitted (for **CLEANSHIP SUPER**, **NOX-x%** and **SOX-x%**)
- external examination and operating tests of the equipment and systems, as required in Pt E, Ch 7, Sec 2 and Pt E, Ch 7, Sec 3 (for all additional class notations related to pollution prevention systems).

Section 10 CBRN Protection

1 General

1.1 Application

1.1.1 The requirements of this Article apply to ships which have been assigned the **CBRN** or **CBRN-AIR BLAST RESISTANCE** additional class notation as described in Ch 1, Sec 2, [6.11].

1.2 Significant modifications

1.2.1 At each survey, the Owner or his representative is to declare to the attending Surveyor that no significant modifications have been made to the installations that could affect the class notations without prior approval by the Society.

2 Annual survey

2.1 General

2.1.1 The CBRN operation manual is to be made available to the Surveyor and may be used as a basis for survey.

An examination of the log-books is to be carried out to verify the proper operation of the systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions and failures which have occurred during the same period.

2.1.2 The annual survey is to include:

- examination and testing, as feasible, of airlocks, cleansing station(s) and CBRN protection plant(s)
- examination of CBRN detection system, including checking of number and location of each detector
- verification that each opening in the citadel and shelter boundaries is provided with a closing appliance in working order and suitably marked
- verification of remote indication, alarm and control functions at the damage control station
- verification of ventilation non-return devices and dampers
- verification of water traps or equivalent devices against air entrance
- examination of CBRN ventilation system, including ducts, filters and dampers
- examination of pre-wetting and washdown system, including piping, valves and nozzles.

2.2 Air blast resistance

2.2.1 In addition, for ships assigned the additional class notation **CBRN-AIR BLAST RESISTANCE**, the annual survey is to include:

- examination of the air blast protective device
- checking that the remotely controlled means of closing ventilation openings are in working order.

3 Class renewal survey

3.1 General

3.1.1 The CBRN operation manual is to be made available to the Surveyor and may be used as a basis for survey.

An examination of the log-books is to be carried out to verify the proper operation of the systems in the period subsequent to the last survey and measures taken to avoid repetition of any malfunctions and failures which have occurred during the same period.

3.1.2 The class renewal survey is to include:

- Check of overpressure levels in the citadel with the collective protection ventilation system working. The required overpressure is to be held for at least 30 min. The test may be carried out with dummy filters in lieu of CBRN filters.

- Verification of gastightness of engine enclosure and associated supply and exhaust ducts, for engines with dedicated air supply.
- Verification of air conditioning capability under CBRN condition.
- Functioning test of the CBRN detection system. Each line is to be tested from the level of the detector, with means defined by the system supplier.
- Functioning test of the pre-wetting and washdown system, including verification that all external surfaces are properly covered, verification of water drainage and verification of section valve remote operation.
- Checking that the environmental conditions related to temperature remain inside the limits as defined in Pt C, Ch 1, Sec 1 with the propulsion machinery at maximum power setting during CBRN operations.

- Verification of gastightness of engine enclosure and associated supply and exhaust ducts, for engines with dedicated air supply.
- Verification of air conditioning capability under CBRN condition.
- Functioning test of the CBRN detection system. Each line is to be tested from the level of the detector, with means defined by the system supplier.
- Functioning test of the pre-wetting and washdown system, including verification that all external surfaces are properly covered, verification of water drainage and verification of section valve remote operation.
- Checking that the environmental conditions related to temperature remain inside the limits as defined in Pt C, Ch 1, Sec 1 with the propulsion machinery at maximum power setting during CBRN operations.

Section 11 Manoeuvrability

1 General

1.1 Application

1.1.1 The requirements of this Section apply to self-propelled ships granted with one or more of the following additional class notations:

MANOVR

1.1.2 These requirements apply in addition to the requirements given in Part A, Chapter 3 and Part A, Chapter 4 versus the type of surveys.

2 MANOVR

2.1 Annual survey

2.1.1 At each annual survey the Owner or his representative is to declare to the attending Surveyor that no repairs, alterations or modifications have been made, which may influence the vessel's manoeuvrability characteristics.

In the event of repairs, alterations or modifications, which, in the opinion of the Society, may influence the vessel's manoeuvrability characteristics, the continued compliance with the criteria as described in Pt E, Ch 9, Sec 1 is to be verified to the satisfaction of the Society.

2.2 Class renewal survey

2.2.1 The requirements given in Sub-article [2.1] for annual survey are to be complied with.

Section 12 Towing

1 General

1.1 Application

1.1.1 The requirements of this Section apply to self-propelled ships granted with one or more of the following additional class notations:

TOW

1.1.2 These requirements apply in addition to the requirements given in Part A, Chapter 3 and Part A, Chapter 4 versus the type of surveys.

2 TOW

2.1 Annual survey

2.1.1 The additional items and equipment to be surveyed together with the scope of the survey shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.1.2 The type and number of additional tests to be performed shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.1.3 The survey shall include:.

- an examination of the emergency towing installation
- the confirmation that the installation is instantaneously available including a pre-rigged aft towing arrangements and a forward chafing gear secured to the strong-point
- an examination of the pick-up gear, towing pennant and chafing gear over the full length for detection of possible deterioration. Where the pennant line is stored in a watertight condition and can be confirmed as being maintained, consideration may be given to waiving the requirement to examine the pennant line over the full length
- an examination of the strong-points, fairleads and pedestal roller together with their attachments to the hull structure.

2.2 Class renewal survey

2.2.1 The additional items and equipment to be surveyed together with the scope of the survey shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.2.2 The type and number of additional tests to be performed shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

Section 13 Helideck

1 General

1.1 Application

1.1.1 The requirements of this Section apply to self-propelled ships granted with one or more of the following additional class notations:

HELICOPTER

1.1.2 These requirements apply in addition to the requirements given in Part A, Chapter 3 and Part A, Chapter 4 versus the type of surveys.

2 HELICOPTER

2.1 Annual survey

2.1.1 The additional items and equipment to be surveyed together with the scope of the survey shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.1.2 The type and number of additional tests to be performed shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.2 Class renewal survey

2.2.1 The additional items and equipment to be surveyed together with the scope of the survey shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

2.2.2 The type and number of additional tests to be performed shall be defined, on a case by case basis, by an agreement between the Surveyor and the Owner representative.

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RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part B
Hull and Stability

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Part B
Hull and Stability

CHAPTER 1
GENERAL

Section 1 Application

Section 2 Symbols and Definitions

Section 3 Documentation to be Submitted

Section 1 Application

1 General

1.1 Structural requirements

1.1.1 Part B of the Rules contains the requirements for determination of the minimum hull scantlings, applicable to all types of seagoing single hull displacement ships of normal form, speed and proportions, made in welded steel construction, with a length not less than 65m. These requirements are to be integrated with those specified in Part E, as applicable, depending on the additional class notations assigned to the ships.

1.1.2 The requirements of Part B and Part E apply also to those steel ships in which parts of the hull, e.g. superstructures or movable decks, are built in aluminium alloys.

1.1.3 Ships whose hull materials are different than those given in [1.1.2] and ships with novel features or unusual hull design are to be individually considered by the Society, on the basis of the principles and criteria adopted in the Rules.

1.1.4 The strength of ships constructed and maintained according to the Rules is sufficient for the draught corresponding to the loading conditions as defined in Ch 5, Sec 1, [2.4.3]. The scantling draught considered when applying the Rules is to be not less than that corresponding to the assigned intact ship deepest full load waterline.

1.1.5 Where scantlings are obtained from direct calculation procedures which are different from those specified in Part B, Chapter 7, adequate supporting documentation is to be submitted to the Society, as detailed in Ch 1, Sec 3.

1.2 Limits of application to lifting appliances and weapons

1.2.1 The fixed parts of lifting appliances, considered as an integral part of the hull, are the structures permanently connected by welding to the ship's hull (for instance crane pedestals, masts, king posts, derrick heel seatings, etc., excluding cranes, derrick booms, ropes, rigging accessories, and, generally, any dismountable parts). The shrouds of masts embedded in the ship's structure are considered as fixed parts.

1.2.2 The fixed parts of lifting appliances and weapons and their connections to the ship's structure are covered by the Rules.

1.2.3 As far as the weapons are concerned, the load effects of blast and recoil on the structures are covered by the Rules. The safety aspects regarding personnel and other systems are not covered by the Rules.

2 Rule application

2.1 Ship parts

2.1.1 General

For the purpose of application of the Rules, the ship is considered as divided into the following three parts:

- the fore part
- the central part
- the aft part.

2.1.2 Fore part

The fore part includes the structures located forward of the collision bulkhead, i.e.:

- the fore peak structures
- the stems.

In addition, it includes:

- the reinforcements of the flat bottom forward area
- the reinforcements of the bow flare area.

2.1.3 Central part

The central part includes the structures located between the collision bulkhead and the after peak bulkhead.

Where the flat bottom forward area or the bow flare area extend aft of the collision bulkhead, they are considered as belonging to the fore part.

2.1.4 Aft part

The aft part includes the structures located aft of the after peak bulkhead.

2.2 Rules applicable to various ship parts

2.2.1 The various Chapters and Sections of Part B are to be applied for the general arrangement and scantling of ship parts according to Tab 1.

Table 1 : Rule requirements of Part B applicable for the general arrangement and scantling of ship parts

Parts	Applicable Chapters and Sections	
	General	Specific
Fore part	Part B, Chapter 1 Part B, Chapter 2 Part B, Chapter 3 Part B, Chapter 4 Part B, Chapter 8 **(1)**, excluding: • Ch 8, Sec 1 • Ch 8, Sec 2 Part B, Chapter 10 Part B, Chapter 11	Ch 8, Sec 1
Central part		Part B, Chapter 5 Part B, Chapter 6 Part B, Chapter 7
Aft part		Ch 8, Sec 2
(1) See also [2.3].		

2.3 Rules applicable to other ship items

2.3.1 The various Chapters and Sections of Part B are to be applied for the general arrangement and scantling of other ship items according to Tab 2.

Table 2 : Rule requirements of Part B applicable for the general arrangement and scantling of other items

Items	Applicable Chapters and Sections
Machinery space	Ch 8, Sec 3
Superstructures and deckhouses	Ch 8, Sec 4
Bow doors and inner doors	Ch 8, Sec 5
Slide shell doors and stern doors	Ch 8, Sec 6
Hatch covers	Ch 8, Sec 7
Movable decks and inner ramps External ramps	Ch 8, Sec 8
Rudders	Ch 9, Sec 1
Hull outfitting and masts	Ch 9, Sec 2 Ch 9, Sec 3 Ch 9, Sec 4 Ch 9, Sec 5

3 Rounding off of scantlings

3.1

3.1.1 Plate thicknesses

The rounding off of plate thicknesses is to be obtained from the following procedure:

a) the net thickness (see Ch 4, Sec 2) is calculated in accordance with the rule requirements

b) corrosion addition t_C (see Ch 4, Sec 2) is added to the calculated net thickness, and this gross thickness is rounded off to the nearest half-millimetre

c) the rounded net thickness is taken equal to the rounded gross thickness, obtained in item b), minus the corrosion addition t_C.

3.1.2 Stiffener section moduli

Stiffener section moduli as calculated in accordance with the rule requirements are to be rounded off to the nearest standard value; however, no reduction may exceed 3%.

Section 2 Symbols and Definitions

1 Units

1.1

1.1.1 Unless otherwise specified, the units used in the Rules are those defined in Tab 1.

Table 1 : Units

Designation	Usual symbols	Units
Ship dimensions	See Article [2]	m
Hull girder section modulus	Z	m^3
Density	ρ	t/m^3
Concentrated loads	P	kN
Linearly distributed loads	q	kN/m
Surface distributed loads (pressures)	p	kN/m^2
Thickness	t	mm
Span of ordinary stiffeners and primary supporting members	ℓ	m
Spacing of ordinary stiffeners and primary supporting members	s	m
Bending moment	M	kN.m
Shear force	Q	kN
Stresses	σ, τ	N/mm^2
Section modulus of ordinary stiffeners and primary supporting members	w	cm^3
Sectional area of ordinary stiffeners and primary supporting members	A	cm^2

2 Definitions

2.1 Symbols

2.1.1

L : Rule length, in m, defined in [4.1]

L_1 : L, but to be taken not greater than 200 m

L_2 : L, but to be taken not greater than 120 m

B : Moulded breadth, in m, defined in [4.4]

B_{WS} : Breadth at full load waterline, in m, defined in [4.4]

D : Depth, in m, defined in [4.5]

T : Moulded draught, in m, defined in [4.6]

Δ : Moulded displacement, in tonnes, at draught, in sea water (density ρ = 1,025 t/m^3)

C_B : Total block coefficient:

$$C_B = \frac{\Delta}{1,025 L B_{WS} T}$$

3 Waterlines

3.1 Subdivision lines

3.1.1 Subdivision load line

Subdivision load line is a waterline used in determining the subdivision of the ship.

3.1.2 Deepest subdivision load line

Deepest subdivision load line is the waterline which corresponds to the greatest draught permitted by the subdivision requirements which are applicable.

3.2 Specific lines

3.2.1 Margin line

Margin line is an imaginary line drawn at side of the hull above which the presence of water is not allowable when the ship, after damage, is in condition of static equilibrium.

Such line divides the hull into two parts:

- the part below the margin line

  Such part when damaged may be floodable according to Ch 3, Sec 3.
- the part above the margin line

  Such part cannot be flooded according to Ch 3, Sec 3 because the buoyancy and stability requirements might result highly compromised (for example for progressive flooding).

Generally the margin line is positioned 76 mm (3") below the Watertight Deck (W.D.).

If, for the purpose of complying the damage stability requirements, some of the Main Transversal Watertight Bulkheads (M.T.W.B.) are extended to a higher deck, here called Bulkhead Deck (B.D.), by means of Auxiliary Transversal Watertight Bulkheads (A.T.W.B.), the margin line may be referred:

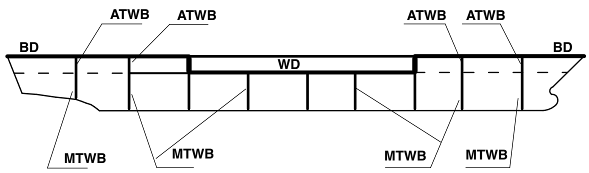
a) to the Bulkhead Deck (B.D.), where the Main Transversal Watertight Bulkheads (M.T.W.B.) are extended by Auxiliary Transversal Watertight Bulkheads (A.T.W.B.)

b) to the Watertight Deck (W.D.), in the other parts.

This represents really the upper limit of the floodable volumes supplied with watertight closure devices which stop the flooding of the undamaged neighbour volumes.

See Fig 1.

Figure 1 : Deck to which the margin line may be referred



3.2.2 Submersible areas

Some areas of the vessel on the Watertight Deck (W.D.) as mooring and quartering areas, in any case may result immersed provided that every access or openings to the buoyant compartments are watertight, so that progressive flooding will be avoided. The bounding bulkheads have to be considered as the hull.

To the purpose of considering an area submersible, the following requirements are to be complied:

- all the openings are to be closed before sailing by means of watertight closure such to face the hydrostatic head corresponding to the maximum draught. These openings are to be of reduced size, such as access hatches
- not to compromise, when immersed, the access to area essential for surviving.

In the submersible areas, the margin line is described as follows:

- in the fore part of the longitudinal extent of the submersible area of the ship, the margin line is limited to the aft main transverse watertight bulkhead bounding this submersible area
- in the aft part of the longitudinal extent of the submersible area of the ship, the margin line is limited to the fore main transverse watertight bulkhead bounding this submersible area.

3.2.3 "V" Lines

At each ship section, "V" Lines are the envelope of the damaged ship waterlines at final flooding stage and during intermediate stages of flooding (see Ch 3, App 4).

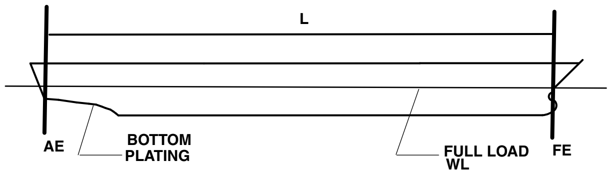
4 Dimensions

4.1 Rule length

4.1.1 The rule length L, see Fig 2, is the distance, in m, measured on the full load waterline between the aft end (AE) and the fore end (FE), as defined in [4.2].

4.1.2 In ships with unusual stem or stern arrangements, the rule length L is considered on a case-by-case basis.

Figure 2 : Rule length



4.2 Ends of rule length L and midship

4.2.1 Aft end

The aft end (AE) of the rule length L is the perpendicular to the deepest full load waterline at the lowest corner between the transom and the bottom plating.

4.2.2 Fore end

The fore end (FE) of the rule length L, is the perpendicular to the full load waterline at the forward side of the stem.

4.2.3 Midship

The midship is the perpendicular to the deepest full load waterline at the distance 0,5L aft of the fore end FE.

4.3 Length between perpendiculars

4.3.1 The length between perpendiculars L_{bp} is the length, in metres, at the waterline corresponding to the full load as defined in Tab 2.

4.4 Moulded breadths

4.4.1 The moulded breadth B is the greatest moulded breadth, in m, measured amidships below the uppermost continuous deck, excluding sponsons.

4.4.2 The breadth B_{WS} is the moulded breadth, in m, measured amidships at the full load waterline “end of life”.

4.5 Moulded depth

4.5.1 The moulded depth D is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the top of the deck at side on the uppermost continuous deck.

In the case of a ship with a solid bar keel, the moulded base line is to be taken at the intersection between the upper face of the bottom plating and the solid bar keel at the middle of length L.

4.6 Moulded draught

4.6.1 The moulded draught T is the distance, in m, measured vertically on the midship transverse section, from the moulded base line to the full load waterline “end of life”.

4.6.2 In the case of ships with a solid bar keel, the moulded base line is to be taken as defined in [4.5.1].

5 Ship weights

5.1 Lightship

5.1.1 The lightship is a ship complete in all respects, but without consumables, stores, and crew and effects, and without any liquids on board except for machinery and piping fluids, such as lubricant and hydraulic, which are at operating levels.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], a lightship condition “at delivery” and a lightship condition “end of life” are to be considered for the assessment of the stability and strength effects.

5.2 Full load

5.2.1 The full load condition corresponds to the ship loaded departure as defined in Tab 2.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], a full load condition “at delivery” and a full load condition “end of life” are to be considered for the assessment of the stability and strength effects.

Table 2 : Definition of loading cases (% of mass or specified maximum loads)

Components	Full load condition	Operational load condition	Minimum operational condition	Comments
Lightship	100%	100%	100%	See [5.1.1]
Crew with luggage	100%	100%	100%	
External personnel with equipment	100%	100%	100%	Personnel not belonging to the crew
Ship logistic material	100%	100%	100%	On board documents, equipment for repairs
Foods	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Ammunition	100%	66,6%	33,3%	In storage spaces above the ship centre of gravity
Helicopters with their logistic	100%	100%	100%	At location as specified
Fuels (propulsion, auxiliaries, helicopters,...)	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces The filling of the overflow fuel oil tanks is to be limited to 75% of the net volume of these tanks
		100%	100%	For capacity provided with an automatic continuous compensation system
Lubricant storage	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Other consumable materials	100%	66,6%	33,3%	Otherwise specified uniformly distributed in storage spaces
Drinking water	100%	66,6%	66,6%	When produced on board
Drinking water	100%	66,6%	33,3%	When not produced on board
Industrial waters	100%	66,6%	66,6%	
Grey and black waters	0%	33,3%	33,3%	
Ballast waters	0%	0%	0%	For the minimum operation condition, ballast necessary to comply with the stability criteria may be accepted, subject that the total displacement including the ballast tanks does not exceed the displacement corresponding to the operational condition
Stabilizing tanks	op. level	op. level	op. level	At the operational level
Non consumables and pumping residues	100%	100%	100%	Corresponding to 2% of the net volume of the capacities; if a value lower than 2% is used, this value is to be justified
Miscellaneous	100%	100%	100%	Mobile liquid or solid ballast

5.3 Operational load

5.3.1 The operational load condition is defined in Tab 2.

Considering the evolution of mass as described in Ch 3, Sec 2, [2.1.4], an operational load condition “at delivery” and an operational load condition “end of life” are to be considered for the assessment of the stability and strength effects.

5.4 Minimum operational load

5.4.1 The minimum operational load is defined in Tab 2.

5.5 Deadweight

5.5.1 The deadweight is the difference, in t, between the displacement, at the full load draught in sea water of density ρ = 1,025 t/m^3, and the lightship.

6 Decks and bulkheads

6.1 General

6.1.1 From the point of view of subdivision and stability of surface vessels, two kinds of tightness are to be defined:

- watertight
- weathertight.

6.1.2 Watertight

The watertight elements assure the tightness even with a constant hydrostatic head.

6.1.3 Weathertight

The weathertight elements assure the tightness under the action of weather agents, hose or temporary phase during rolling periods.

6.2 Bulkhead deck (B.D.)

6.2.1 The bulkhead deck is the highest deck to which auxiliary watertight transversal bulkheads are raised. The watertight boundaries after damage are limited to the bulkhead deck.

6.3 Exposed decks - Upper decks (E.D.)

6.3.1 Above the volume limited by the bulkhead deck, weathertight volumes under exposed decks or part of them may exist.

The sum of such volumes plus those defined in [6.2] (compressive volume watertight and weathertight) constitute the intact stability reserve.

The enclosed superstructures as defined in [8.2.1] may be considered as intact stability reserve.

6.4 Watertight deck (W.D.)

6.4.1 The watertight deck is the first continuous watertight deck above the waterline, up to which the main transversal watertight bulkheads (M.T.W.B.) are to be extended.

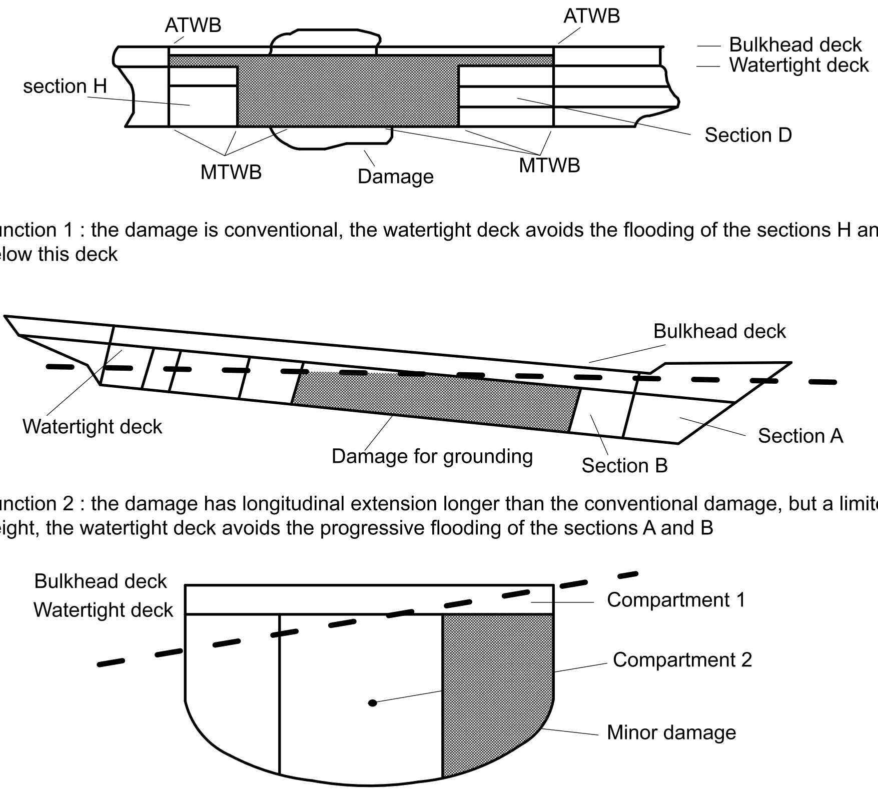
The watertight deck acts a vertical limit (see Fig 3, function 2) for flooding of the ship caused by damage to the sideshell below the waterline and thus prevents progressive flooding of undamaged compartments in a transverse direction (see Fig 3, function 3). Similarly it prevents progressive flooding in a longitudinal direction (see Fig 3, function 1) when the sideshell breach involves the entire height of the ship and when not all M.T.W.B. are extended up to the bulkhead deck.

The watertight deck is the deck below which all openings in the sideshell and all passages crossing main transversal bulkheads are forbidden or otherwise guided according to the requirements of Ch 2, Sec 1, Tab 2 “Requirements for openings and crossing in several water (weather)tight elements”.

The watertightness of elements crossing the watertight deck is to be ensured and openings in this deck are to be supplied with devices which make them watertight.

As a rule, the watertight deck generally serves as the “damage control deck”.

Figure 3 : Functions of the watertight deck (W.D.)



Function 1 : the damage is conventional, the watertight deck avoids the flooding of the sections H and D below this deck

Function 2 : the damage has longitudinal extension longer than the conventional damage, but a limited height, the watertight deck avoids the progressive flooding of the sections A and B

Function 3 : the damage is extended less than the conventional damage, the watertight deck avoids the flooding of the compartments 1 and 2, so timing the major effects of the damage

6.5 Damage control deck

6.5.1 The damage control deck is a deck above the waterline after damage that permits access along the length of the vessel, for the purpose of efficiently coordinating and conducting damage control. It is, in general, continuous and is typically the lowest deck upon which movement from forward to aft and vice versa is possible, via watertight openings in the transversal watertight bulkheads.

The damage control deck is to be positioned above point A shown in Ch 3, App 4, Fig 2, at each transverse watertight bulkhead. Where this is not possible, it is to be shown that alternate arrangements are able to permit the safe and effective conduct of damage control activities, including control of progressive flooding, to the satisfaction of the Society.

The deck structure constituting the damage control deck, along with all elements crossing this deck are to be watertight. Openings in the damage control deck are to be supplied with devices which make them watertight

6.6 Main transversal watertight bulkhead (M.T.W.B.)

6.6.1 The adequate subdivision of the internal volume by main transversal watertight bulkheads is essential to achieve an adequate buoyancy and stability in case of damage.

The main transversal watertight bulkheads extend up to the watertight deck from side to side.

Their essential task is to limit compartments and therefore to avoid the progressive flooding from a damaged to an intact compartment.

6.7 Main watertight compartment

6.7.1 A main watertight compartment is a volume bounded by two main transversal watertight bulkheads up to the watertight deck and by two auxiliary transversal watertight bulkheads between the watertight deck and the bulkhead deck and topped by the watertight deck (W.D.).

It has to be distinguished from the safety zone of fire protection.

The minimum distance between M.T.W.B., therefore the minimum length of a compartment, is provided by the formulae:

- 3 m + 3% L_{bp} , for ships of length between perpendiculars less than 250 m
- 10,5 m for ships of length between perpendiculars not less than 250 m.

6.8 Auxiliary transversal watertight bulkheads (A.T.W.B.)

6.8.1 The auxiliary transversal watertight bulkheads (A.T.W.B.) are the extension of main transversal watertight bulkheads (M.T.W.B.) above the watertight deck (W.D.) up to the bulkhead deck (B.D.).

They give the possibility to limit the longitudinal extension of flooding above the watertight deck (W.D.) and to add a further reserve of buoyancy/stability consequent to the volume bounded by such bulkheads, watertight deck and bulkhead deck.

7 Spaces definition

7.1 Machinery space

7.1.1 Machinery space is to be taken as extending from the moulded base line to the margin line and between the extreme main transverse watertight bulkheads, bounding the spaces containing the main and auxiliary propulsion machinery, boilers serving the needs of propulsion.

7.2 Ro-ro cargo spaces

7.2.1 Ro-ro cargo spaces are spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship in which goods (packaged or in bulk, or in land vehicles, or in barges or crafts) can be loaded and unloaded normally in a horizontal direction.

7.3 Passenger spaces

7.3.1 Passengers

Passengers means every person other than:

- the captain and the members of the crew or other persons employed or engaged in any capacity on board a ship on the business of that ship, and
- a child under one year of age.

7.3.2 Passenger spaces

Passenger spaces are those spaces which are provided for the accommodation and use of passengers, excluding baggage, store, provisions and mail rooms.

In all cases volumes and areas are to be calculated to moulded lines.

7.4 Special personnel

7.4.1 Special personnel means all persons who are not passengers or members of the crew or children of under one year of age and who are carried on board in connection with the special purpose of that ship because of special work being carried out aboard that ship.

7.5 Special category spaces

7.5.1 Special category spaces are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles, or barges or crafts, or helicopters with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access.

7.6 Military special category spaces

7.6.1 Military special category spaces are special category spaces intended for the carriage of motor vehicles, or barges, crafts or helicopters with ammunition.

8 Superstructures

8.1 General

8.1.1 A superstructure is a decked structure, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than 0,04 B.

8.2 Enclosed and open superstructures

8.2.1 A superstructure may be:

- enclosed, where:
  - it is enclosed by front, side and aft bulkheads complying with the requirements of Ch 8, Sec 4
  - all front, side and aft openings are fitted with efficient weathertight means of closure
- open, where it is not enclosed.

8.3 Raised quarterdeck

8.3.1 A raised quarterdeck is a partial superstructure of reduced height.

8.4 Deckhouse

8.4.1 A deckhouse is a decked structure other than a superstructure, located on the main deck or above.

8.5 Trunk

8.5.1 A trunk is a decked structure similar to a deckhouse, but not provided with a lower deck.

9 Deck positions

9.1 Definitions

9.1.1 Position 1

Position 1 includes:

- exposed main deck and raised quarter decks
- exposed superstructure decks situated forward of 0,25 L from the fore end FE.

9.1.2 Position 2

Position 2 includes exposed superstructure decks situated aft of 0,25 L from the fore end FE.

10 Reference co-ordinate system

10.1

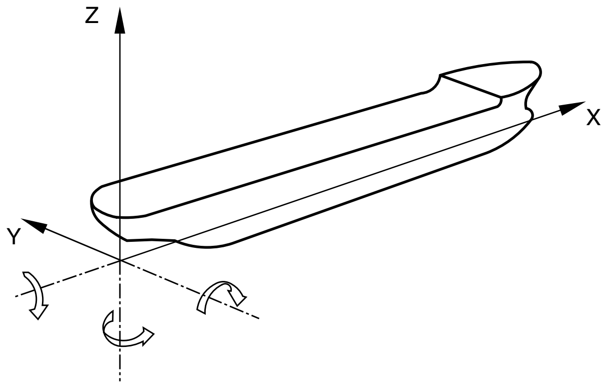
10.1.1 The ship's geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 4):

- Origin: the intersection between the longitudinal plane of symmetry of ship, the aft end of L and the baseline
- X axis: the longitudinal axis, positive forwards
- Y axis: the transverse axis, positive towards portside
- Z axis: the vertical axis, positive upwards.

10.1.2 Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

10.1.3 A different co-ordinate system may be used subject that the description of the co-ordinate system is clearly indicated in the trim and stability booklet and the same co-ordinate system is used throughout the booklet.

Figure 4 : Reference co-ordinate system



Section 3 Documentation to be Submitted

1 Documentation to be submitted for all ships

1.1 Ships built under the Society supervision

1.1.1 Plans and documents to be submitted for approval

The plans and documents to be submitted to the Society for approval are listed in Tab 1.

The above plans and documents are to be supplemented by further documentation which depends on the service notation and, possibly, the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, as specified in Article [2].

Structural plans are to show details of connections of the various parts and, in general, are to specify the materials used, including their manufacturing processes, welded procedures and heat treatments. See also Ch 11, Sec 1, [1.6].

1.1.2 Plans and documents to be submitted for information

In addition to those in [1.1.1], the following plans and documents are to be submitted to the Society for information:

- general arrangement
- capacity plan, indicating the volume and position of the centre of gravity of all compartments and tanks, if this information is not already included in the general arrangement plan
- lines plan
- hydrostatic curves
- lightweight distribution
- design load plan, indicating all applicable design loads according to Ch 5, Sec 6.

In addition, when direct calculation analyses are carried out by the Designer according to the rule requirements, they are to be submitted to the Society.

Table 1 : Plans and documents to be submitted for approval for all ships

Plan or document	Containing also information on
Watertight subdivision decks Watertight subdivision bulkheads Watertight tunnels	Openings and their closing appliances, if any
Plan of watertight doors and scheme of relevant manoeuvring devices	Manoeuvring devices Electrical diagrams of power control and position indication circuits
Loading manual	See Ch 10, Sec 2, [3]
Calculations relevant to intact stability and damage stability	See Ch 3, Sec 3
Stability documentation	See Ch 3, Sec 1, [3.1]
Midship section Transverse sections Shell expansion Decks and profiles Double bottom Pillar arrangements Framing plan Deep tank and ballast tank bulkheads, wash bulkheads	Class characteristics Main dimensions Draught at minimum operational condition (at delivery) and associated displacement Draught at full load condition (end of life) and associated displacement Frame spacing Maximum ahead service speed Density of cargoes Design loads on decks and double bottom Steel grades Location and height of air vent outlets of various compartments Corrosion protection Openings in decks and shell and relevant compensations Boundaries of flat areas in bottom and sides Details of structural reinforcements and/or discontinuities Bilge keel with details of connections to hull structures
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 9, Sec 1, [11].	

Plan or document	Containing also information on
Fore part structure	Location and height of air vent outlets of various compartments
Machinery space structures Foundations of propulsion machinery and boilers	Type, power and r.p.m. of propulsion machinery Mass and centre of gravity of machinery and boilers
Aft part structure	Location and height of air vent outlets of various compartments
Sternframe or sternpost, sterntube Propeller shaft boss and brackets **(1)**	
Rudder and rudder horn **(1)**	Maximum ahead service speed
Transverse thruster, if any, general arrangement, tunnel structure, connections of thruster with tunnel and hull structures	
Superstructures and deckhouses Machinery space casing	Extension and mechanical properties of the aluminium alloy used (where applicable)
Helicopter landing decks	General arrangement Main structure Characteristics of helicopters: maximum mass, distance between axles of wheels or skids, print area of wheels or skids, rotor diameter
Plan of ventilation	Use of spaces
Scuppers and sanitary discharges	
Bulwarks and freeing ports	Arrangement and dimensions of bulwarks and freeing ports on the watertight deck and decks above the watertight deck
Hawse pipes	
Windows and side scuttles, arrangements and details	
Sea chests, stabilizer recesses, etc.	
Plan of manholes	
Plan of access to and escape from spaces	
Plan of outer doors and hatchways	
Bow doors, stern doors and inner doors, if any, side doors and other openings in the side shell	Closing appliances Electrical diagrams of power control and position indication circuits for bow doors, stern doors, side doors, inner doors, television system and alarm systems for ingress of water
Movable decks and ramps, if any	
Hatch covers, if any	Design loads on hatch covers Sealing and securing arrangements, type and position of locking bolts Distance of hatch covers from the full load waterline and from the fore end
Derricks and lifting appliances	Design loads (forces and moments) including weapon loads Connections to the hull structures
Plan of tank testing	Testing procedures for the various compartments Height of pipes for testing
Equipment number calculation	Geometrical elements for calculation List of equipment Construction and breaking load of steel wires Material, construction, breaking load and relevant elongation of synthetic ropes
Emergency towing arrangement	See Pt E, Ch 10, Sec 2
(1) Where other steering or propulsion systems are adopted (e.g. steering nozzles or azimuth propulsion systems), the plans showing the relevant arrangement and structural scantlings are to be submitted. For azimuth propulsion systems, see Ch 9, Sec 1, [11].	

2 Further documentation to be submitted for ships with certain additional class notations

2.1 General

2.1.1 Depending on the additional class notation (see Pt A, Ch 1, Sec 2) assigned to the ship, other plans or documents may be required to be submitted to the Society, in addition to those in [1.1]. They are listed in [2.2] for the additional class notations which require this additional documentation.

2.2 Additional class notations

2.2.1 The plans or documents to be submitted to the Society are listed in Tab 2.

Table 2 : Plans and documents to be submitted depending on additional class notations

Additional class notation	Plans and documents
SEA-KEEP	see Pt E, Ch 9, Sec 3
MON-HULL	see Pt E, Ch 5, Sec 1, [1.2]

Part B
Hull and Stability

CHAPTER 2
GENERAL ARRANGEMENT DESIGN

Section 1	Subdivision Arrangement
Section 2	Compartment Arrangement
Section 3	Access and Openings Arrangement

Section 1 Subdivision Arrangement

1 General

1.1 Definitions

1.1.1 Ship dimensions

The ship dimensions are defined in Ch 1, Sec 2, [6].

1.1.2 Watertight decks and bulkheads

The definitions of the watertight decks and bulkheads are given in Ch 1, Sec 2.

1.1.3 V-lines

V-lines are oblique lines as defined in Ch 3, App 4 corresponding to possible water level limits in a ship transversal section after damage.

2 Number and arrangement of transverse watertight bulkheads

2.1 Number of main watertight bulkheads

2.1.1 General

All ships, in addition to complying with the requirements of [2.1.2], are to have at least the following main transverse watertight bulkheads:

- one collision bulkhead
- one aft bulkhead
- two bulkheads forming the boundaries of the machinery space in ships with machinery amidships, and a bulkhead forward of the machinery space in ships with machinery aft. In the case of ships with an electrical propulsion plant, both the generator room and the engine room are to be enclosed by watertight bulkheads.

2.1.2 Additional bulkheads

As a guidance, the minimum number of main transverse watertight bulkheads versus ship lengths can be estimated from Tab 1.

Irrespective of Tab 1, the number and spacing of main transverse watertight bulkheads are to be such as to comply with stability criteria (see Ch 3, Sec 3).

Table 1 : Minimum number of bulkheads

Length, in m	Total number of bulkheads	
	Machinery amidships	Machinery aft **(1)**
$L < 65$	4	3
$65 \le L < 85$	4	4
$85 \le L < 90$	5	5
$90 \le L < 105$	5	5
$105 \le L < 115$	6	5
$115 \le L < 125$	6	6
$125 \le L < 145$	7	6
$145 \le L < 165$	8	7
$165 \le L < 190$	9	8
$L \ge 190$	to be considered individually	
(1) With aft bulkhead forming after boundary of machinery space.		

2.2 Number of auxiliary watertight bulkheads

2.2.1 Criteria

The number of auxiliary watertight bulkheads is defined with respect to the operational constraints and to fulfill the damage stability criteria (see Ch 3, Sec 3).

2.3 Bulkhead arrangement

2.3.1 Bulkhead effectiveness

To be effective, the distance between two adjacent main watertight bulkheads cannot be lower than 3,0 m plus 3% of the length L_{bp} of the ship or 10,5 m, whichever is the lesser.

2.3.2 Stepped bulkheads

Where it is not practicable to arrange watertight bulkhead in one plane, a stepped bulkhead may be fitted provided that [2.3.1] is fulfilled. In this case, the part of the deck which forms the step is to be watertight and equivalent in strength to the bulkhead.

3 Collision bulkhead

3.1 Arrangement of collision bulkhead

3.1.1 A fore peak or collision bulkhead is to be fitted which is to be watertight up to the watertight deck. This bulkhead is to be located at a distance, in m, from the forward perpendicular of not less than 5% of the length L of the ship and not more than 3,0 m plus 5% of the length L of the ship.

3.1.2 Where any part of the ship below the waterline extends forward of the fore perpendicular, e.g. a bulbous bow, the distances, in metres, stipulated in [3.1.1] are to be measured from a point either:

- at mid length of such an extension, or
- at a distance 1,5% of the length L of the ship forward of the fore perpendicular, or
- at a distance 3,0 m forward of the fore perpendicular; whichever gives the smallest measurement.

3.1.3 The bulkhead may have steps or recesses provided they are within the limits prescribed in [3.1.1] or [3.1.2].

No door, manhole, ventilation duct or any other opening is to be fitted in this bulkhead.

3.1.4 The Society may, on a case by case basis, accept a distance from the collision bulkhead to the fore perpendicular greater than the maximum specified in [3.1.1] and [3.1.2], provided that subdivision and stability calculations show that, when the ship is in upright condition on full load, flooding of the space forward of the collision bulkhead will not result in any part of the bulkhead deck becoming submerged, or in any unacceptable loss of stability.

4 After peak, machinery space bulkheads and stern tubes

4.1 General

4.1.1 An after peak bulkhead, and bulkheads dividing the machinery space from the cargo and personnel spaces forward and aft, are also to be fitted and made watertight up to the watertight deck. The after peak bulkhead may be stepped, provided the degree of safety of the ship as regards subdivision is not thereby diminished.

5 Openings and crossings in watertight bulkheads and decks

5.1 Definitions

5.1.1 Openings mean a passage of large size, through which the passage and the movement of personnel or material through bulkheads, decks and hull are possible as well as the crossings of air ducts, of engine discharges and intakes.

Crossings are intended to be passages of small size for cables or pipes.

Note 1: The passages for shafting are considered as crossings.

5.2 Regulations

5.2.1 Openings and crossings in various elements are allowed according to Tab 2, provided they are watertight or weathertight as necessary to comply with intact and damage stability criteria. Additional requirements are also provided in Part C.

Openings and crossings in transverse watertight bulkheads inside the V-line (as defined in Ch 3, App 4) may be not watertight apart from particular prescriptions. The number of openings in a watertight deck (W.D.) are to be the minimum compatible with the internal arrangements and general plans. Such openings are to be supplied with devices which make them watertight.

Vertical crossings of pipes, air ducts or electrical cables in the watertight deck (W.D.) are to be supplied with a structural watertight device.

Table 2 : Allowed openings and crossings in several water(weather)tight elements

Interested element	Hatches and bolted closures	Doors, panels, hatches	Portlights	Trunks and ventilation inlets	Engine inlets and discharges**(1)**	Cable crossings	Pipe crossings
Decks							
Bulkhead deck **(4)**	yes	yes	no	yes	yes	yes	yes
Watertight deck **(4)**	yes	yes	no	yes	yes **(2)**	yes	yes
Exposed decks	yes	yes	yes	yes	yes	yes	yes
Bulkhead							
M.T.W.B.	no **(6)**	no **(5)**	no	no	no	yes	yes
A.T.W.B. (between W.D. & M.D.)	yes	yes	no	yes	no	yes	yes
Shell							
Below W.D.	no	no **(7)**	no	no	no	no **(3)**	yes
Between B.D. & W.D.	yes	yes	yes	yes	no	yes	yes
Between B.D. & E.D.	yes	yes	yes	yes	yes	yes	yes
Other elements							
Tanks	yes	no	no	no	no	yes	yes
Double bottoms	yes	no	no	no	no	yes	yes
Watertight elements below W.D.	yes	yes	no	yes	no	yes	yes
Cofferdams	yes	no	no	no	no	yes	yes

(1) Submerged discharges are considered as pipe crossings.
(2) Provided that the watertightness of ducts between W.D. and B.D. is assured.
(3) Except for particular applications (sonar, hull sensors, ecosounders...).
(4) In case all the main transversal watertight bulkheads are extended above the watertight deck (W.D.) up to the bulkhead deck (B.D.) by an auxiliary watertight bulkhead, the tightness integrity of the first deck is to be applied to the second.
(5) With the exception of the watertight door in the bulkhead bounding the steering gear local, which is to be approved in the contract.
(6) Subject to [5.2.2].
(7) With the exception of a limited number of doors which can be accepted; such doors have to be enclosed with watertight boundaries (bulkhead and access doors) inside the ship, so that this watertight envelop provides sufficient tightness to avoid any progressive flooding.

5.2.2 Bolted openings in more watertight bulkheads below the watertight deck may be accepted if mentioned in the technical specifications and on a case by case basis, provided that they are:

- necessary for maintenance purposes
- permanently closed at sea
- designed and constructed, to the satisfaction of the Society, so as to maintain the fire, smoke and watertight integrity of the bulkhead as well as their structural strength to shock.

6 Doors

6.1 General

6.1.1 Doors are not allowed in main transverse watertight bulkheads below the watertight deck (see Tab 2).

6.1.2 Doors located in auxiliary transverse watertight bulkheads between the watertight deck and the bulkhead deck are to be watertight and fitted with a notice to show if the door is normally open, normally closed or permanently closed.

6.1.3 Doors which may be immersed by the "V-lines" damage waterline as described in Ch 3, App 4 are to be normally closed at sea, i.e. kept closed, used if authorized by the notice affixed on the door, and closed again after use.

6.1.4 Watertight doors located between the watertight deck and the bulkhead deck are to be strengthened such as to resist to the static head equivalent to a water height equal to the distance between the watertight deck and the bulkhead deck.

When detailed information on the head of water after damage is available and justified, such information can be considered for the strengthening of the doors.

Section 2 Compartment Arrangement

1 Flooding management

1.1 Protection

1.1.1 The requirements for openings in watertight bulkheads and decks are given in Ch 2, Sec 1, [5] and Ch 2, Sec 3, [1.1.2].

1.1.2 All cables and piping penetrations located within the watertight boundaries of flooded compartments and below the V-line damage waterline have to be watertight when closed to the maximum waterhead.

1.2 Detection

1.2.1 For detection system applicable for **AUT-QAS** notation, see Pt E, Ch 4, Sec 1.

1.3 Pumping

1.3.1 Floodable dry spaces have to be provided with a fixed water pumping installation or access for movable pumps from above the damage control deck as defined in Ch 1, Sec 2, [6.5].

1.3.2 The pumping capacity is to be at least as required in Pt C, Ch 1, Sec 10, [6.6.3].

2 Cofferdams

2.1 Definition

2.1.1 A cofferdam means an empty space arranged so that compartments on each side have no common boundary; a cofferdam may be located vertically or horizontally. As a rule, a cofferdam is to be of sufficient size to allow inspection.

2.2 Cofferdam arrangement

2.2.1 Cofferdams are to be provided between the compartments intended for liquid hydrocarbons (fuel oil, lubricating oil) and those intended for fresh water (drinking water, water for propelling machinery and boilers) as well as between ammunition stores and tanks intended for the carriage of liquid hydrocarbons.

2.2.2 Cofferdams are only required between fuel oil double bottoms and tanks immediately above where the inner bottom plating is subjected to the head of fuel oil contained therein, as in the case of a double bottom with its top raised at the sides.

Where a corner to corner situation occurs, tanks are not considered to be adjacent.

Adjacent tanks not separated by cofferdams are to have adequate dimensions to ensure easy inspection.

2.2.3 A cofferdam is to be provided to separate tanks containing JP5 NATO(F44) carried as cargo or for the purpose of replenishment of aircraft from any of the following spaces:

- tanks containing other liquid hydrocarbons. The cofferdam between JP5 NATO(F44) tanks and tanks containing other liquid hydrocarbons may however be omitted provided that at least one JP5 NATO(F44) tank on board doesn't have any common boundary with tanks containing other liquid hydrocarbons
- tanks for drinking water and stores containing provisions intended for human consumption
- category A machinery spaces
- ammunition stores
- accommodation spaces. The cofferdam between JP5 tanks and accommodation spaces may however be omitted where the adjacent bulkhead or deck is not provided with any access opening and is coated with a layer of material ensuring gastightness.

Cofferdams of this type may be used as spaces for the installation of JP5-NATO (F44) pumps.

Note 1: Machinery spaces of category A are defined in Pt C, Ch 4, Sec 1, [2.22].

3 Ballast compartments

3.1 General

3.1.1 Water ballast may not be carried in tanks intended for fuel oil.

4 Double bottoms

4.1 Auxiliary ships

4.1.1 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

4.2 Frontline ships

4.2.1 A double bottom is to be required as far as practicable within the machinery spaces.

5 Compartments forward of the collision bulkhead

5.1 General

5.1.1 The fore peak and other compartments located forward of the collision bulkhead may not be arranged for the carriage of fuel oil.

6 Machinery compartments

6.1 General

6.1.1 When longitudinal bulkheads are fitted in machinery spaces, adequate self-operating arrangements are to be provided in order to avoid excessive heel after damage.

Where such arrangements constitute a cross-flooding system, their area is to be calculated in accordance with the requirements in Ch 3, App 3. In addition, such systems are to comply with the criteria in Ch 3, Sec 3.

6.2 Two machinery compartments

6.2.1 When the ship is fitted with two machinery compartments, the requirements in Ch 2, Sec 1, [4.1.1] are to be applied.

7 Shaft tunnels

7.1 General

7.1.1 Shaft tunnels are to be watertight to possible internal flooding.

8 Watertight ventilators and trunks

8.1 General

8.1.1 Watertight ventilators and trunks are to be carried at least up to the V-line damage waterline as described in Ch 3, App 4.

9 Fuel oil tanks

9.1 General

9.1.1 The arrangements for the storage, distribution and utilization of the fuel oil are to be such as to ensure the safety of the ship and persons on board.

9.1.2 The requirements of Pt C, Ch 1, Sec 10, [11.5.1] have also to be taken into account.

10 Ammunition storage compartments

10.1 General

10.1.1 Particular care is to be taken for the arrangement of ammunition storage compartments to prevent risk of explosion or ship loss in case of explosion.

11 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system

11.1 Tank protection and segregation

11.1.1 Tanks containing chemical treatment fluids for exhaust gas pollution prevention system are to comply with requirements of Pt C, Ch 1, Sec 11, [3.2] for tank containing urea.

Section 3 Access and Openings Arrangement

1 General

1.1 Number and size of access and openings

1.1.1 The number and size of manholes for trimming and access openings to tanks or other enclosed spaces are to be kept to the minimum consistent with the satisfactory operation of the ship.

1.1.2 Opening tightness

All openings located within the watertight boundaries used for the damage stability calculations, giving access to a flooded compartment and outside the V line (as defined in Ch 3, App 4), are to be watertight when closed to the maximum waterhead.

2 Double bottom

2.1 Inner bottom manholes

2.1.1 Inner bottom manholes are to be not less than 400 mm x 400 mm or 500 mm x 380 mm clear light. Their number and location are to be so arranged as to provide convenient access to any part of the double bottom.

2.1.2 Inner bottom manholes are to be closed by watertight plate covers.

Doubling plates are to be fitted on the covers, where secured by bolts.

Where no ceiling is fitted, covers are to be adequately protected from damage by the cargo.

2.2 Floor and girder manholes

2.2.1 Manholes are to be provided in floors and girders so as to provide convenient access to all parts of the double bottom.

2.2.2 The size of manholes and lightening holes in floors and girders is, in general, to be less than 50 per cent of the local height of the double bottom.

Where manholes of greater sizes are needed, edge reinforcement by means of flat bar rings or other suitable stiffeners may be required.

2.2.3 Manholes may not be cut into the continuous centreline girder or floors and girders below pillars, except where allowed by the Society on a case by case basis.

3 Tanks, water ballast tanks and cofferdams

3.1 General

3.1.1 Tanks, water ballast tanks and cofferdams are to be served by at least one manhole and one ladder.

3.1.2 External openings required to be watertight are to be of sufficient strength and, except for hatch covers, are to be fitted with indicator in the safety control room.

3.2 Access through decks

3.2.1 Opening protection

If an access is to remain open for operational efficiency, it is to be fitted with a light panel, or equivalent device, to prevent falls of a person when the hatchway remains open.

3.3 Access within tanks

3.3.1 Manholes

Where manholes are fitted, as indicated in [2.2.2], access is to be facilitated, as far as practicable, by means of steps and hand grips with platform landings on each side.

3.4 Construction of ladders

3.4.1 General

In general, the ladders are to be vertical. The flights of ladders are not to be more than 9 m in actual length. Resting platforms of adequate dimensions are to be provided.

3.4.2 Construction

Ladders and handrails are to be constructed of steel of adequate strength and stiffness and securely attached to the tank structure by stays. The method of support and length of stay are to be such that vibration is reduced to a practical minimum.

External ladders and handrails in composites are acceptable, except if they are used to access the life saving appliances.

Side stringers are to be flat bars of not less than 60 mm by 6 mm in section, or equivalent.

3.4.3 Width of ladders

The width of ladders between stringers is not to be less than 400 mm.

3.4.4 Treads

The treads are to be equally spaced at a distance apart measured vertically not exceeding 300 mm. They are to be formed of two square steel bars of not less than 16 mm by 16 mm in section fitted to form an horizontal step with the edges pointing upward, or of equivalent construction. The treads are to be welded to the side stringers.

3.4.5 Sloping ladders

All sloping ladders are to be provided with handrails of substantial construction on both sides fitted at a convenient distance above the treads.

4 Air pipes

4.1 General

4.1.1 Internal open end of air pipes

The open end of air pipes terminating within a superstructure is to be fitted inside the V line (as defined in Ch 3, App 4) or above the V-line damage waterline when located outside the V line.

CHAPTER 3
STABILITY

Section 1	General
Section 2	Intact Stability
Section 3	Damage Stability
Section 4	Sea-Keeping
Appendix 1	Inclining Test and Lightweight Check
Appendix 2	Trim and Stability Booklet
Appendix 3	Calculation Method for Cross-Flooding Arrangements
Appendix 4	Buoyancy Reserve - “V” Line Method
Appendix 5	Evaluation of the Heeling Moment due to Athwart Wind (Intact Vessel)
Appendix 6	Sea-Keeping Calculations

Section 1 General

1 Definitions

1.1

1.1.1 General

Except otherwise specified, the definition of the parameters and ship components mentioned in this Chapter are given in Ch 1, Sec 2.

2 General

2.1 Application

2.1.1 All ships may be assigned class only after it has been demonstrated that their intact and damage stability is adequate for the service intended.

Except otherwise specified, adequate intact and damage stability means compliance with the requirements specified in this Chapter taking into account the ship's size and type. In any case, the level of intact and damage stability is not to be less than that provided by the rules of Ch 3, Sec 2 and Ch 3, Sec 3.

Additional requirements maybe indicated in the relevant chapters of Part E corresponding to the intended service notation.

2.1.2 Approval of the Naval Authority

Evidence of approval by the Naval Authority concerned may be accepted for the purpose of classification.

3 Examination procedure

3.1 Documents to be submitted

3.1.1 List of documents

For the purpose of the examination of the stability, the documentation listed in Ch 1, Sec 3, [1.1.2] is to be submitted for information.

The stability documentation to be submitted for approval, as indicated in Ch 1, Sec 3, is as follows:

- Inclining lightship test report for the ship, as required in [3.2] or:
  - where the stability data is based on a sister ship, the inclining test report of that sister ship along with the lightship measurement report for the ship in question, or
  - where lightship particulars are determined by methods other than inclining of the ship or its sister, the lightship measurement report of the ship along with a summary of the method used to determine those particulars
- trim and stability booklet, as required in Ch 3, App 2
- damage stability calculations, as required in Ch 3, Sec 3, [1.1.1]
- damage control documentation, as required in Ch 3, Sec 3, [1.2].

A copy of the trim and stability booklet, the damage control documentation and the loading computer documentation is to be available on board for the attention of the Captain.

3.1.2 Provisional documentation

The Society reserves the right to accept or demand the submission of provisional stability documentation for examination.

Provisional stability documentation includes loading conditions based on estimated lightship values.

3.1.3 Final documentation

Final stability documentation based on the results of the inclining test or the lightweight check is to be submitted for examination.

3.2 Inclining test - Lightweight check

3.2.1 Definitions

a) Lightweight

   The lightship weight definition is given in Ch 1, Sec 2, [5.1].

b) Inclining test

The inclining test is a procedure which involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the ship. By using this information and applying basic naval architecture principles, the ship's vertical centre of gravity (VCG or KG) is determined.

c) Lightweight check

The lightweight check is a procedure which involves auditing all items which are to be added, deducted or relocated on the ship at the time of the inclining test so that the observed condition of the ship can be adjusted to the lightship condition. The weight and longitudinal, transverse and vertical location of each item are to be accurately determined and recorded. The lightship displacement and the longitudinal centre of gravity (LCG) can be obtained using this information, as well as the static waterline of the ship at the time of the inclining test as determined by measuring the distance between the waterline and a reference deck verified draught marks of the ship, the ship hydrostatic data relevant to the actual trim and the sea water density.

3.2.2 General

Any ship for which a stability investigation is requested in order to comply with class requirements is to be initially subjected to an inclining test permitting the evaluation of the position of the lightship centre of gravity, or a light-weight check of the lightship displacement, so that the stability data can be determined.

3.2.3 Inclining test

The inclining test is required in the following cases:

- any new ship, after its completion
- any ship, if deemed necessary by the Society, where any alterations are made so as to materially affect the stability.

3.2.4 Detailed procedure

A detailed procedure for conducting an inclining test and the lightweight is included in Ch 3, App 1.

Section 2 Intact Stability

1 General

1.1 Information for the Captain

1.1.1 Stability booklet

Each ship is to be provided with a stability booklet approved by the Society, which contains sufficient information to enable the Captain to operate the ship in compliance with the applicable requirements contained in this Section.

Where any alterations are made to the ship so as to materially affect the stability information supplied to the Captain, amended stability information is to be provided. If necessary the ship is to be re-inclined.

Stability data and associated plans are to be drawn up in the official language or languages of the issuing country. If the languages used are neither English nor French, the text is to include a translation into one of these languages.

The format of the trim and stability booklet and the information included are specified in Ch 3, App 2.

1.1.2 Periodical lightweight and stability check

At a time not exceeding ten years of the delivery, a lightweight survey is to be carried out to verify any changes in lightship displacement and longitudinal centre of gravity.

A new survey will have to be performed at midterm of the design ship life time.

In both case, the full process as defined in Ch 3, App 1 is to be applied.

1.1.3 Loading instrument

As a supplement to the approved stability booklet, a loading instrument approved by the Society is to be provided to facilitate the stability calculations mentioned in Ch 3, App 2.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4].

1.2 Permanent ballast

1.2.1 If used, permanent ballast is to be located in accordance with a plan approved by the Society and in a manner that prevents shifting of position. Permanent ballast is not to be removed from the ship or relocated within the ship without the approval of the Society. Permanent ballast particulars are to be noted in the ship's stability booklet.

1.2.2 No liquid permanent ballast is allowed.

Permanent solid ballast is to be installed under the supervision of the Society.

2 Design criteria

2.1 General intact stability criteria

2.1.1 General

The intact stability criteria specified in [2.3] to [2.8] are to be complied with for the loading conditions mentioned for project verification in Ch 1, Sec 2, [5.2], Ch 1, Sec 2, [5.4].

2.1.2 Elements affecting stability

A number of influences such as beam-wind on ships with large windage area, icing of topsides, water trapped on deck, rolling characteristics, etc., which adversely affect stability are to be taken into account.

2.1.3 Elements reducing stability

Provisions are to be made for a safe margin of stability at all stages of the voyage, regard being given to additions of weight, such as those due to absorption of water and icing and to loss as of weight such as those due to consumption of fuel and stores.

All deck areas where water can be trapped will have to be considered with the maximum possible water level.

Effect of ship turning, crowding of special personnel, wind and rolling, liquid free surfaces, icing, cargo lifting are covered by [2.3] to [2.8].

The intact stability characteristics of the ship are to be investigated through the following analysis:

a) righting arms (GZ curve) of the ship in the different loading conditions

b) behaviour of the ship under heeling actions such as:

   1) severe wind and rolling

   2) ice accretion

   3) high speed turning

   4) heavy cargo lifting

   5) crowding of special personnel on one side of the ship

   6) Simultaneous effect of wind and special personnel crowding.

The requirement of the reactions of the ship to the above heeling actions and the criteria which the ship is to comply with are dependent on her type.

2.1.4 Ship mass evolution

Except otherwise specified, the stability is to be assessed taking into account an evolution of mass per year on the ship life time due to modernization, maintenance, etc., as defined in Tab 1.

Table 1 : Ship mass evolution

Type of ship	Displacement in % of light ship mass	Centre of gravity
All ships	+ 0,3% / year	+ 0,2% / year

2.1.5 Definition of angles of righting arms curves

θ_d : Ultimate angle of dynamic stability

It is the angle over which the reserve of dynamic stability is not sufficient any more (the dynamic capsizing happens) to face a constant inclining moment (invariable with the heeling), suddenly applied to the ship. Its value corresponds to that of the angle at which the value of the area A is the same as the value of the area B (Fig 1)

θ_0 : Limit of static stability

It is the angle corresponding to the maximum heeling moment (this moment is applied to the ship increasingly to the purpose of avoiding all the dynamic effects) which the ship may face before the capsizing

θ_s : Capsizing angle (over this angle the capsizing of the ship happens even if the inclining moment disappears)

θ_f : Flooding angle (i.e. the lowest angle at which the first opening not closed is reached)

This is the angle corresponding to the minimum angle of heel to which at least one unprotected point (see [2.1.6]) is immersed

θ_r : Rolling angle

θ_c : Static equilibrium angle caused by an external action

θ_e : Equilibrium angle after damage (without external actions).

2.1.6 Location of the flooding angle

The points of flooding are only the unprotected points which may endanger the stability or the efficiency of the ship (openings leading to large volumes and of size such that the emptying means present on board are not sufficient to face the input of sea water through them), i.e. ventilators in the engine room (see Fig 2, Fig 3 and Fig 4).

In the case of a trunk supplied with a closure device or an on-off valve, two cases may rise:

a) either the devise or the valve are proper for the hydrostatic head correspondent to a heeling angle of 70°; in such a case, the trunk is not considered as a point of flooding unprotected, or

b) the device or the valve are proper for a hydrostatic head h lesser than that of item a). In such a case, the point of flooding is to be positioned raised of the value h.

Figure 1 : Righting arms curve and angles

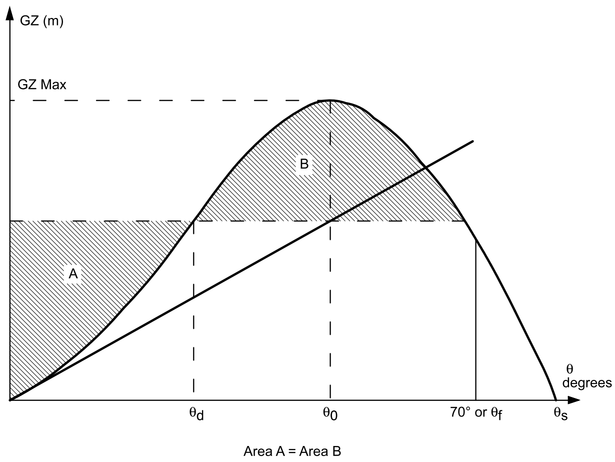


Figure 2 : Flooding angle - Example 1

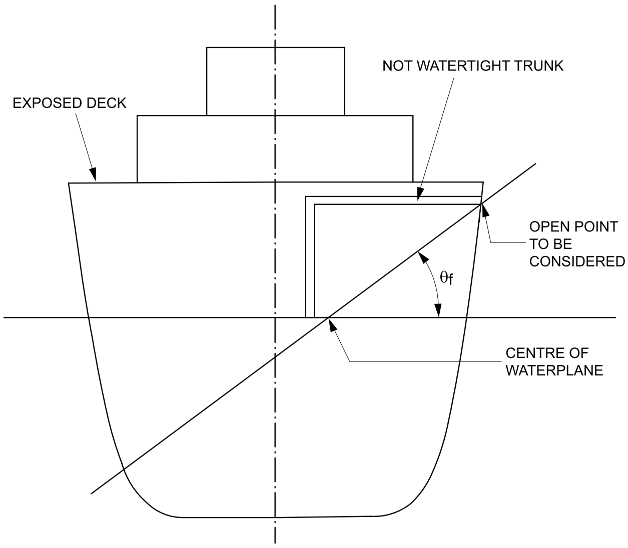


Figure 3 : Flooding angle - Example 2

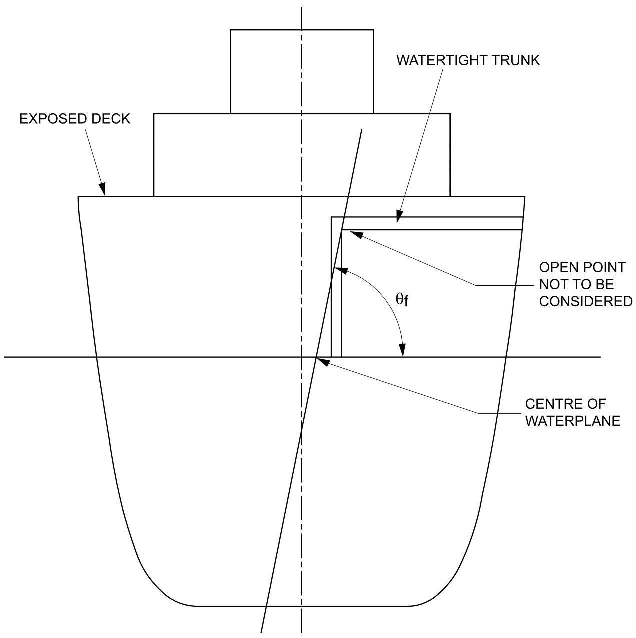
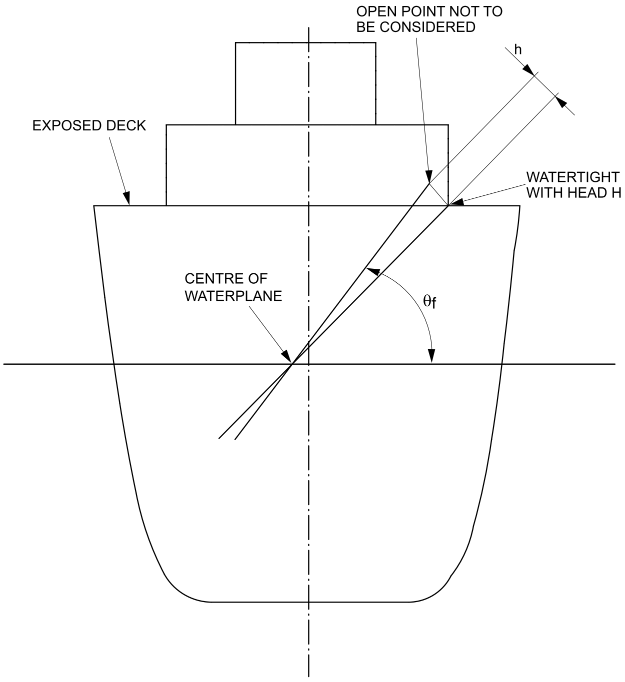


Figure 4 : Flooding angle - Example 3



2.1.7 Righting arms curve

In creating the righting arms curve, the following rules are to be taken into account: the calculation of the righting arms for the considered heeling angles is to be carried out taking in account the change of trim and the free surface effects.

The arms curve is to be stopped when the smallest of the following values is reached:

a) 70°

b) θ_f (angle at which openings not supplied with at least weathertight devices remain submerged), or

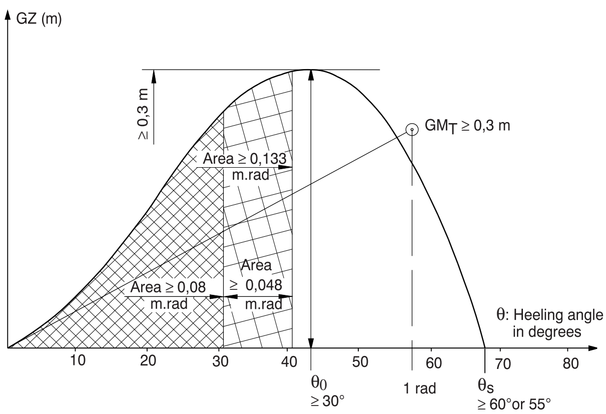
c) θ_s (capsizing angle).

2.1.8 Requirements for the righting arms curve

The righting arm curve is to be in compliance with the requirements listed in Tab 2 and represented in Fig 5.

The maximum value of the righting arm curve (GZ Max) is to be identified as per Fig 6 and is to be taken, in any case, between 30° and 50°.

Figure 5 : Righting arms curve criteria



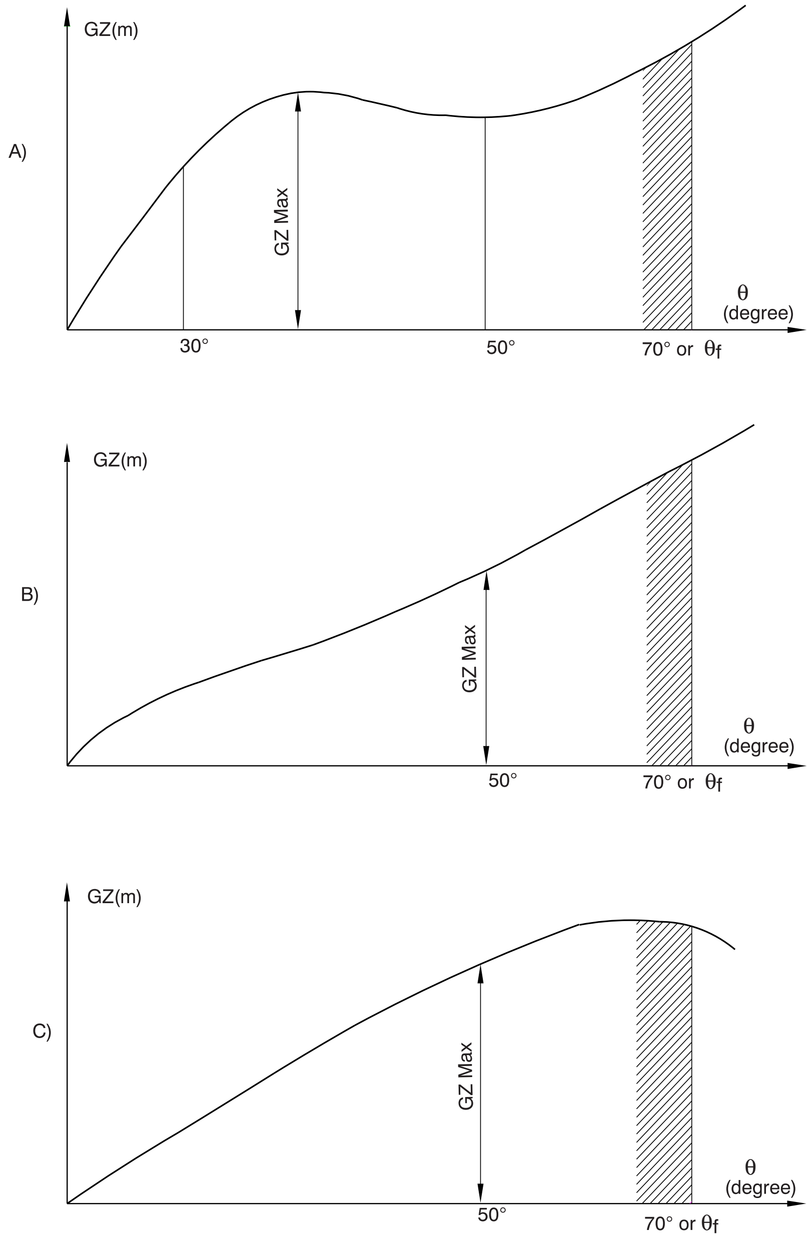
θ_0 : Extreme angle of static stability

θ_s : Capsizing angle.

Table 2 : Minimum values required for the righting arms curve in intact condition

Area under the righting arm curve (GZ) up to 30° or θ_f	Not less than 0,080 m rad (15 feet degree)
Area under the righting lever (GZ) up to 40° or θ_f	Not less than 0,133 m rad (25 feet degree)
Area under the righting arm curve (GZ) between 30° and 40°	Not less than 0,048 m rad (9 feet degree)
Value of the maximum righting arm curve between 30° and 50° (GZ Max)	Not less than 0,3 m (1 foot)
Heeling angle corresponding to the maximum righting arm curve (GZ Max)	Not less than 30°
Value of the initial metacentric height corrected for free surface effect (GM_{corr})	Not less than 0,3 m (1 foot)
Value of the capsizing angle (θ_s)	• Higher than 60° for ships with lightship displacement less than or equal to 5000 t • Higher than 55° for ships with lightship displacement greater than 5000 t

Figure 6 : GZ Max to be considered



If $\theta_f < 50°$, the value of GZ Max is to be considered between 30° and θ_f.

The criteria reported in Tab 2 define the minimum requirements, not the maximum.

Anyway, it is recommended not to exceed the value of GM in order to avoid high dangerous accelerations.

2.2 Effect of free surfaces of liquids in tanks

2.2.1 Tanks for liquids

For all loading conditions, the initial metacentric height and the righting lever curve are to be corrected for the effect of free surfaces of liquids in tanks.

2.2.2 Decks

Decks are provided with efficient drainage arrangement to prevent accumulation of entrapped water due to weather conditions, cleaning or fire fighting. In particular, the effect of accumulation of water is to be investigated for one single large space.

If the drainage arrangement is not considered efficient by the Society, free surface effects may be required, case by case, for the stability calculations.

2.2.3 Consideration of free surface effects

Free surface effects are to be considered whenever the filling level in a tank is less than 98% of full condition.

Free surface effects need not be considered where a tank is normally full, i.e. filling level is 98% or above.

Free surface effects for small tanks may be ignored under the condition in [2.2.9].

2.2.4 Categories of tanks

Tanks which are taken into consideration when determining the free surface correction may be one of two categories:

- tanks with fixed filling level (e.g. water ballast):

  The free surface correction is to be defined for the actual filling level to be used in each tank.
- tanks with variable filling level (e.g. consumable liquids such as fuel oil, diesel oil, and fresh water):

  Except as permitted in [2.2.6] and [2.2.7], the free surface correction is to be the maximum value attainable among the filling limits envisaged for each tank, consistent with any operating instructions.

2.2.5 Consumable liquids

In calculating the free surface effect in tanks containing consumable liquids, it is to be assumed that, for each type of liquid, at least one transverse pair or a single centreline tank has a free surface and the tank or combination of tanks taken into account is to be the one where the effect of free surface is the greatest. In particular, for the departure conditions where tanks are 100% filled, one maximum free surface for each type of liquid is to be considered. Otherwise, the free surface corresponding to the actual filling is to be considered for each capacity.

2.2.6 Water ballast tanks

Where water ballast tanks, including anti-rolling tanks and anti-heeling tanks, are to be filled or discharged during the course of a voyage, the free surface effect is to be calculated to take account of the most onerous transitory stage relating to such operations.

2.2.7 GM_0 and GZ curve corrections

The corrections to the initial metacentric height and to the righting lever curve are to be addressed separately as indicated in a) and b) below:

a) In determining the correction to the initial metacentric height, the transverse moments of inertia of the tanks are to be calculated at 0° angle of heel according to the categories indicated in [2.2.4].

b) The righting lever curve may be corrected by any of the following methods:
   - correction based on the actual moment of fluid transfer for each angle of heel calculated according to the categories indicated in [2.2.4]
   - correction based on the moment of inertia, calculated at 0° angle of heel, modified at each angle of heel calculated; corrections may be calculated according to the categories indicated in [2.2.4]
   - correction based on the summation of M_{fs} values for all tanks taken into consideration, as specified in [2.2.9].

Whichever method is selected for correcting the righting lever curve, only that method is to be presented in the ship's trim and stability booklet. However, where an alternative method is described for use in manually calculated loading conditions, an explanation of the differences which may be found in the results, as well as an example correction for each alternative, are to be included.

2.2.8 Remainder of liquid

The usual remainder of liquids in the empty tanks need not be taken into account in calculating the corrections, providing the total of such residual liquids does not constitute a significant free surface effect.

2.2.9 Small tanks

Small tanks which satisfy the following conditions using the values of k corresponding to an angle of inclination of 30° need not be included in the correction:

$$\frac{M_{fs}}{\Delta_{min}} < 0,01\,m$$

where:

Δ_{min} : Minimum operational condition ship displacement, in t (see Ch 1, Sec 2, [5.4.1]).

2.3 Severe wind and rolling

2.3.1 Purpose

A ship is to be able to withstand weather and marine adverse conditions without risking its own safety.

The wind and rolling verification ensure a good level of safety for such condition.

The speed of the wind is ruled in Tab 3.

2.3.2 Stability requirements

The wind and rolling verification shall be carried out, comparing the righting arms curve and the heeling arms curve.

The characteristics of speed and distribution of wind are specified in [2.3.3].

2.3.3 Wind speed

The wind action is to be considered cross directed, its speeds are those reported in Tab 3.

Such speeds are different according to the navigation the ship is to follow and its age (less or more than 10 years).

The heeling action of the wind is to be calculated according to Ch 3, App 5.

2.3.4 Dynamic effects

For the purpose of taking account of the heeling caused by wind combined with rolling, the value of the heeling arm GZ1 in the proximity of the angle of static equilibrium (θ_c) is to be less than 60% of the maximum value of the righting arm (GZ Max).

2.3.5 Rolling and reserve of stability

The value of the rolling angle used for the check is to be 25°.

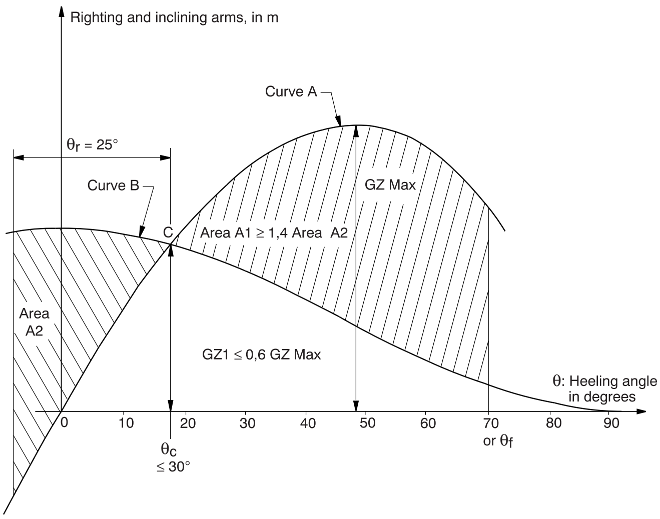
The ship is considered in condition of static equilibrium (point C in Fig 7); from that point a rolling angle of 25° is taken into account.

The following areas are considered:

- "A2", heeling area
- "A1", righting area.

To ensure a sufficient level of safety, area "A1" is to be at least 40% greater than area "A2".

Figure 7 : Severe wind and rolling criteria



Curve A: Righting arms curve (GZ)

Curve B: Wind inclining arms curve.

2.3.6 Maximum value of the angle of static equilibrium

The maximum allowable value of the static equilibrium (θ_c) is 30°.

That to be sure that the ship operates safely.

2.3.7 Stability requirements for wind and rolling

The stability requirements for wind and rolling actions are as follows:

a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 1,4 A2

c) $\theta_c \leq 30°$.

Table 3 : Theoretical speed of the wind

Service of the ship	Speed for ships with age of service less than 10 years	Speed for ships with age of service not less than 10 years
UNRESTRICTED SERVICE		
a) Ships expected to withstand the full force of tropical cyclones	100 knots	90 knots
b) Ships expected to avoid centres of tropical cyclones	80 knots	70 knots
COASTAL SERVICE		
a) Ships expected to withstand the full force of tropical cyclones	100 knots	90 knots
b) Ships expected to avoid centres of tropical cyclones	80 knots	70 knots
c) Ships which have to return into harbour with wind force 8	60 knots	50 knots
SERVICE IN HARBOUR	60 knots	50 knots

2.4 Icing

2.4.1 General

For ships which may operate in areas North of latitude 65° and South of latitude 60° and anyway in seas where icing, in winter periods, is expected, the heeling actions due to ice accretion on superstructures and decks are to be taking into account.

In such areas, an icing mass is expected in the more exposed zones of the ship to the adverse conditions (fore part), with the triple effect of:

- the increasing of displacement
- the trim changing
- the centre of gravity elevation.

2.4.2 Calculation assumption

For the purpose of evaluating the stability of a ship in the condition of ice accretion, the following assumptions are to be considered:

a) the curve of righting arms relevant to the loading conditions is to take into account the effects of the ice accretion mass (see [2.4.3]) and the free surfaces

b) the check of the stability of the ship under the combined action of wind and rolling is to be performed similarly to [2.3], but taking into account values of wind speeds 30% less than those in Tab 3.

For ships where devices for removing ice are available, the action of such devices is to be disregarded.

2.4.3 Guidance relating to ice accretion

For ships with lightship displacement not greater than 1000 t, the weight of ice accretion to be considered is 10% of its full load displacement.

For ships with lightship displacement greater than 1000 t, the weight distribution of the ice accretion to be considered is as follows:

- just the fore third of the length of the ship from the exposed deck and the decks above, including the sides, is to be taken into account. Masts are excluded from the calculation.

A uniform weight distribution of ice accretion, of 140 kg/m^2 for the horizontal areas and 70 kg/m^2 for the vertical or oblique areas, is to be considered.

2.4.4 Centre of gravity of ice accretion

For ships with lightship displacement not greater than 1000 t, the centre of gravity of the ice accretion is to be considered coincident with the centre of gravity of the ship in the different loading conditions.

For ships with lightship displacement greater than 1000 t, the centre of gravity of the ice accretion is to be considered in its own position.

2.4.5 Stability requirements for icing and wind

The effect of ice accretion is to be considered in accordance with the requirements of Tab 4 and Fig 9.

For the effects of wind and roll, the following criteria are to be complied with:

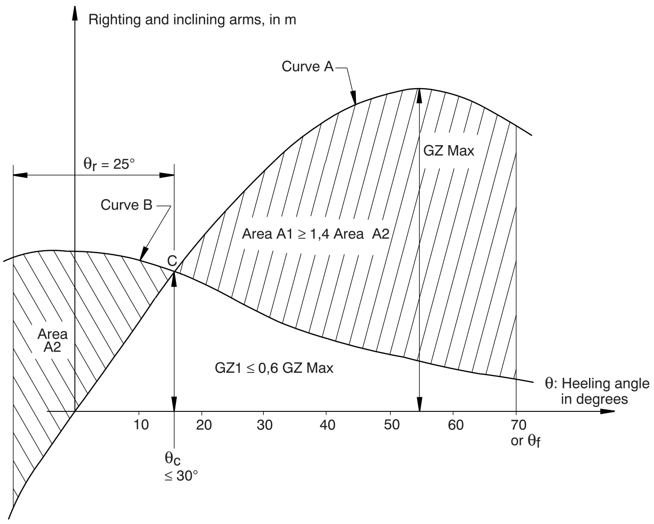
a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 1,4 A2

c) $\theta_c \leq 30°$.

See Fig 8.

Figure 8 : Icing criteria with wind



Curve A : Righting arms curve corrected for icing

Curve B : Wind inclining arms curve.

Figure 9 : Icing criteria without wind

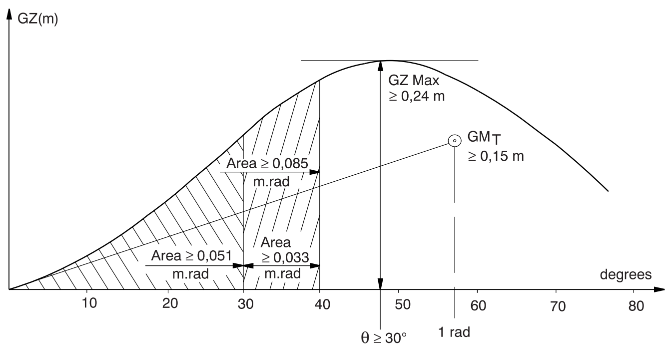


Table 4 : Requirement for righting lever curve for the loading conditions with ice accretion

Area under the righting lever curve (GZ curve) up to 30°, or θ_c, if less than 30°	Higher than 0,051 m·rad (9,60 feet-degrees)
Area under the righting lever curve (GZ curve) up to 40°, or θ_c, if less than 40°	Higher than 0,085 m·rad (16 feet-degrees)
Area under the righting lever curve (GZ curve) between the angles of heel 30° and 40°, or θ_c, if less than 40°	Higher than 0,033 m·rad (6,20 feet-degrees)
The maximum righting lever GZ	At least 0,24 m (0,8 feet)
Heeling angle corresponding to the maximum righting arm (GZ Max)	Higher than 30° (not less than 25°)
Initial metacentric height (liquid) corrected for the actions of free surfaces moments (GM_{corr})	Not less than 0,15 m (0,5 feet)

2.5 High speed turning

2.5.1 When the ship turns at high speed, an inclining moment arises which may be prominent.

The purpose of the stability checking for high speed turning is the behaviour of the ship in such an occasion.

2.5.2 High speed turning

The inclining lever (IL) due to the high speed turning is to be considered based on the following formula:

$$IL = \left(\frac{V^2}{R}\right) \cdot \left(\frac{a\cos\theta}{g}\right)$$

where:

V : Speed, in m/sec, of the ship in the turning operating. Such a value may be assumed equal to 80% of the maximum speed when the ship starts the turning

R : Turning radius, in m (if unknown, it may be assumed equal to 3,3 L_{bp})

g : Gravity acceleration

a : Vertical distance, in m, between the centre of gravity of the ship and its drifting centre (if unknown, it may be taken the half of mean draught)

θ : Heeling angle, in degrees (see Fig 10).

2.5.3 Stability requirements for high speed turning

The stability requirements for high speed turning are the following (see Fig 10):

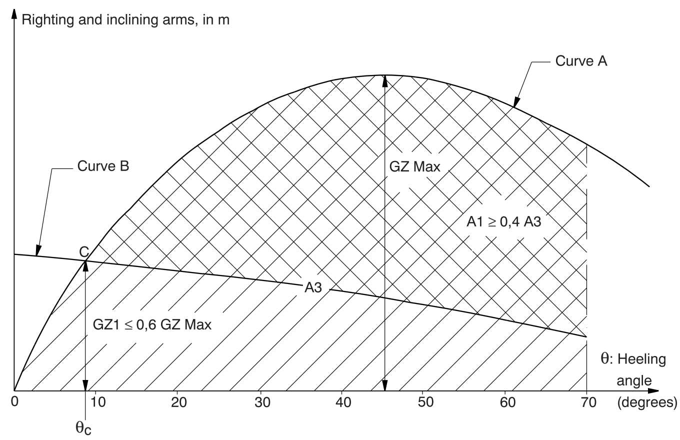
a) GZ1 ≤ 0,6 GZ Max

b) A1 ≥ 0,4 A3

c) $\theta_c \leq 15°$

Note 1: Such a value corresponds to the maximum value of the equilibrium angle corresponding to that allowable for a good working of the essential devices of the ship.

Figure 10 : High speed turning criteria



Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms (IL) curve for evolution at high speed

A1 : Area between righting curve (curve A) and inclining curve (curve B)

A3 : Total area below the righting arms curve.

2.6 Heavy cargo lifting in still water

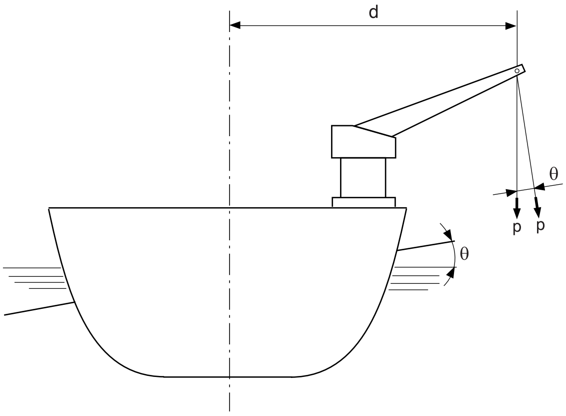
2.6.1 The lifting of weights is a decisive factor in checking the stability of a ship of small dimensions.

In fact the lifted mass, applied to the upper end of the derrick, raises the centre of gravity, reducing, consequently, the value of the initial metacentric height (see Fig 11).

The present sub-article deals with raising of weights in still water.

It is strongly suggested to avoid raising of weights in rough sea. For that, if essential, particular considerations are required.

Figure 11 : Heavy cargo lifting



2.6.2 Intact stability criteria

Two cases may arise:

a) The weight of the cargo is known:

In such a case the stability requirements in [2.6.3] are to be complied with.

b) The weight of the cargo is unknown:

In such a case, the maximum allowable weight, complying with requirement [2.6.3], is to be determined.

In both cases, the righting arms curve (GZ) built, taking into account the increasing of:

- displacement
- raising of the centre of gravity, and
- conditions set up in [2.1.7],

is to be compared with the heeling arms curve defined according to the following formula:

$$H_a = \frac{p\ d\cos\theta}{\Delta}$$

where:

H_a : Heeling arms, in m

p : Weight to be raised, in t

d : Transverse distance, in m, between the centreline of the ship and the more external end of the derrick

Δ : Displacement, in t, of the ship with the raised weight

θ : Heeling angle, in degrees.

2.6.3 Stability requirements for heavy cargo lifting

To comply the stability criteria, the ship is to meet the following requirements (see Fig 12):

a) The value of the static equilibrium angle θ_c caused by the heeling for the cargo raising is to be not more than 15° or the value of the dynamic equilibrium angle θ_d (see [2.1.5]), if lesser:

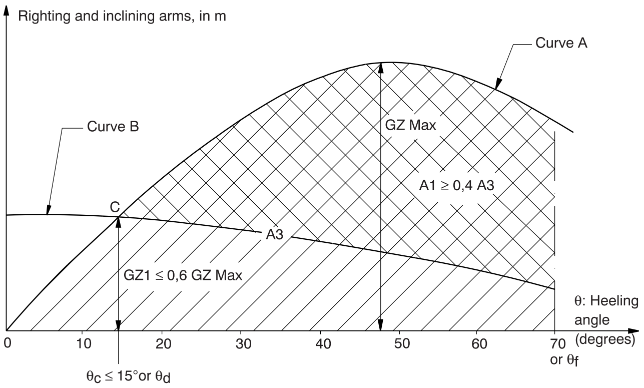
$\theta_c \leq$ Min (15° ; θ_d)

b) GZ1 ≤ 0,6 GZ Max (as in [2.3.4]).

c) The value of the area of the residual stability diagram, represented as area A1 in Fig 12, is to be not less than 40% of the total area below the stability curve, represented by area A3 in Fig 12:

A1 ≥ 0,4 A3.

Figure 12 : Heavy cargo lifting criteria



Curve A : Righting arms curve of the ship in the intact condition

Curve B : Inclining arms (H_a) curve due to cargo lifting

A1 : Area between righting curve (curve A) and inclining curve (curve B)

A3 : Total area below the righting arms curve.

2.7 Crowding of special personnel on one side

2.7.1 The crowding of special personnel (as defined in Ch 1, Sec 2, [7.3.1]) on a ship of small dimensions where a large number of personnel is embarked may be the cause of stability problems. In fact, the crowding on one side of the ship causes a heeling moment which produces a considerable reduction of the dynamic stability reserve.

2.7.2 Calculation assumption

All the special personnel is considered crowded on the upper deck where the personnel is allowed to be located and as more as possible at side, taking into account the following requirements:

a) 4 persons by square metre

b) mean weight of each person: 75 kg.

The heeling arms curve is to be calculated (see [2.7.3]) and compared with the righting lever curve defined in [2.1.7].

2.7.3 Heeling arms calculation

The heeling arms H_a (see Fig 13), in m, caused by the transversal movement of special personnel is calculated by the following formula:

$$H_a = \frac{p\ d\cos\theta}{\Delta}$$

where:

p : Weight of moved special personnel, in t

d : Transverse distance, in m, from the centreline of the ship to the centre of gravity of the area on which the special personnel is crowed

Δ : Displacement of the ship, in t

θ : Heeling angle, in degrees.

2.7.4 Stability requirements for crowding of special personnel

To fulfil the stability criteria, the ship is to comply with the following requirements (see Fig 13):

a) The value of the static equilibrium angle (θ_c) caused by the crowding of special personnel at side is to be not higher than 15° or the value of the dynamic equilibrium angle θ_d (see [2.1.5]), if lesser:

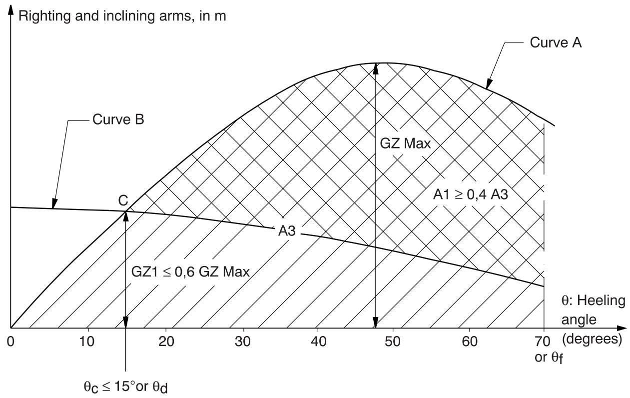
$\theta_c \leq$ Min (15° ; θ_d)

b) GZ1 ≤ 0,6 GZ Max

c) The value of the area of the residual stability diagram, consequent to the crowding of special personnel at side, represented as area A1 in Fig 13 is to be not less than 40% of the total area below the stability curve, represented by area A3 in the same Figure:

A1 ≥ 0,4 A3.

Figure 13 : Special personnel crowding criteria

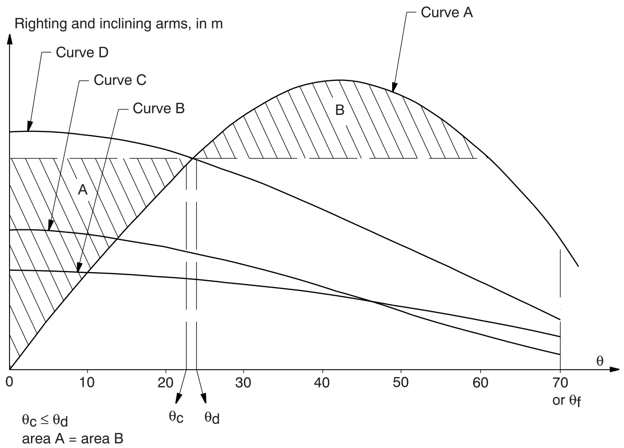


Curve A : Righting arms curve of the ship in the intact condition
Curve B : Inclining arms (H_a) curve due to special personnel crowding
A1 : Area between righting curve (curve A) and inclining curve (curve B)
A3 : Total area below the righting arms curve.

2.8 Simultaneous effect of wind and special personnel crowding

2.8.1 The heeling action reported in [2.3] and [2.7] may be arranged together considered simultaneously. Anyway, in such a case, the only requirement is that the static equilibrium angle resulting from both heeling actions be not higher than the value of the dynamic equilibrium angle θ_d as defined in [2.1.5] and Fig 14. The wind speed to be considered is the maximum speed for which special personnel is allowed to be located on the exposed decks.

Figure 14 : Special personnel crowding criteria with wind



θ_d : Extreme angle of dynamic stability
θ_c : Balancing angle
Curve A : Righting arms curve of the ship in the intact condition
Curve B : Inclining arms curve due to special personnel crowding
Curve C : Wind inclining arms curve
Curve D : Inclining arms curve due to both actions of wind and special personnel crowding.

Section 3 Damage Stability

1 General

1.1 On board supports

1.1.1 Damage stability documentation

For all ships, documents including damage stability calculations are to be submitted.

The damage stability calculations are to include:

a) the list of characteristics (volume, centre of gravity, permeability) of each compartment which can be damaged

b) a table of openings in bulkheads, decks and side shell reporting all the information about:
- identification of the opening
- vertical, transverse and horizontal location
- type of closure: sliding, hinged or rolling for doors
- type of tightness: watertight, weathertight or unprotected
- operating system: remote control, local operation, indicators on the bridge, television surveillance, water leakage detection, audible alarm, as applicable; foreseen utilisation: open at sea, normally closed at sea, kept closed at sea

c) the list of all damage cases corresponding to the applicable requirements

d) the detailed results of damage stability calculations for all the loading conditions foreseen in the applicable requirements

e) the limiting GM/KG curve, if foreseen in the applicable requirements

f) the capacity plan

g) the arrangement of cross flooding pipes, showing the location of remote controls for valves or special mechanical means for correcting the list due to flooding, if any

h) a plan showing the doors (location, tightness), if this information is not already included in the general arrangement plan.

1.1.2 Loading instrument

As a supplement to the approved damage stability documentation, a loading instrument, approved by the Society, is to be provided to facilitate the damage stability calculations mentioned in [1.1.1].

The following loading instrument documentation is to be provided:
- loading instrument approved by Society
- on board user's manual for examination.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in Ch 10, Sec 2, [4.6].

1.2 Damage control

1.2.1 Documentation to be supplied

The Captain of the ship is to be supplied with the data necessary to maintain sufficient intact stability under service conditions to enable the ship to withstand the critical damage. In the case of ships requiring cross-flooding, the Captain of the ship is to be informed of the conditions of stability on which the calculations of heel are based and be warned that excessive heeling might result should the ship sustain damage when in less favourable condition.

The data referred to above, to enable the Captain to maintain sufficient intact stability, are to include information which indicates the maximum permissible height of the ship's centre of gravity above keel (KG), or alternatively, the minimum permissible metacentric height (GM) for a range of draught or displacements sufficient to include all service conditions. The information is to show the influence of various trims taking into account the operational limits.

1.2.2 Damage control documentation

The damage control documentation is to include a damage control plan which is intended to provide ship's officers with clear information on the ship's watertight compartmenting and equipment related to maintaining the boundaries and effectiveness of the compartmentation so that, in the event of damage causing flooding, proper precautions can be taken to prevent progressive flooding through openings therein and effective action can be taken quickly to mitigate and, where possible, recover the ship's loss of stability.

The damage control documentation is to be clear and easy to understand. It is not to include information which is not directly relevant to damage control and is to be provided in the language or languages of the ship's officers.

Plans showing clearly, for each deck and hold, the boundaries of the watertight compartments, the openings therein with the means of closure and position of any controls thereof, and the arrangements for the correction of any list due to flooding are to be permanently exhibited for the guidance of the officer in charge of the ship. In addition, booklets containing the aforementioned information are to be made available to the officers of the ship.

Watertight doors that may be permitted to remain open during navigation are to be indicated in the damage control plan with the indication that “doors are always to be ready for immediate closure”, Detailed description of the information to be included in the damage control documentation is reported in [2.4].

1.2.3 Draught marks

Each ship is to be provided with scales of draughts marked clearly at the bow and stern.

In the case where the draught marks are not located where they are easily readable, or operational constraints trade make it difficult to read the draught marks, then the ship is also to be fitted with a reliable draught indicating system by which the bow and stern draught can be determined.

2 Conditions and criteria

2.1 Approaches to be followed for damage stability investigation

2.1.1 General

Damage stability calculations are required in order to achieve a minimum degree of safety after flooding.

The metacentric height (GM), stability levers (GZ) and centre of gravity positions for judging the final surviving conditions are to be calculated by the constant displacement (lost buoyancy) method.

2.1.2 Methodology

The approach is based on standard dimensions of damage extending anywhere along the ship's length or between transverse bulkheads depending on the relevant requirements.

The consequence of such standard of damage is the creation of a group of damage cases, the number of which, as well as the number of compartments involved in each case, depends on the ship's dimensions and internal subdivision.

For each loading condition, each damage case is to be considered and all the applicable criteria are to be complied with.

2.2 Progressive flooding

2.2.1 Definition

Progressive flooding is the additional flooding of spaces which were not previously assumed to be damaged. Such additional flooding may occur through openings or pipes, as indicated in [2.2.2] and [2.2.3], which are located within the V lines as described in Ch 3, App 4.

2.2.2 Openings

The openings may be listed in the following categories, depending on their means of closure:

a) Unprotected

Unprotected openings are openings which are not fitted with at least weathertight means of closure.

Unprotected openings which form part of the limit of the enclosed spaces included in the damage stability calculations and which are located below the waterline after damage (at any stage of flooding) are not allowed; see also [2.4.8] item a).

b) Weathertight

Openings fitted with weathertight means of closure are not able to sustain a constant head of water, but they can be intermittently immersed within the positive range of stability.

Weathertight openings may lead to progressive flooding if they are located below the waterline after damage (at any stage of flooding).

c) Watertight

Internal openings fitted with watertight means of closure are able to sustain a constant head of water corresponding to the distance between the lowest edge of this opening and the bulkhead deck. When detailed information on the head of water after damage is available and justified, such information can be considered for the determination of the constant head of water.

Air pipe closing devices may not be considered watertight, unless additional arrangements are fitted in order to demonstrate that such closing devices are effectively watertight.

Manhole covers may be considered watertight provided the cover is fitted with bolts located such that the distance between their axes is less than five times the bolt's diameter.

Access hatch covers leading to holds may be considered watertight.

Watertight openings do not lead to progressive flooding.

2.2.3 Pipes

Progressive flooding through pipes coming out into internal spaces of the ship may occur when:

a) the pipes and connected valves are located within the assumed damage, and no valves are fitted outside the damage

b) the pipes, even if located outside the damage, satisfy all of the following conditions:
   - the pipe connects a damaged space to one or more space(s) located outside the damage
   - the highest vertical position of the pipe is below the waterline, and
   - no valves are fitted.

The possibility of progressive flooding through ballast piping passing through the assumed extent of damage, where positive action valves are not fitted to the ballast system at the open ends of the pipes in the tanks served, is to be considered. Where remote control systems are fitted to ballast valves and these controls pass through the assumed extend of damage, then the effect of damage to the system is to be considered to ensure that the valves would remain closed in that event.

If pipes, ducts or tunnels are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed flooded.

2.3 General

2.3.1 Loading conditions

The damage stability criteria specified in [2.4] are to be complied with for the loading conditions mentioned in Ch 1, Sec 2, [5.2] and Ch 1, Sec 2, [5.4] and the loading conditions allowing to take into account the possible evolution of mass during the ship life as given in Ch 3, Sec 2, [2.1.2].

However, the lightship condition not being an operational loading case, no verification are required for this case.

2.3.2 Calculation assumptions

Calculations are to be performed in accordance with [2.4.2] to [2.4.7] and to take into consideration the proportions and design characteristics of the ship and the arrangement and configuration of the damaged compartments. For these calculations, the ship is to be assumed in the worst anticipated service condition as regards stability.

Effects of free surfaces of liquids in tanks are to be taken into account as defined in Ch 3, Sec 2, [2.2].

Damaged compartments, when filled of liquid, are to be subject to run-off, when relevant.

Where it is proposed to fit decks, inner skins or longitudinal bulkheads of sufficient tightness to seriously restrict the flow of water, the Society is to be satisfied that proper consideration is given to such restrictions in the calculations.

2.4 Damage and criteria

2.4.1 Introduction

The present sub-article defines the stability requirements to be complied with when a ship is in damage conditions.

The compliance with such requirements assumes the floating of the ship after several damage cases and the survival such that the return to the harbour is possible.

2.4.2 Damage

The damage to take into account is a continuous breach in the hull of the ship caused by a combat shot or an event at sea.

The damage is applied anywhere within the ship's length L.

All positions of the damage along the ship are to be considered.

a) Longitudinal damage extension
   1) Ships of length L not greater than 91,5 m

      The extension of the damage causes the flooding of two adjacent watertight compartments (see Ch 1, Sec 2, [6.7] and Fig 1)
   2) Ships of length L greater than 91,5 m

      They are divided into two categories:
      - Category I

        Major warships, excluding corvettes, auxiliary ships or ships employed for carriage of important operational equipment. The longitudinal extension to be taken into account for such a category is 15% of L at each point of L. Nevertheless, if the general specification states it, such a length may be reduced to an extension interesting three adjacent compartments (see Ch 1, Sec 2, [6.7] and Fig 1)
      - Category II

        Ships supplied with a basin or a hangar of remarkable dimensions and all the ships which are not included in category I. The longitudinal extension of the damage to be taken into account is equivalent to the extension of two adjacent compartments (see Fig 1).

b) Vertical damage extension

   The vertical extension of the damage is to be such that all the deck closures and platforms within the damaged area are destroyed (see Fig 2).

c) Transversal damage extension

The transversal extension of the damage may reach the centre line of the ship without nevertheless including it (see Fig 3).

If any damage of lesser, above indicate, would result in a more severe condition regarding the compliance with the following damage stability criteria, such damage is to be assumed in the calculations.

Figure 1 : Standard damage case - Longitudinal extension (example of damage on the shell and extension of flooding)

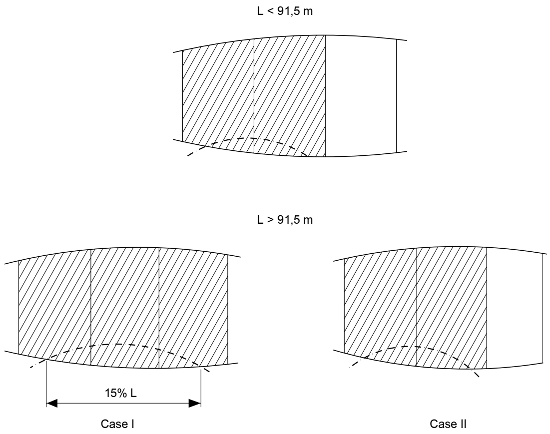


Figure 2 : Standard damage case - Vertical extension (example of vertical penetration and flooding extension)

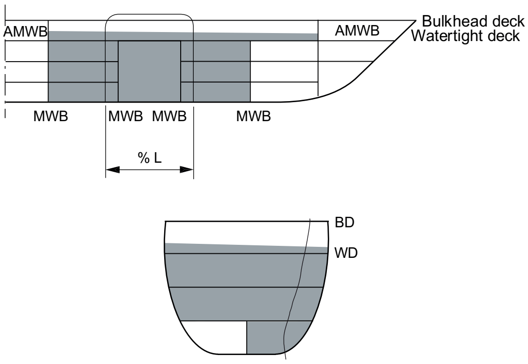
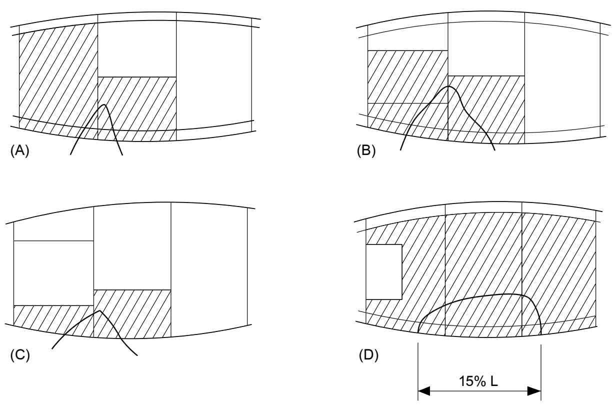


Figure 3 : Standard damage case - Transversal extension (example of transversal penetration and flooding extension)



(A) and (B): Flooding of two compartments where the longitudinal bulkhead remains undamaged

(C) : Flooding of two compartments where the longitudinal lateral bulkheads remain watertight and may generate a stability condition more unfavourable caused by the heeling

(D) : Other case of flooding.

Table 1 : Values of permeability

Spaces	Permeability
Diesel engine and auxiliaries	0,85
Steam engines	0,90
Boilers	0,80
Pumps, steering gears and stabilisators	0,90
Mooring chains storage	0,65
Technical activities	0,95
Stores and refrigerated goods	0,80**(1)**
Intended for liquids	0 or 0,98**(2)**
Accommodation and military operational areas	0,95
Ammunition storage	0,80**(1)**
Void compartments	0,97

(1) when partially loaded: 0,95 (see Ch 1, Sec 2, [5.3]).
(2) whichever results in the more severe requirements.

2.4.3 Permeability

For the damage stability calculations, the volume and surface permeabilities are to be in general as reported in Tab 1. Other values can be accepted when duly justified.

The permeability for cargo spaces intended for the stowage of land vehicles, barges, helicopters and containers is to be derived by calculation in which the land vehicles, barges, helicopters and containers are to be assumed as non-watertight and their permeability equal to 0,65.

In no case is the permeability of cargo spaces in which the goods, vehicles and containers are carried to be taken less than 0,60.

2.4.4 Free surface effects

For partially filled tanks, a free surface effect is to be considered as defined in Ch 3, Sec 2, [2.2.3].

2.4.5 Run-off weights after damage

When a tank is involved in a damage, its content runs-off through the consequent breach. Such content is called run-off weight and is to be taken into account in damage stability calculation.

2.4.6 Calculation of closed openings

a) Below the watertight deck

   Access in decks and watertight doors below the watertight deck may be considered open or closed. In such a case, the more unfavourable condition is to be considered in the damage stability analysis.

b) Above the watertight deck (included)

   All the watertight doors (outside the "V" line), when laying out of the damaged area, are to be considered closed.

2.4.7 Cross-flooding and equalisation

a) Cross-flooding

   The cross-flooding to be taken into account in the damage stability calculations may be accepted under the following conditions:

   1) self acting cross-connection
   2) the system is independent without any power supply
   3) the flooding is to be completed in the time:
      - for $D < 4500t$: time < 2 min
      - for $4500t < D < 10000t$: time $< 0,1(D/1000)^2$ min
      - for $D > 10000t$: time < 10 min

      where:

      D : Full load displacement.

   Suitable information concerning the use of cross-flooding fittings is to be supplied to the Captain of the ship.

   For cross-flooding verification, see Ch 3, App 3.

b) Passive equalisation

Passive equalisation complements the effect of cross-flooding, but uses controls means which are manually operated from above the damage control deck (opening of valves). The controls are to be operable with a maximum heel angle of 20°. The equalisation system is to be independent without any power supply. The time needed for passive equalisation may not exceed 15 min.

c) Active equalisation

After the passive equalisation of the ship, all active equalisation measures including mechanically driven ones (like transfer of content of fuel tanks) may be used, if not explicitly prohibited by the stability manual, in order to right itself the ship.

2.4.8 Residual stability after damage

The residual stability of the ship at the end of flooding is calculated taking the following into account:

- characteristics of the righting arms curves for all the damage cases
- relating such curves with the heeling arms curves caused by the wind athwartship.

a) Righting arms curve

1) Characteristics of righting arms curve

Such a curve is to comply with the following requirements:

- it is to be carried out by the loss of buoyancy method. Such a method, recognised by IMO (International Maritime Organisation), studies the damage maintaining constant the displacement of the ship (the flooded volume does not take part in buoyancy of the ship)
- the calculation of the righting arms at several angles is to be performed at equilibrium of longitudinal moment (changeable trim), corrected for free surface effects
- the hull is limited to the bulkhead deck
- the righting arms curves are extending to the smallest of the following angles:
  - θ_s (capsizing angle)
  - θ_f (angle at which the first opening results submerged)
  - 45°

2) Stability criteria required

- Before the passive equalisation of the ship, if present:
  - survival condition

    Provided that particular requirements are present in the contract or in the specification, the ship at the end of flooding is to reach an equilibrium heeling angle not more than 20°:

    $\theta_e < 20°$
  - initial metacentric height

    The initial metacentric height value at a null angle is to be calculated.

  Particular considerations are necessary if, in such a case, such a value results negative or too small. Surely the value of the initial metacentric height at null angle points out the possibility of a lolling. In such a case the passive equalisation by movement of weights onboard may result dangerous. The analysis is to take into account actions (change of trim, lowering of centre of gravity, etc.) which allow the reaching of a positive value of the initial metacentric height, and therefore to avoid the lolling.
- After the passive equalisation of the ship, if present, or at the end of flooding, in any case:
  - survival condition

    Provided that particular requirements are present in the contract or in the specification, the ship at the end of flooding is to reach an equilibrium heeling angle not more than 15°:

    $\theta_e < 15°$
  - initial metacentric height

    The initial metacentric height value at a null angle is to be positive:

    $GM_{corr} > 0$
  - waterline after damage (margin line)

    At the end of flooding and passive equalisation, the trim and equilibrium angle is to be such that the requirements as defined in Ch 1, Sec 2, [3.2.1] are complied with.
  - stability reserve (see Fig 4)

    The area A_1, representative of the righting energy, is to be higher than the value calculated from Tab 2. It represents the results of a statistic research among several ships, and gives the amount of minimum righting energy such that face the heeling energy caused by a moderate sea.

    $A_1 > RSA$

b) Comparison between the righting arms and heeling arms curves for severe wind and rolling

1) Method to evaluate the stability

The method is the same as defined in Ch 3, Sec 2, [2.3]. Nevertheless, the values of rolling and speed of wind to be taken into account are those presented in Tab 3 and Tab 4.

2) Stability requirements

- Before the equalisation of the ship, at the end of flooding, for the contemporary action of severe wind and rolling as reported in item 1), the ship is to maintain positive initial metacentric height, i.e. she is never to capsize. The maximum value of the righting arm reduced by the value of the heeling arm at the same angle is to be positive:

  $GZ\ Max - GZ_{Heel} > 0$

- After the equalisation of the ship, if present, or at the end of flooding in any case:
  - the ship is to have a stability reserve such to make possible her return in the harbour. To this purpose the value of the maximum righting arm reduced by the value of the heeling arm at the same angle is to be not less than 0,08 m:

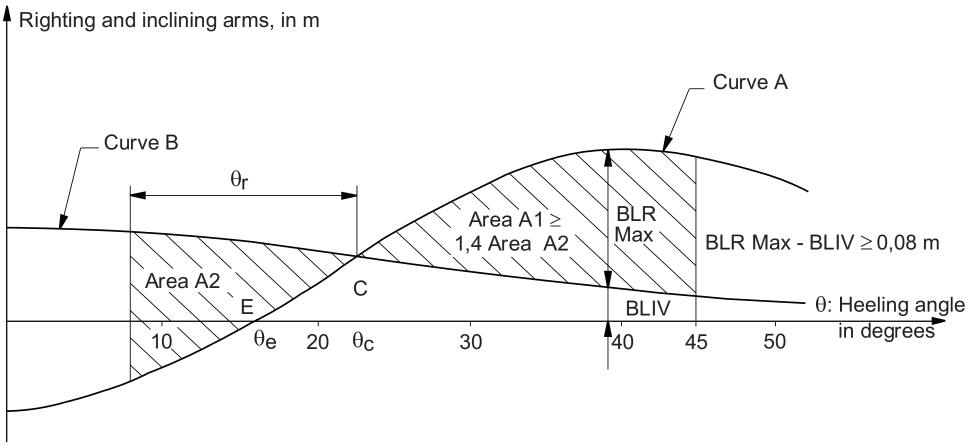
    $GZ\ Max - GZ_{Heel} > 0{,}08$
  - the value of the area A_1 is to be not less than area A_2 increased by 40%:

    $A_1 > 1{,}4\ A_2$

    See Fig 4.

  The area A_2 is limited to the value of rolling angle θ_r determined from Tab 4.

Figure 4 : Righting arms curve and heeling arms caused by severe wind and rolling



Curve A : Righting arms curve at the end of the flooding

Curve B : Heeling arms curve caused by severe wind and rolling.

Table 2 : Values of the areas representative of the stability reserve required at the end of the flooding (as a function of the displacement)

Displacement/1000 (in tons)	Area, in m·deg	Area, in m·rad
0	2,25	0,039
0,5	1,55	0,027
1,0	1,39	0,024
1,5	1,30	0,023
2,0	1,21	0,021
2,5	1,15	0,020
3,0	1,10	0,019
3,5	1,04	0,018
4,0	0,99	0,017
5,0	0,92	0,016
6,0	0,87	0,015
7,0	0,80	0,014
8,0	0,77	0,013
9,0	0,73	0,013
10,0	0,69	0,012

Displacement/1000 (in tons)	Area, in m·deg	Area, in m·rad
12,5	0,80	0,014
15,0	0,75	0,013
17,5	0,72	0,012
20,0	0,69	0,012
25,0	0,64	0,011
30,0	0,61	0,011
35,0	0,59	0,010
40,0	0,57	0,010
45,0	0,57	0,010
50,0	0,57	0,010
55,0	0,57	0,010
60,0	0,58	0,010
65,0	0,59	0,010
70,0	0,62	0,011
75,0	0,65	0,011
80,0	0,71	0,012

Table 3 : Determination of speed of the wind to be taken into account in damage stability calculations

Displacement/1000 (in tons)	Wind speed, in knots	Displacement/1000 (in tons)	Wind speed, in knots	Displacement/1000 (in tons)	Wind speed, in knots
0	20,0	4,25	31,6	16	40,7
0,25	21,7	4,50	31,9	17	41,3
0,50	22,8	4,75	32,2	18	41,8
0,75	23,9	5,00	32,4	19	42,2
1,00	24,7	6,50	34,5	20	42,8
1,25	25,5	7,00	35,0	21	43,3
1,50	26,2	7,50	35,4	22	43,7
1,75	26,8	8,00	35,7	23	44,1
2,00	27,4	8,50	36,1	24	44,5
2,25	28,0	9,00	36,5	25	45,0
2,50	28,5	9,50	36,8	30	47,1
2,75	29,0	10,0	37,1	35	49,5
3,00	29,5	11,0	37,7	40	51,7
3,25	30,0	12,0	38,4	50	55,0
3,50	30,4	13,0	39,0	60	58,3
3,75	30,8	14,0	39,6	70	61,7
4,00	31,2	15,0	40,1	80	65,0

Table 4 : Rolling angle at the end of the flooding (as a function of the initial displacement)

Displacement/1000 (in tons)	Roll angle, in degree	Displacement/1000 (in tons)	Roll angle, in degree	Displacement/1000 (in tons)	Roll angle, in degree
0,3	13,0	12	9,0	30,0	6,8
0,5	12,9	13	8,8	31,0	6,7
0,8	12,7	14	8,7	32,0	6,6
1,0	12,5	15	8,5	33,0	6,5
1,3	12,4	16	8,4	34,0	6,4
1,5	12,2	17	8,2	35,0	6,4
2,0	11,9	18	8,1	37,5	6,2
2,5	11,6	19	7,9	40,0	6,1
3,0	11,5	20	7,8	42,5	5,9
3,5	11,3	21	7,7	45,0	5,8
4,0	11,1	23	7,4	47,5	5,7
5,0	10,7	24	7,3	50,0	5,6
6,0	10,4	25	7,2	55,0	5,4
7,0	10,1	26	7,2	60,0	5,2
8,0	9,9	27	7,1	65,0	5,2
9,0	9,6	28	7,0	70,0	5,1
10,0	9,4	29	6,9	80,0	5,0
11,0	9,2				

Section 4 Sea-Keeping

1 General

1.1 Introduction

1.1.1 Ship operability

The operability of a military ship is directly linked to the task performance of the crew, the operability of the weapons systems and equipment and the ability of the ship to transit as required. The task performance of the crew is influenced by seasickness, fatigue and motion induced interruptions, whereas ship motions and accelerations limit the operability of weapons systems and equipment.

1.1.2 Operation limits

The operation limits depend on the specific operation the ship is to perform. For transit operations, the operation limits ensure that ship motions and accelerations do not adversely affect the ship structure, systems and equipment needed for the mission nor the task performance of the crew.

Operation limits for the hull are set to prevent structural damage caused by slamming or wetness (water on deck), and to prevent degradation of the ship operability due to propeller emergence.

1.1.3 Verification approach

It is a basic requirement that sea-keeping assessment is performed in order to verify the ability of the ship to transit as required during transit operations. This verification is treated in the current section.

Verification of a vessel’s sea-keeping characteristics with respect to operational limits for other specific operations, such as flight and replenishment at sea operations, is covered by additional class notations and, as such, subject to the requirements in Pt E, Ch 9, Sec 3.

1.1.4 Transit operations (TRAN)

The TRAN mission models the situation where the ship is sailing from one place to another, with the crew performing routine shipboard activities for transit and patrol. In terms of a vessel’s sea-keeping characteristics, this mission depends upon the ship's ability to transit as required across the seas.

Survivability in extreme seas is therefore a special subset of the TRAN mission. Two aspects of survivability are of major importance: the ultimate stability and the ultimate strength. As such, it is necessary to determine and take into account extreme values for wave induced bending moments.

By default, the wave induced bending moments are to be taken as described in Ch 5, Sec 2, [3]. As an alternative, the designer may perform direct computations in order to derive design values that may be used instead. In such a case, the principles and criteria to be adopted in a long term sea-keeping assessment used to derive these values are provided in Ch 3, App 6. The applicability of results of long term sea-keeping assessments as an alternative to the requirements in Ch 5, Sec 2, [3] are to be approved by the Society on a case-by-case basis.

Other requirements for the hull and equipment in the context of the TRAN mission are given in Article [2].

1.2 Assessment procedure

1.2.1 Parameters

The methods for calculating the parameters to be considered for the sea-keeping assessment are defined in Article [2].

1.2.2 Evaluation

The values of the ship sea-keeping parameters are to be assessed by means of computer calculations and/or small-scale model tests in a model basin.

The computer calculations are to be performed as described in Ch 3, App 6, and the following documentation is to be provided:

- justification of the validity of the used software
- parameters to be calculated
- computation input data
- computation results
- model test results that verify and/or replace calculated results.

Concerning model tests, the following documentation is to be provided:

- parameters to be measured
- detailed test program
- analysis procedure of measured data
- sea- and ship loading-condition during the tests
- test results and their analysis.

1.3 Environmental conditions

1.3.1 Sea state

Sea state is an expression used to categorise wave conditions and normally a sea state comprises a significant wave height Hs and a wave period.

Unless otherwise specified, the environmental conditions to be considered for sea-keeping analyses are to be taken from NATO STANAG 4154 Ed. 4.

Whenever computer calculations or model scale tests are used, i.e. when the environmental conditions are selectable, the sea states used for the verification of the criteria in [2.3] are to be defined as described in [1.3.2] and [1.3.3].

The limiting sea state defines the sea state up to and including which the sea-keeping criteria can be satisfied for the TRAN mission.

1.3.2 Wave height

Generally, the references to the wave height are to be taken as the significant wave height Hs, i.e. the average of the 1/3 largest wave heights in a sea state.

The description of sea states shown in Ch 3, App 6, Tab 2 defines the significant wave height as ranges, not absolute values. For this reason, sea states are to be referred to not only by their number, but also whether it is a low, mid or high sea state. For example, for the sea states defined as per STANAG 4154, a low sea state 6 has Hs = 4,0 m, mid sea state 6 has Hs = 5,0 m and high sea state 6 has Hs = 6,0 m.

The wave height to be considered for the verifications is to be the largest significant wave height relative to the specified sea state; for example, if a mid sea state 6 is specified, Hs is to be taken as 5,0 m, but if only sea state 6 is specified, Hs is to be taken equal to 6,0 m.

1.3.3 Wave period

Generally, references to the wave period are to be taken as the modal wave period, as per STANAG 4154.

For the TRAN mission, at least three periods are to be considered, the values of which are to be taken from STANAG 4154. For other cases, one period value will, in general, be sufficient.

1.4 Requirements to be complied with

1.4.1 The requirements of Article [2] are equivalent to the requirements in NATO STANAG 4154 Ed.4

2 Hull

2.1 General

2.1.1 Scope

The sea-keeping performance is to be evaluated in order to ensure that the ship motions do not become so severe that slamming, water on deck and propeller emergences can damage the hull structure or equipment, and verify that they do not prevent the ship from transiting in weather conditions where the ship is expected to carry out its mission.

2.1.2 Requirements

It is to be ensured that the ship is able to perform the TRAN mission by verifying that the parameters evaluated do not exceed the criteria defined in [2.3].

Unless otherwise specified, the parameters evaluated are to comply with the criteria for a limiting sea state not less than mid sea state 5 as defined in STANAG 4154.

2.2 Parameters

2.2.1 Wetness index

The wetness index is defined as the number of occurrences of water on deck in an hour. This index is to be based on the variance ($m_{0,M}$) of the relative vertical motion at the bow combined with the distance between the deepest subdivision load line and the weather deck at the same location:

$WI = N_Z \, F(D_F)$

where:

$$F(D_F) = \exp\left(-\left(\frac{D_F}{\sqrt{2m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

2.2.2 Slamming index

The slamming index is defined as the number of times in an hour a keel emergence is followed by a re-entry in water that exceeds a certain threshold velocity:

$SI = N_Z\ F(V_{TH})\ F(T_{SL})$

where:

$F(V_{TH})$: Probability of exceeding the threshold velocity:

$$F(V_{TH}) = \exp\left(-\left(\frac{V_{TH}}{\sqrt{2m_{0,V}}}\right)^2\right)$$

$F(T_{SL})$: Probability of keel emergence:

$$F(T_{SL}) = \exp\left(-\left(\frac{T_{SL}}{\sqrt{2m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,V}$: Zero order spectral moment of relative vertical velocity response

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

The location of the slamming assessment is to be at the keel at 3/20 L behind the fore perpendicular.

The vertical threshold velocity is based on the ship length, and defined, in m/s, as:

$$V_{TH} = 3,66\sqrt{\frac{L}{158,5}}$$

2.2.3 Propeller emergence

Propeller emergence is defined as the number of times the highest quarter part of the propeller diameter (D_{PROP}) emerges from the sea surface in an hour. This index is to be based on the variance ($m_{0,M}$) of the relative vertical motion at the propeller location combined with the distance from the propeller axis to the calm water sea surface (Z_{PROP}).

According to the above definitions and the dimensions shown in Fig 1, propeller emergence occurs when the relative motion exceeds Z_{PE} defined as:

$$Z_{PE} = Z_{PROP} - \frac{1}{4}D_{PROP}$$

The number of propeller emergences in an hour can now be determined as:

$PE = N_Z\ F(Z_{PE})$

where:

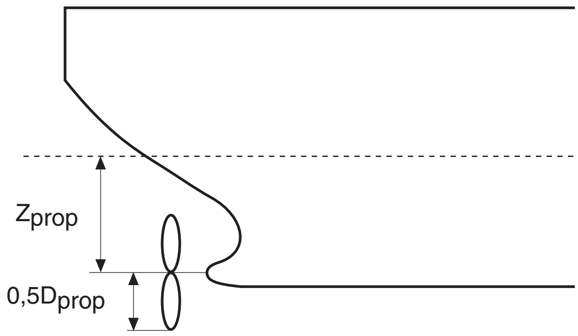
$$F(Z_{PE}) = \exp\left(-\left(\frac{Z_{PE}}{\sqrt{2m_{0,M}}}\right)^2\right)$$

$$N_Z = \frac{3600}{2\pi}\sqrt{\frac{m_{2,M}}{m_{0,M}}}$$

$m_{0,M}$: Zero order spectral moment of relative vertical motion response

$m_{2,M}$: Second order spectral moment of relative vertical motion response.

Figure 1 : Dimensions for calculation of relative motion Z_{PE}



2.3 Criteria

2.3.1 The criteria that ensure that wetness, slamming and propeller emergence events do not become excessive are given in Tab 1 for all monohull ships.

Ships with sponsons are also to comply with the additional criteria given in Tab 2.

Table 1 : Hull criteria limits

MONOHULL		
Parameter	Limit	Location
Wetness index (WI)	30/hr	Forward perpendicular
Slamming index (SI)	20/hr	Keel, 3/20 L aft of FP
Propeller emergence (PE)	90/hr	1/4 propeller diameter above shaft center / Top of water jet inlet

Table 2 : Additional hull criteria limits for ships with sponsons

Parameter	Limit	Location
Slamming index (SI)	20/hr	Sponson

Appendix 1 Inclining Test and Lightweight Check

1 Inclining test and lightweight check

1.1 General

1.1.1 General conditions of the ship

Prior to the test, the Society's Surveyor is to be satisfied of the following:

- the weather conditions are to be favourable
- the ship is to be moored in a quiet, sheltered area free from extraneous forces, such as to allow unrestricted heeling. The ship is to be positioned in order to minimise the effects of possible wind, stream and tide
- the ship is to be transversely upright and the trim is to be taken not more than 1% of the length between perpendiculars. Otherwise, hydrostatic data and sounding tables are to be available for the actual trim
- cranes, derrick, lifeboats and liferafts capable of inducing oscillations are to be secured
- main and auxiliary boilers, pipes and any other system containing liquids are to be filled
- the bilge and the decks are to be thoroughly dried
- preferably, all tanks are to be empty and clean, or completely full. The number of tanks containing liquids is to be reduced to a minimum taking into account the above-mentioned trim. In particular the filling of slack tanks is to be less than 80% to avoid any influence of structural elements. The shape of the tank is to be such that the free surface effect can be accurately determined and remain almost constant during the test. All cross connections are to be closed
- the weights necessary for the inclination are to be already on board, located in the correct place
- all work on board is to be suspended and crew or personnel not directly involved in the inclining test is to leave the ship
- the ship is to be as complete as possible at the time of the test. The number of weights to be removed, added or shifted is to be limited to a minimum. Temporary material, tool boxes, staging, sand, debris, etc., on board is to be reduced to an absolute minimum.

1.1.2 Inclining weights

The total weight used is preferably to be sufficient to provide a minimum inclination of one degree and a maximum of four degrees of heel to each side. The Society may, however, accept a smaller inclination angle for large ships provided that the requirement on pendulum deflection or U-tube difference in height specified in [1.1.4] is complied with. Test weights are to be compact and of such a configuration that the VCG (vertical centre of gravity) of the weights can be accurately determined. Each weight is to be marked with an identification number and its weight. Re-certification of the test weights is to be carried out prior to the incline. A crane of sufficient capacity and reach, or some other means, is to be available during the inclining test to shift weights on the deck in an expeditious and safe manner. Water ballast is generally not acceptable as inclining weight.

1.1.3 Water ballast as inclining weight

Where the use of solid weights to produce the inclining moment is demonstrated to be impracticable, the movement of ballast water may be permitted as an alternative method. This acceptance would be granted for a specific test only, and approval of the test procedure by the Society is required. As a minimal prerequisite for acceptability, the following conditions are to be required:

- inclining tanks are to be wall-sided and free of large stringers or other internal members that create air pockets
- tanks are to be directly opposite to maintain ship's trim
- specific gravity of ballast water is to be measured and recorded
- pipelines to inclining tanks are to be full. If the ship's piping layout is unsuitable for internal transfer, portable pumps and pipes/hoses may be used
- blanks must be inserted in transverse manifolds to prevent the possibility of liquids being "leaked" during transfer. Continuous valve control is to be maintained during the test
- all inclining tanks are to be manually sounded before and after each shift
- vertical, longitudinal and transverse centres are to be calculated for each movement
- accurate sounding/ullage tables are to be provided. The ship's initial heel angle is to be established prior to the incline in order to produce accurate values for volumes and transverse and vertical centres of gravity for the inclining tanks at every angle of heel. The draught marks amidships (port and starboard) are to be used when establishing the initial heel angle
- verification of the quantity shifted may be achieved by a flowmeter or similar device
- the time to conduct the inclining is to be evaluated. If time requirements for transfer of liquids are considered too long, water may be unacceptable because of the possibility of wind shifts over long periods of time.

1.1.4 Pendulums

The use of three pendulums is recommended but a minimum of two are to be used to allow identification of bad readings at any one pendulum station. However, for ships of a length equal to or less than 30 m, only one pendulum can be accepted. They are each to be located in an area protected from the wind. The pendulums are to be long enough to give a measured deflection, to each side of upright, of at least 10 cm. To ensure recordings from individual instruments are kept separate, it is suggested that the pendulums be physically located as far apart as practical.

The use of an inclinometer or U-tube is to be considered in each separate case. It is recommended that inclinometers or other measuring devices only be used in conjunction with at least one pendulum.

1.1.5 Means of communications

Efficient two-way communications are to be provided between central control and the weight handlers, and between central control and each pendulum station. One person at a central control station is to have complete control over all personnel involved in the test. The internal means of communication inside the ship may be used for this purpose.

1.1.6 Documentation

The person in charge of the inclining test is to have available a copy of the following plans at the time of the test:

- hydrostatic curves or hydrostatic data
- general arrangement plan of decks, holds, inner bottoms, etc
- capacity plan showing capacities and vertical and longitudinal centres of gravity of cargo spaces, tanks, etc. When water ballast is used as inclining weights, the transverse and vertical centres of gravity for the applicable tanks, for each angle of inclination, are to be available
- tank sounding tables
- draught mark locations
- docking drawing with keel profile and draught mark corrections (if available).

1.1.7 Determination of the displacement

The Society's Surveyor is to carry out all the operations necessary for the accurate evaluation of the displacement of the ship at the time of the inclining test, as listed below:

- draught mark readings are to be taken at aft, midship and forward, at starboard and port sides
- the mean draught (average of port and starboard readings) is to be calculated for each of the locations where draught readings are taken and plotted on the ship's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot is to yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, the freeboards/ draughts are to be retaken
- the specific gravity of the sea water is to be determined. Samples are to be taken from a sufficient depth of the water to ensure a true representation of the sea water and not merely surface water, which could contain fresh water from run off of rain. A hydrometer is to be placed in a water sample and the specific gravity read and recorded. For large ships, it is recommended that samples of the sea water be taken forward, midship and aft, and the readings averaged. For small ships, one sample taken from midship is sufficient. The temperature of the water is to be taken and the measured specific gravity corrected for deviation from the standard, if necessary. A correction to water specific gravity is not necessary if the specific gravity is determined at the inclining experiment site. Correction is necessary if specific gravity is measured when the sample temperature differs from the temperature at the time of the inclining (e.g., if the check of specific gravity is performed at the office). Where the value of the average calculated specific gravity is different from that reported in the hydrostatic curves, adequate corrections are to be made to the displacement curve
- all double bottoms, as well as all tanks and compartments which can contain liquids, are to be checked, paying particular attention to air pockets which may accumulate due to the ship's trim and the position of air pipes, and also taking into account the provisions of [1.1.1]
- it is to be checked that the bilge is dry, and an evaluation of the liquids which cannot be pumped, remaining in the pipes, boilers, condenser, etc., is to be carried out
- the entire ship is to be surveyed in order to identify all items which need to be added, removed or shifted to bring the ship to the lightship condition. Each item is to be clearly identified by its weight and the location of its centre of gravity
- the possible solid permanent ballast is to be clearly identified and listed in the report.

1.1.8 The incline

The standard test generally employs eight distinct weight movements as shown in Fig 1.

The weights are to be transversely shifted, so as not to modify the ship's trim and the vertical position of the centre of gravity.

After each weight shifting, the new position of the transverse centre of gravity of the weights is to be accurately determined.

After each weight movement, the distance the weight was moved (centre to centre) is to be measured and the heeling moment calculated, multiplying the distance by the amount of weight moved. The tangent is calculated for each pendulum, dividing the deflection by the length of the pendulum. The resultant tangents are plotted on the graph as shown in Fig 2.

The pendulum deflection is to be read when the ship has reached a final position after each weight shifting.

During the reading, no movement of personnel is allowed.

For ships with a length equal to or less than 30 m, six distinct weight movements may be accepted.

Figure 1 : Weight shift procedure

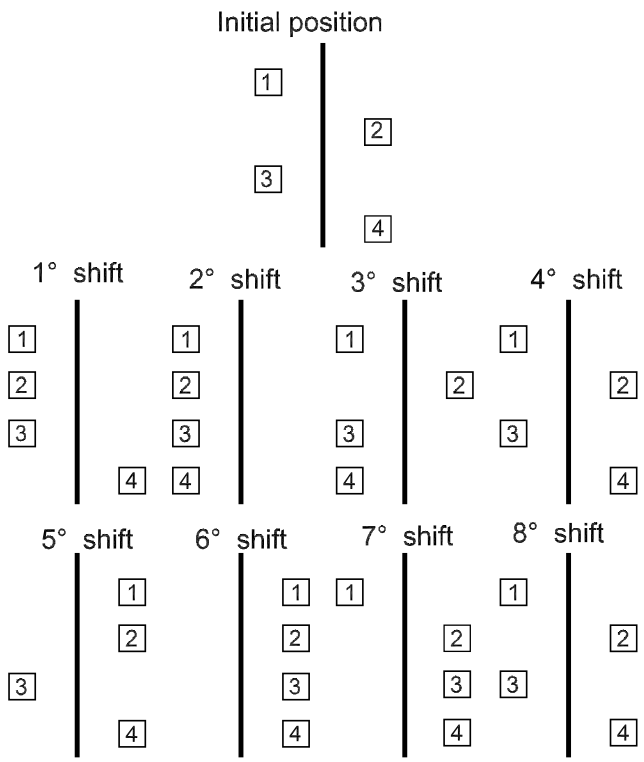
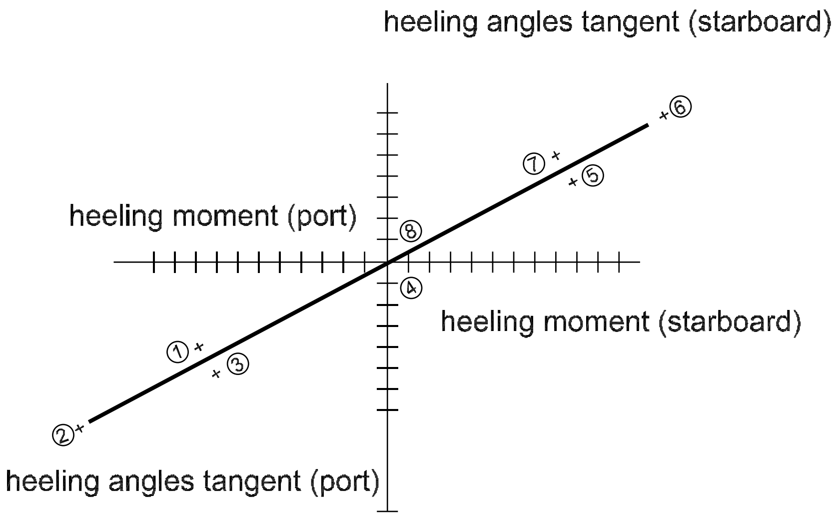


Figure 2 : Graph of resultant tangents



Appendix 2 Trim and Stability Booklet

1 Trim and stability booklet

1.1 Information to be included in the trim and stability booklet

1.1.1 General

A trim and stability booklet is a stability manual, to be approved by the Society, which is to contain sufficient information to enable the Captain to operate the ship in compliance with the applicable requirements contained in the Rules.

The format of the stability booklet and the information included vary depending on the ship type and operation.

1.1.2 List of information

The following information is to be included in the trim and stability booklet:

- a general description of the ship, including:
  - the ship's name and the Society classification number
  - the ship type and service notation
  - the class notations
  - the yard, the hull number and the year of delivery
  - the moulded dimensions
  - the draught corresponding to the minimum operational loaded ship (defined in Ch 1, Sec 2, [5.4]), the draught corresponding to the assigned full loaded ship (defined in Ch 1, Sec 2, [5.2])
  - the displacement corresponding to the above-mentioned draughts
- clear instructions on the use of the booklet
- general arrangement and capacity plans indicating the assigned use of compartments and spaces (cargo, stores, accommodation, etc.)
- a sketch indicating the position of the draught marks referred to the ship's perpendiculars
- hydrostatic curves or tables corresponding to the design trim, and, if significant trim angles are foreseen during the normal operation of the ship, curves or tables corresponding to such range of trim are to be introduced. A clear reference relevant to the sea density, in t/m^3, is to be included as well as the draught measure (from keel or underkeel)
- cross curves (or tables) of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- tank sounding tables or curves showing capacities, centres of gravity, and free surface data for each tank
- lightship data from the inclining test, as indicated in Ch 3, Sec 1, [3.2], including lightship displacement, centre of gravity co-ordinates, place and date of the inclining test, as well as the Society approval details specified in the inclining test report. It is suggested that a copy of the approved test report be included.

  Where the above-mentioned information is derived from a sister ship, the reference to this sister ship is to be clearly indicated, and a copy of the approved inclining test report relevant to this sister ship is to be included
- standard loading conditions and examples for developing other acceptable loading conditions using the information contained in the booklet
- intact stability results (total displacement and its centre of gravity co-ordinates, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 2 as well as possible additional criteria specified in Part D when applicable, reporting a comparison between the actual and the required values) are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.2]
- damage stability results (total displacement and its maximum permissible centre of gravity height, draughts at perpendiculars, GM, GM corrected for free surfaces effect, GZ values and curve, criteria as indicated in Ch 3, Sec 3 as well as possible additional criteria specified in Part D when applicable, reporting a comparison between the actual and the required values)

are to be available for each of the above-mentioned operating conditions. The method and assumptions to be followed in the stability curve calculation are specified in [1.2]

- information on loading restrictions (maximum allowable load on double bottom, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria) when applicable
- information about openings (location, tightness, means of closure), pipes or other progressive flooding sources. the opening used for the calculation of the down flooding angle has to be clearly identified
- information concerning the use of any special cross-flooding fittings with descriptions of damage conditions which may require cross-flooding, when applicable
- any other necessary guidance for the safe operation of the ship
- a table of contents and index for each booklet.

1.2 Stability curve calculation

1.2.1 General

Hydrostatic and stability curves are normally prepared on a designed trim basis. However, where the operating trim or the form and arrangement of the ship are such that change in trim has an appreciable effect on righting arms, such change in trim is to be taken into account.

1.2.2 Superstructures, deckhouses, etc. which may be taken into account

Enclosed superstructures complying with Ch 1, Sec 2 may be taken into account.

The second tier of similarly enclosed superstructures may also be taken into account.

Deckhouses on the main deck may be taken into account, provided that they comply with the conditions for enclosed superstructures laid down in Ch 1, Sec 2.

Where deckhouses comply with the above conditions, except that no additional exit is provided to a deck above, such deckhouses are not to be taken into account; however, any deck openings inside such deckhouses are to be considered as closed even where no means of closure are provided.

Deckhouses, the doors of which do not comply with the requirements of Ch 8, Sec 4, [1.5.4], are not to be taken into account; however, any deck openings inside the deckhouse are regarded as closed where their means of closure comply with the requirements of Ch 8, Sec 7, [8.3] or Ch 8, Sec 7, [9.2], as relevant.

Deckhouses on decks above the main deck are not to be taken into account, but openings within them may be regarded as closed.

Superstructures and deckhouses not regarded as enclosed may, however, be taken into account in stability calculations up to the angle at which their openings are flooded (at this angle, the static stability curve is to show one or more steps, and in subsequent computations the flooded spaces are to be considered non-existent).

Trunks may be taken into account. Hatchways may also be taken into account having regard to the effectiveness of their closures.

1.2.3 Angle of flooding

In cases where the ship would sink due to flooding through any openings, the stability curve is to be cut short at the corresponding angle of flooding and the ship is to be considered to have entirely lost its stability.

Small openings such as those for passing wires or chains, tackle and anchors, and also holes of scuppers, discharge and sanitary pipes are not to be considered as open if they submerge at an angle of inclination more than 30°. If they submerge at an angle of 30° or less, these openings are to be assumed open if the Society considers this to be a source of significant progressive flooding; therefore such openings are to be considered on a case by case basis.

Appendix 3 Calculation Method for Cross-Flooding Arrangements

1 Calculation method for cross-flooding arrangements

1.1 Cross-flooding area

1.1.1 Cross-flooding area calculation

The cross-flooding area S, in m^2, can be calculated from the following formula:

$$S = \frac{2W}{tF(\sqrt{2gH_o} + \sqrt{2gH_F})}$$

where:

W : Volume, in m^3, of water entering the equalising compartments during the period considered

t : Time, in s, necessary to complete the equalisation

F : Factor, to be taken equal to:

$$F = \frac{1}{\sqrt{1 + \sum k}}$$

In general, a value of F equal to 0,65 may be used. Anyway, for particular shape of pipes, appropriate values of k are to be used in the above formula

k : Dimensionless factor of reduction of speed through the duct, being a function of bends, valves, etc., in the cross-flooding system, to be obtained from [1.1.2], as the case may be

g : Gravity acceleration, in m/s^2:

$g = 9{,}81\ m/s^2$

H_o : Initial head of water, in m

H_F : Final head of water after cross-flooding, in m.

1.1.2 Factor of reduction k

The factor of reduction is to be calculated depending on the following cases:

- Case 1: 90° circular bend
- Case 2: Radius bend R/D = 2
- Case 3: Mitre bend
- Case 4: 90° double mitre bend
- Case 5: Pipe inlet
- Case 6: Pipe outlet
- Case 7: Non-return valve
- Case 8: Pipe friction losses
- Case 9: Gate valve
- Case 10: Butterfly valve
- Case 11: Disc valve.

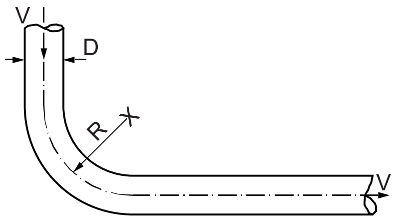
Case 1: 90° CIRCULAR BEND (see Fig 1)

The factor k is defined in Tab 1.

Table 1 : Values of factor k

R/D	2	3	4	5	6	7
k	0,30	0,26	0,23	0,20	0,18	0,17

Figure 1 : 90° circular bend



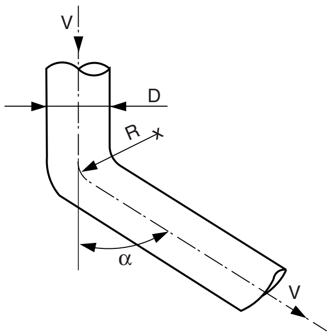
Case 2: RADIUS BEND R/D = 2 (see Fig 2)

The factor k is defined in Tab 2.

Table 2 : Values of factor k

α°	15	30	45	60	75	90
k	0,06	0,12	0,18	0,24	0,27	0,30

Figure 2 : Radius bend R/D = 2



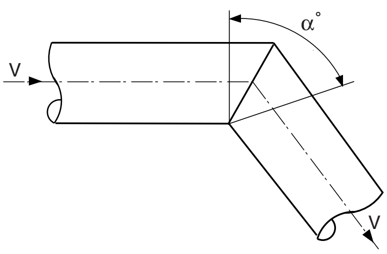
Case 3: MITRE BEND (see Fig 3)

The factor k is defined in Tab 3.

Table 3 : Values of factor k

α°	5	15	30	45	60	90
k	0,02	0,06	0,17	0,32	0,68	1,26

Figure 3 : Mitre bend



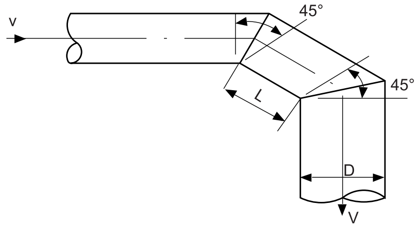
Case 4: 90° DOUBLE MITRE BEND (see Fig 4)

The factor k is defined in Tab 4.

Table 4 : Values of factor k

L/D	1	2	3	4	5	6
k	0,41	0,40	0,43	0,46	0,46	0,44

Figure 4 : 90° double mitre bend



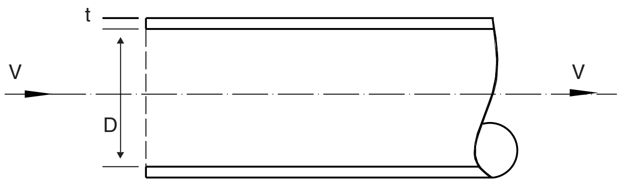
Case 5: PIPE INLET (see Fig 5)

The factor k is defined in Tab 5.

Table 5 : Values of factor k

t/D	0,01	0,02	0,03	0,04	0,05	> 0,05
k	0,83	0,68	0,53	0,46	0,44	0,43

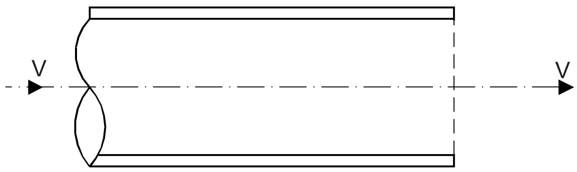
Figure 5 : Pipe inlet



Case 6: PIPE OUTLET (see Fig 6)

k = 1,0

Figure 6 : Pipe outlet

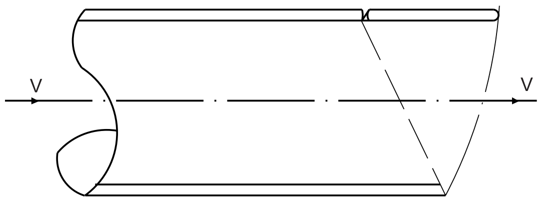


Case 7: NON-RETURN VALVE (see Fig 7)

k = 0,5

The value of k actually increases with decrease in Froude number, particularly below speeds of 2m/sec.

Figure 7 : Non-return valve



Case 8: PIPE FRICTION LOSSES

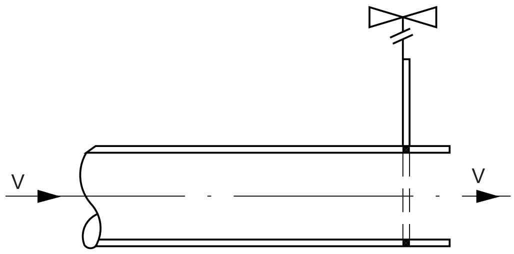
k = 0,02/D per unit length

The coefficient above is a mean value and does in fact vary as Reynold's number (i.e. varies with V for constant D and v) as well as with relative roughness.

Case 9: GATE VALVE (see Fig 8)

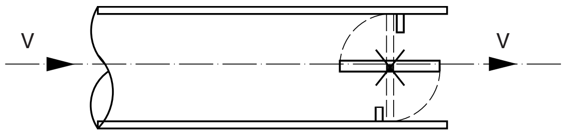
k = 0,3

Figure 8 : Gate valve



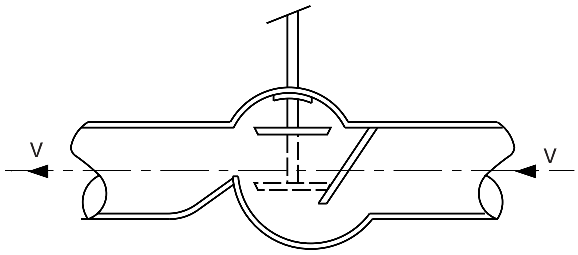
Case 10: BUTTERFLY VALVE (see Fig 9)
k = 0,8

Figure 9 : Butterfly valve



Case 11: DISC VALVE (see Fig 10)
k = 6,0

Figure 10 : Disc valve



1.1.3 Overflows

In general, the area of overflows relevant to the connected compartments is to be not less than S/10, where S is defined in [1.1.1].

Appendix 4 Buoyancy Reserve - "V" Line Method

1 Buoyancy reserve

1.1 Purpose

1.1.1 This method allows to define the zones of flooding interested in damage cases.

The buoyancy check assures that the water couldn't exceed the margin line after the ship reaches the equilibrium at the end of the flooding.

It is necessary to take into account the dynamic effect of the rolling, which may cause a progressive flooding with considerable reduction of the stability characteristics of the ship.

The purpose of the "V" Line calculation is to determine, at the design stage, the areas which may be flooded after damage. If the waterline at the equilibrium after damage cannot be located above the margin line, the dynamic effects, such as rolling of the ship, waves, may cause water to be above the margin line. In this respect, progressive flooding may occur to spaces not previously flooded. Consequently it is necessary to define watertight boundaries in order to keep sufficient buoyancy and stability to the ship.

1.1.2 Method

The longitudinal envelope of the waterlines at the end of each symmetrical flooding for all examined loading conditions is to be taken into account.

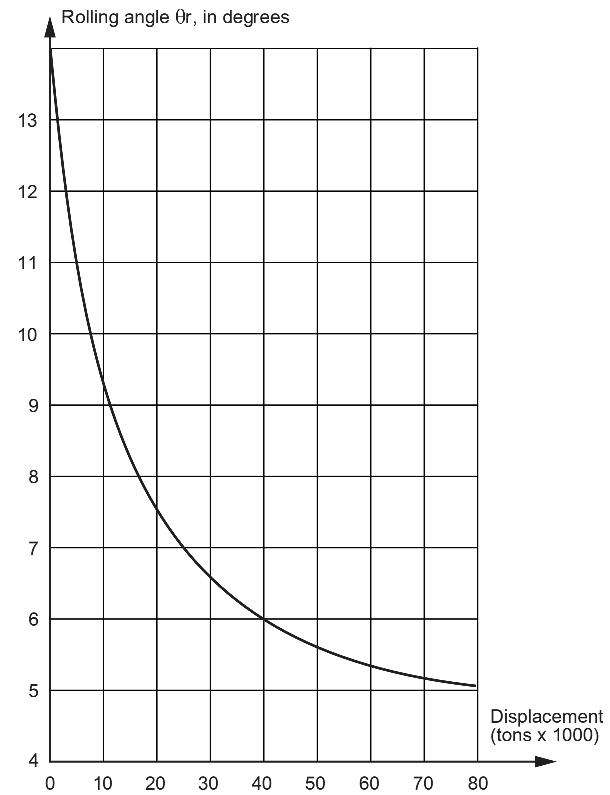
In each transversal section interested by such envelope, proceed as follows (see Fig 2):

a) an heeling angle equal to 15° is to be considered (safety target). This angle may be reduced when obtained from direct damage stability calculations

b) a further rolling angle is applied as shown in Fig 1

c) an elevation of the consequent level of 1,25 m is added to the waterline to consider the movement of the water inside the ship.

Figure 1 : Rolling angles to be taken into account in damage stability calculations, valid also in "V" Line tracing



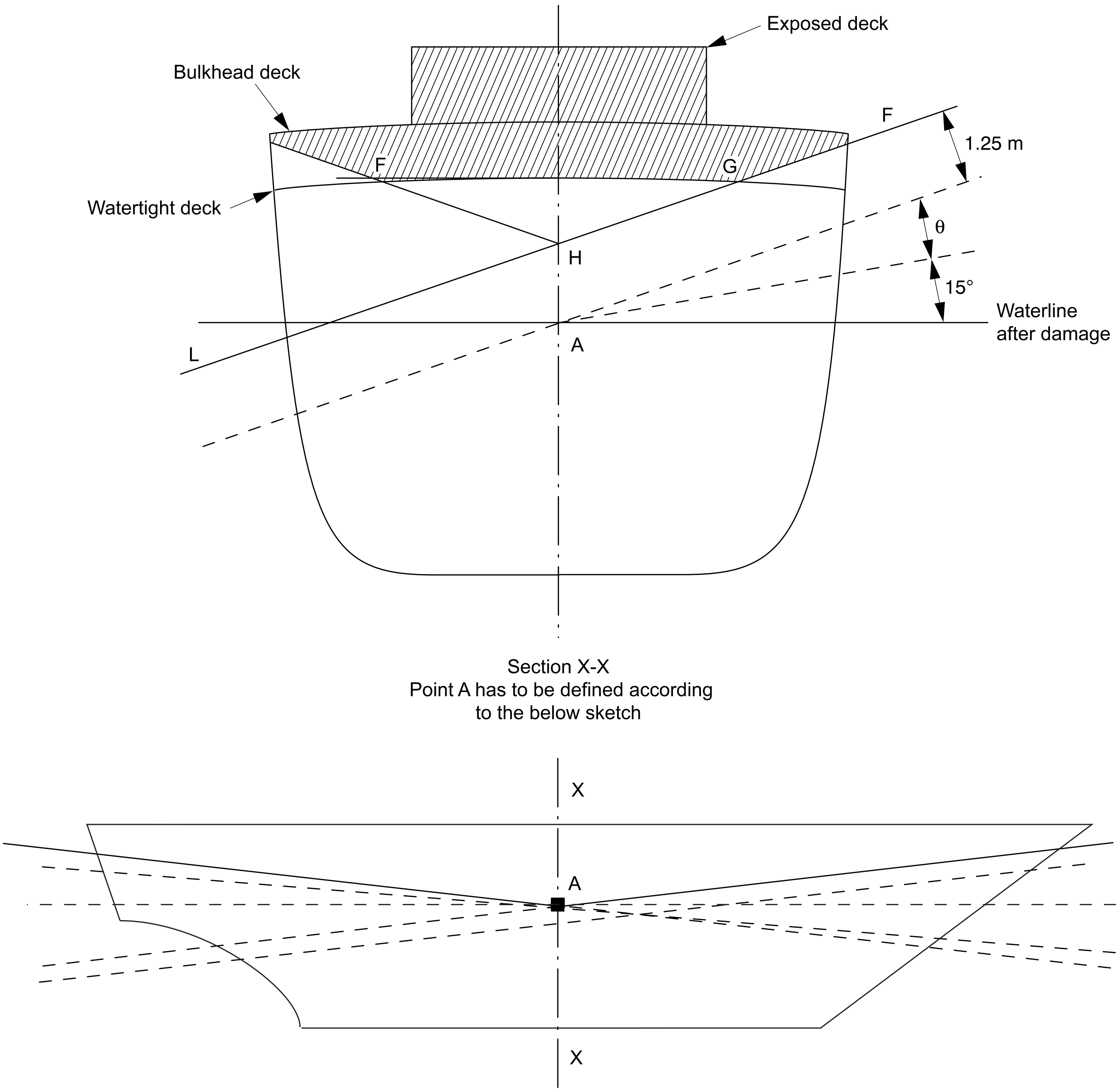
1.1.3 Interpretation of the obtained “V” Line

The “V” Line identifies, in each transversal section, two different zones above the watertight deck:

a) **zone inside “V” Line**, where it is possible to cross the auxiliary transversal bulkheads and the bulkhead deck without particular requirements relevant to the restoring of watertight integrity

b) **zone outside “V” Line**, where each crossing and/or opening is to be provided with a system of watertight closure as described in Ch 2, Sec 3.

Figure 2 : “V” Line example



Appendix 5 Evaluation of the Heeling Moment due to Athwart Wind (Intact Vessel)

1 Evaluation of the heeling moment due to athwart wind (intact vessel)

1.1 Intact stability

1.1.1 The inclining moment, IM, in t·m, caused by the wind is carried out with the following formula:

$$IM = \frac{0,0195 V^2 A h \cos^2 \theta}{1000}$$

where (see Fig 2):

V : Wind speed, in knots

h : Vertical distance, in m, between the windage centre surface and the driftage centre surface which may be considered at middle of draught

A : Area of windage surface, in m², above the waterline

θ : Transverse heeling angle, in degrees.

1.1.2 To obtain the value of the inclining arm, the value obtained from [1.1.1] is to be divided by the displacement of the vessel at the loading condition in question.

1.1.3 To define the heeling moment curve caused by the wind together with the result of the formula in [1.1.1], Fig 1 is to be used. In that Figure, the changing of the wind speed is represented as a function of the height above the waterline for a theoretical speed of 100 knots at 10 m. The value of the wind on the windage area is to be corrected by the ratio with such a curve.

1.1.4 For the purpose of facilitating the task, the values reported in Tab 1 may be used; they give, calculated from the formula in [1.1.1], the values of the inclining moment, taking account of the gradient of the wind speed as a function of the height above the waterline.

Figure 1 : Speed of the wind as a function of the height above the waterline

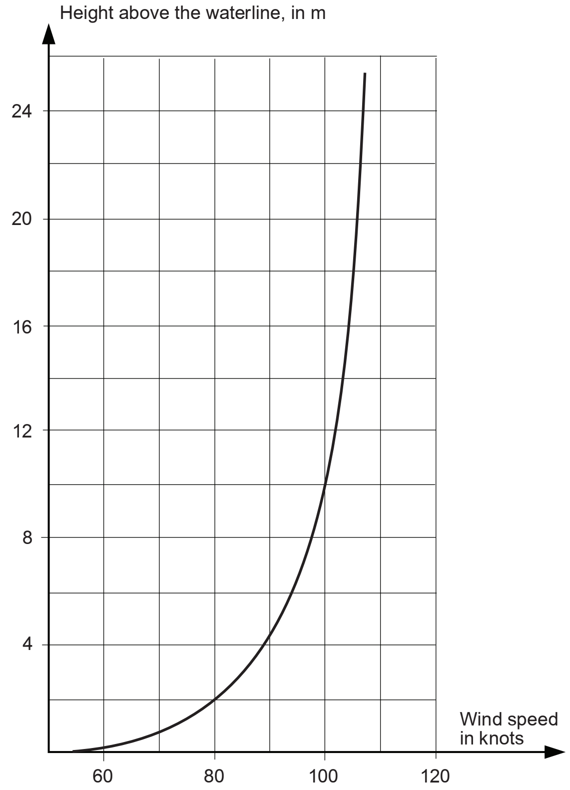


Figure 2 : Example showing the elements used in carrying out the heeling arms caused by the wind

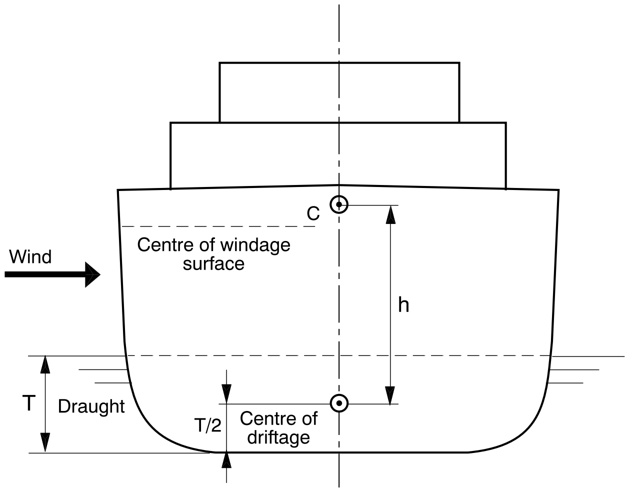


Table 1 : Inclining moment (t·m) per m² for a theoretical wind speed of 100 knots

Height above waterline (in m)	Ship centre of lateral resistance below waterline (in m)											
	0,25	0,50	0,75	1,00	1,25	1,50	1,75	2,00	2,25	2,50	2,75	3,00
0-2	0,13	0,16	0,19	0,21	0,24	0,27	0,29	0,32	0,35	0,37	0,40	0,43
2-4	0,45	0,49	0,52	0,56	0,59	0,63	0,66	0,70	0,73	0,77	0,80	0,84
4-6	0,87	0,91	0,95	0,99	1,03	1,08	1,12	1,16	1,20	1,24	1,28	1,32
6-8	1,31	1,36	1,40	1,45	1,49	1,54	1,58	1,63	1,67	1,72	1,76	1,81
8-10	1,76	1,81	1,86	1,90	1,95	2,00	2,05	2,09	2,14	2,19	2,24	2,28
10-12	2,23	2,28	2,33	2,38	2,43	2,48	2,53	2,58	2,63	2,67	2,72	2,77
12-14	2,72	2,77	2,82	2,87	2,93	2,98	3,03	3,08	3,13	3,18	3,23	3,28
14-16	3,22	3,27	3,32	3,37	3,43	3,48	3,53	3,59	3,64	3,	3,74	3,80
16-18	3,73	3,78	3,84	3,89	3,95	4,00	4,05	4,11	4,16	4,22	4,27	4,32
18-20	4,23	4,29	4,34	4,40	4,45	4,51	4,56	4,62	4,67	4,7369	4,78	4,84
20-22	4,77	4,83	4,88	4,94	5,00	5,05	5,11	5,16	5,22	5,28	5,33	5,39
22-24	5,30	5,35	5,41	5,47	5,53	5,58	5,64	5,70	5,75	5,81	5,87	5,92
24-26	5,78	5,83	5,89	5,95	6,00	6,06	6,12	6,18	6,23	6,29	6,35	6,40
26-28	6,23	6,29	6,35	6,40	6,46	6,52	6,58	6,63	6,69	6,75	6,80	6,86
28-30	6,69	6,75	6,80	6,86	6,92	6,98	7,03	7,09	7,15	7,20	7,26	7,32
Height above waterline (in m)	Ship centre of lateral resistance below waterline (in m)											
	3,25	3,50	3,75	4,00	4,25	4,50	4,75	5,00	5,25	5,50	5,75	6,00
0-2	0,46	0,48	0,51	0,54	0,56	0,59	0,62	0,64	0,67	0,70	0,72	0,75
2-4	0,87	0,91	0,94	0,98	1,01	1,05	1,08	1,12	1,15	1,19	1,22	1,26
4-6	1,36	1,41	1,45	1,49	1,53	1,57	1,61	1,65	1,70	1,74	1,78	1,82
6-8	1,85	1,90	1,94	1,99	2,03	2,08	2,12	2,17	2,22	2,26	2,31	2,35
8-10	2,33	2,38	2,43	2,47	2,52	2,57	2,62	2,66	2,71	2,76	2,81	2,86
10-12	2,82	2,87	2,92	2,97	3,02	3,07	3,12	3,17	3,22	3,27	3,32	3,37
12-14	3,34	3,39	3,44	3,49	3,54	3,59	3,64	3,69	3,75	3,80	3,85	3,90
14-16	3,85	3,90	3,95	4,01	4,06	4,11	4,17	4,22	4,27	4,32	4,38	4,43
16-18	4,38	4,43	4,49	4,54	4,59	4,65	4,70	4,76	4,81	4,86	4,92	4,97
18-20	4,89	4,95	5,00	5,06	5,11	5,17	5,22	5,28	5,33	5,39	5,44	5,50
20-22	5,44	5,50	5,56	5,61	5,67	5,72	5,78	5,84	5,89	5,95	6,01	6,06
22-24	5,98	6,04	6,10	6,15	6,21	6,27	6,32	6,38	6,44	6,49	6,55	6,61
24-26	6,46	6,52	6,58	6,63	6,69	6,75	6,80	6,86	6,92	6,98	7,03	7,09
26-28	6,92	6,98	7,03	7,09	7,15	7,20	7,26	7,32	7,38	7,43	7,49	7,55
28-30	7,38	7,43	7,49	7,55	7,60	7,66	7,72	7,78	7,83	7,89	7,95	8,00

1.1.5 Calculation procedure

a) The windage area is to be divided into strips 2 m in height starting from the considered waterline

b) The surface of each strip is to be calculated, in m^2

c) The vertical position of the centre of driftage area is to be evaluated (corresponding approximately to the half draught) and each strip is to be assigned a moment value as indicated in Tab 1

d) Each surface calculated in item b) is to be multiplied by its assigned moment value obtained in item c)

e) All the moments so obtained are to be added in order to have a moment corresponding to a theoretical wind speed of 100 knots

f) For a wind speed different from 100 knots, the value obtained in item e) is to be multiplied by the following value:

$$\left(\frac{V}{100}\right)^2$$

1.2 Damage stability

1.2.1 The same approach as in [1.1.1] is to be followed, taking account of:

h : Vertical distance, in m, between the windage centre surface and the driftage centre surface (which may be considered at middle of draught) in the final equilibrium after damage.

Appendix 6 Sea-Keeping Calculations

1 Introduction

1.1 General

1.1.1 This Appendix applies to ships with typical hull shape. Ships of unusual type or design are to be considered by the Society on a case by case basis.

The requirements are based on the assumption that a frequency domain strip theory sea-keeping code is being used for the calculations. The software to be used are to be documented and supported by validation documents.

1.2 Scope

1.2.1 The scope of the present Appendix is to supply details on how the sea-keeping calculations are to be performed. Requirements are given primarily on how to perform the short term assessments, but also some recommendations concerning long term assessments are given.

The short term assessments comprise all analyses of the ship behaviour in a single sea state, and thus short term assessments yield all necessary information for the determination of:

- wetness index
- slamming index
- propeller emergence
- Motion Induced Interruption
- RMS values of all ship motions and accelerations.

Long term assessments of the sea-keeping yield estimates of, e.g., the long term distribution of the vertical bending moment.

2 Short term assessment

2.1 General

2.1.1 Short term assessments serve to analyse a ship sea-keeping behaviour in a given sea state. The sea states to be considered for the required rule checks are defined in Ch 3, Sec 4.

2.2 Loading conditions

2.2.1 The sea-keeping verifications should be carried out for following loading conditions:

- auxiliary ships: full load and operational condition
- front and second line ships: operational condition.

2.3 Ship speed

2.3.1 Unless otherwise specified, a discrete set of ship speeds to be agreed with the Society is to be considered for the short term sea-keeping calculations.

2.4 Wave spectrum

2.4.1 General

The wave spectrum to be applied in the short term sea-keeping calculations is based on the characteristics of the sea area where the ship is going to operate:

- open ocean conditions: Bretschneider spectrum with both short and long crested seas
- limited fetch sea areas (e.g. North Sea): JONSWAP spectrum with short crested sea.

2.4.2 Bretschneider spectrum

The Bretschneider spectrum, or two parameter Pierson-Moskowitz spectrum, is defined as:

$$S(\omega) = \frac{H_S^2}{4\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi}\left(\frac{2\pi}{T_Z}\right)^4 \omega^{-4}\right)$$

where:

H_S : Significant wave height, in m

ω : Angular wave frequency, in rad/s

T_Z : Zero up-crossing period, in s.

2.4.3 JONSWAP spectrum

The JONSWAP spectrum is defined as:

$$S(\omega)=173\frac{H_S^2 T_S (T_S\omega)^{-5}}{F_1 F_2^4}\exp(-692(F_2 T_S\omega)^{-4})\gamma^{\exp[-(0,206F_2T_S\omega-1)^2/2\sigma^2]}$$

where:

H_S : Significant wave height, in m

ω : Angular wave frequency, in rad/s

T_S : Mean wave period, in s

γ : JONSWAP peakedness parameter

$$\sigma = \begin{cases} 0,07 \text{ for } \omega \le (0,206F_2T_S)^{-1} \\ 0,09 \text{ for } \omega > (0,206F_2T_S)^{-1} \end{cases}$$

The values of F_1 and F_2 are given in Tab 1.

Unless otherwise agreed with the Society, the peakedness parameter γ should be taken to 3,3, corresponding to the mean JONSWAP spectrum.

Table 1 : F_1 and F_2 values as function of γ

γ	F_1	F_2
1	1,00	1,00
2	1,24	0,95
3	1,46	0,93
3,3 **(1)**	1,52	0,92
4	1,66	0,91
5	1,86	0,90
6	2,04	0,89
(1) Mean JONSWAP spectrum		

2.4.4 Wave spreading

In case of short crested sea a spreading function is to be applied to the wave spectrum when calculating the spectral moments of the response processes. The spreading function is defined as:

$$D(\psi) = \frac{2}{\pi}\cos^2(\bar{\psi}-\psi)$$

where:

ψ : Heading angle

ψ : Angle ranging from $(\psi - \pi/2)$ to $(\psi + \pi/2)$.

2.5 Hydrodynamic model

2.5.1 Short term assessment of the sea-keeping behaviour is to imply that RAO's (Response Amplitude Operators) are to be calculated for:

- A suitable range of wave frequencies to cover the range of the sea spectrum (typically 0,2-2,0 rad/s, with not less than 20 frequencies). Most frequencies are to be placed in the range where most wave energy is present, and the calculation of RAO's at irregular frequencies, or for wave frequencies where the encounter frequency approaches zero, is to be avoided.
- At least 12 evenly distributed heading angles: 0°, 30°, 60°, … , 330° (with 0° being the following sea).

2.6 Spectral moments

2.6.1 The n'th order response spectral moments are to be determined as follows:

- Short crested sea:

$$m_n = \int_0^{\infty}\int_{\bar{\psi}-\frac{\pi}{2}}^{\psi+\frac{\pi}{2}}\left|\omega-\frac{\omega^2 V}{g}\cos\psi\right|^n |\phi(\omega)|^2 S(\omega)D(\psi)d\psi d\omega$$

- Long crested sea:

$$m_n = \int_0^{\infty}\left|\omega-\frac{\omega^2 V}{g}\cos\psi\right|^n |\phi(\omega)|^2 S(\omega)d\omega$$

where:

V : Ship speed, in m/s

g : Gravity acceleration ($g = 9,81$ m/s^2)

ψ : Heading angle

$D(\psi)$: Spreading function

$\phi(\omega)$: RAO

$S(\omega)$: Wave spectrum

ω : Wave frequency, in rad/s.

2.7 RMS values

2.7.1 The Root Mean Square (RMS) value of a response is defined as:

$$RMS = \sqrt{m_0}$$

where m_0 is the zero'th order spectral moment of the response.

3 Long term assessment

3.1 General

3.1.1 Long term assessments serve to estimate long term distributions of the various ship responses, typically the wave induced amidships vertical bending moment.

Such a long term distribution can thence be used to obtain estimates of the extreme responses, e.g. the most probable largest response in 10^8 wave cycles.

3.2 Hydrodynamic model

3.2.1 Unless otherwise agreed with the Society, the long term assessments should be carried out with the following hydrodynamic model:

- zero forward speed
- Bretschneider wave spectrum
- short crested sea
- a suitable range of wave frequencies to cover the range of the sea spectrum (typically 0,2-2,0 rad/s with not less than 20 frequencies). Most frequencies are to be placed in the range where most wave energy is present, and the calculation of RAO's at irregular frequencies is to be avoided
- at least 12 evenly distributed heading angles
- uniform distribution of heading angles, meaning that the same probability (e.g. 1/12 if 12 heading angles are considered) is assigned to each considered heading
- extreme responses are to be determined at 10^{-8} probability of exceeding.

3.3 Sea state scatter diagram

3.3.1 The scatter diagram to be applied in the spectral approach relates the probability of occurrence to a wide range of sea states, characterised by their significant wave height and zero up-crossing period.

When considering unrestricted service the scatter diagram shown in Tab 2 is to be applied. However, in case of ship with a restricted navigation notation, different scatter diagrams may be applied when agreed on with the Society.

Table 2 : Recommended sea state scatter diagram for unrestricted service

H_S	T_Z																	
	1,5	2,5	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5	SUM
0,5	0	0	1,3	133,7	865,6	1186	634,2	186,3	36,9	5,6	0,7	0,1	0	0	0	0	0	0	3050
1,5	0	0	0	29,3	986	4976	7738	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0	0	0	22575
2,5	0	0	0	2,2	197,5	2158,8	6230	7449,5	4860,4	2066	644,5	160,2	33,7	6,3	1,1	0,2	0	0	23810
3,5	0	0	0	0,2	34,9	695,5	3226,5	5675	5099,1	2838	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0	19128
4,5	0	0	0	0	6	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0	13289
5,5	0	0	0	0	1	51	498,4	1602,9	2372,7	2008,3	1126	463,6	150,9	41	9,7	2,1	0,4	0,1	8328
6,5	0	0	0	0	0,2	12,6	167	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1	4806
7,5	0	0	0	0	0	3	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0	2586
8,5	0	0	0	0	0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1	1309
9,5	0	0	0	0	0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1	626
10,5	0	0	0	0	0	0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4	1,2	0,3	0,1	285
11,5	0	0	0	0	0	0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1	124
12,5	0	0	0	0	0	0	0,1	1	4,4	9,9	12,8	11	6,8	3,3	1,3	0,4	0,1	0	51
13,5	0	0	0	0	0	0	0	0,3	1,4	3,5	5	4,6	3,1	1,6	0,7	0,2	0,1	0	21
14,5	0	0	0	0	0	0	0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0	0	8
15,5	0	0	0	0	0	0	0	0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0	0	3
16,5	0	0	0	0	0	0	0	0	0	0,1	0,2	0,2	0,2	0,1	0,1	0	0	0	1
SUM	0	0	1	165	2091	9280	19922	24879	20870	12898	6245	2479	837	247	66	16	3	1	100.0000

Note 1: H_S is the significant wave height and T_Z is the zero up-crossing period of the short term sea states. The probability of a sea state is given as fractions of 100.000.

Part B
Hull and Stability

CHAPTER 4
STRUCTURE DESIGN PRINCIPLES

Section 1	Materials
Section 2	Net Scantling Approach
Section 3	Strength Principles
Section 4	Bottom Structure
Section 5	Side Structure
Section 6	Deck Structure
Section 7	Bulkhead Structure

Section 1 Materials

1 General

1.1 Characteristics of materials

1.1.1 Materials used during construction of ships are to comply with the applicable requirements of NR216 Materials and Welding.

1.1.2 Materials other than those covered in [1.1.1] may be accepted, provided that their specification (e.g. manufacture, chemical composition, mechanical properties, welding, etc.) is submitted to the Society for approval.

1.2 Testing of materials

1.2.1 Materials are to be tested in compliance with the applicable requirements of NR216 Materials and Welding.

1.3 Manufacturing processes

1.3.1 The requirements of this Section presume that welding and other cold or hot manufacturing processes are carried out in compliance with current sound working practice and the applicable requirements of NR216 Materials and Welding.

In particular:

- parent material and welding processes are to be approved within the limits stated for the specified type of material for which they are intended
- specific preheating may be required before welding
- welding or other cold or hot manufacturing processes may need to be followed by an adequate heat treatment.

2 Steels for hull structure

2.1 Application

2.1.1 Steel having a specified minimum yield stress equal to 235 N/mm² is regarded as normal strength steel and is denoted “NSS”. Steel having a higher specified minimum yield stress is regarded as higher strength steel and is denoted “HSS”.

Steel grades are referred to as follows:

- A, B, D and E denote normal strength steel grades
- AH, DH and EH denote higher strength steel grades.

Tab 1 gives the mechanical characteristics of steels generally used in the construction of ships.

Higher strength steels other than those indicated in Tab 1 are considered by the Society on a case-by-case basis.

2.1.2 When steels with a minimum guaranteed yield stress R_{eH} other than 235 N/mm² are used on a ship, hull scantlings are to be determined, taking into account the material factor k defined in [2.3].

2.1.3 Characteristics of steels with specified through thickness properties are given in NR216, Ch 3, Sec 1, [12].

Table 1 : Mechanical properties of hull steels

Steel grades	t, in mm	R_{eH}, in N/mm²	R_m, in N/mm²
A-B-D-E	≤ 100	235	400 - 520
AH32-DH32-EH32	≤ 100	315	440 - 570
FH32	≤ 50		
AH36-DH36-EH36	≤ 100	355	490 - 630
FH36	≤ 50		
AH40-DH40-EH40 FH40	≤ 50	390	510 - 660
Note 1: Refer to NR216 Materials and Welding, Ch 2, Sec 1, [2]. t : Gross thickness R_{eH} : Minimum yield stress R_m : Ultimate minimum tensile strength.			

2.2 Information to be kept on board

2.2.1 A plan indicating the steel types and grades adopted for the hull structures is to be kept on board. Where steels other than those indicated in Tab 1 are used, their mechanical and chemical properties, as well as any workmanship requirements or recommendations, are to be available on board together with the above plan. When materials with sensitive know-how are used, it may be accepted that they are only documented on case by case for repair in service.

2.3 Material factor k

2.3.1 Unless otherwise specified, the material factor k has the values defined in Tab 2, as a function of the minimum guaranteed yield stress R_{eH}.

For intermediate values of R_{eH} , k may be obtained by linear interpolation.

Table 2 : Material factor k

R_{eH} , in N/mm²	k
235	1,00
315	0,78
355	0,72
390	0,68

2.3.2 Steels with a yield stress lower than 235 N/mm² or greater than 390 N/mm² are considered by the Society on a case-by-case basis.

When steels with a yield stress greater than 390 N/mm² are used, the material factor k is limited to 0,68 for scantlings calculations under Rules loads.

2.3.3 For strength checks as detailed in Part B, Chapter 7 and Part B, Chapter 8 under local loads whose frequency of appearance is not liable to create fatigue damage (e.g. helicopter landing), the minimum yield stress of the material R_y may be considered equal to R_{eH} , subject to the special agreement of the Society on a case-by-case basis.

2.4 Grades of steel

2.4.1 For the purpose of the selection of steel grades to be used for the various structural members, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 3.

Tab 3 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

2.4.2 Materials are to be of a grade not lower than that indicated in Tab 3 or in Tab 5 for front line or second line ships, depending on the material class and structural member gross thickness (see [2.4.5]).

2.4.3 For strength members not mentioned in Tab 3, grade A/AH may generally be used.

2.4.4 Single strakes required to be of class III or of grade E/EH are to have a breadth within 0,4L amidships not less than (800 + 5 L) mm, but not necessarily greater than 1800 mm.

2.4.5 The steel grade is to correspond to the as-fitted gross thickness when this one is greater than the gross thickness obtained from the net thickness required by the Rules, according to Ch 4, Sec 2, [1].

2.4.6 Steel grades of plates or sections of gross thickness greater than the limiting thicknesses in Tab 1 are considered by the Society on a case-by-case basis.

2.4.7 In specific cases, such as in [2.4.8], with regard to stress distribution along the hull girder, the classes required within 0,4 L amidships may be extended beyond that zone, on a case-by-case basis.

2.4.8 The material classes required for the strength deck plating, the sheerstrake and the upper strake of longitudinal bulkheads within 0,4 L amidships are to be maintained over an adequate length across the poop front and at the ends of the bridge, where fitted.

2.4.9 Rolled products used for welded attachments on hull plating, such as gutter bars and bilge keels, are to be of the same grade (or equivalent) as the one used for the hull plating in way.

Where it is necessary to weld attachments to the sheerstrake or stringer plate, attention is to be given to the appropriate choice of material and design, the workmanship and welding and the absence of prejudicial undercuts and notches, with particular regard to any free edges of the material.

2.4.10 In the case of full penetration welded joints located in positions where high local stresses may occur perpendicular to the continuous plating, the Society may, on a case-by-case basis, require the use of rolled products having adequate ductility properties in the through thickness direction, such as to prevent the risk of lamellar tearing (Z type steel, see NR216 Materials and Welding). For such situation involving small weight of plates, a case-by-case consideration is to be given.

2.4.11 In highly stressed areas other than Class III according to Tab 3, the Society may require that plates of gross thickness greater than 20 mm are of grade D/DH or E/EH.

Table 3 : Application of material classes and grades

Structural member category	Material class or grade	
	Within 0,4 L amidships	Outside 0,4 L amidships
SECONDARY: Lower strake in longitudinal bulkhead Deck plating exposed to weather (in general) Side plating	I	A / AH**(6)**
PRIMARY: Bottom plating (including keel plate) Strength deck plating **(1)** Continuous longitudinal members above strength deck (excluding continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length) Upper strake in longitudinal bulkhead Vertical strake (hatch side girder) and upper sloped strake in topside tank	II	A / AH **(7)**
SPECIAL: Sheerstrake at strength deck **(2)** Stringer plate in strength deck**(2)** Deck strake at longitudinal bulkhead Bilge strake **(3)** **(4)** Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(6)**	III	II **(8)** (I outside 0,6 L amidships)

(1) Plating at corners of large hatch openings to be considered on a case-by-case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur
(2) To be not less than grade E/EH within 0,4L amidships in ships greater than 250 m in length
(3) May be of class II in ships less than 150 m in length and having a double bottom over the full breadth
(4) To be not less than grade D/DH in ships greater than 250 m in length
(5) To be not less than grade D/DH
(6) To be of class I for front line or second line ships
(7) To be of class II for front line and second line ships
(8) To be of class III for front line and second line ships.

Note 1: Plating materials for sternframes, rudders, rudder horns and shaft brackets are generally to be of grades not lower than those corresponding to class II.
For rudder and rudder blade plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders), class III is to be applied.

Note 2: Bedplates of seats for propulsion and auxiliary engines inserted in the inner bottom are to be of class I. In other cases, the steel may be generally of grade A. Different grades may be required by the Society on a case-by-case basis.

Note 3: Plating at corners of large hatch openings on decks located below the strength deck, in the case of hatches of holds for refrigerated cargoes, and insert plates at corners of large openings on side shell plating are generally to be of class III.

Table 4 : Material grade requirements for classes I, II and III

Class	I		II		III	
Gross thickness, in mm	NSS	HSS	NSS	HSS	NSS	HSS
$t \leq 15$	A	AH	A	AH	A	AH
$15 < t \leq 20$	A	AH	A	AH	B	AH
$20 < t \leq 25$	A	AH	B	AH	D	DH
$25 < t \leq 30$	A	AH	D	DH	D	DH
$30 < t \leq 35$	B	AH	D	DH	E	EH
$35 < t \leq 40$	B	AH	D	DH	E	EH
$40 < t \leq 50$	D	DH	E	EH	E	EH

Note 1: see [2.1.1] for definitions of NSS and HSS.

2.5 Grades of steel for structures exposed to low air temperatures

2.5.1 For ships intended to operate in areas with low air temperatures (–20°C or below), e.g. regular service during winter seasons to Arctic or Antarctic waters, the materials in exposed structures are to be selected based on the design temperature t_D , to be taken as defined in [2.5.2].

2.5.2 The design temperature t_D is to be taken as the lowest mean daily average air temperature in the area of operation, where:

Mean : Statistical mean over observation period (at least 20 years)

Average : Average during one day and night

Lowest : Lowest during one year.

Fig 1 illustrates the temperature definition.

For seasonally restricted service, the lowest value within the period of operation applies.

2.5.3 For the purpose of the selection of steel grades to be used for the structural members above the lowest ballast waterline and exposed to air, the latter are divided into categories (SECONDARY, PRIMARY and SPECIAL), as indicated in Tab 5.

Tab 5 also specifies the classes (I, II and III) of the materials to be used for the various categories of structural members.

For non-exposed structures and structures below the lowest ballast waterline, see [2.4].

2.5.4 Materials may not be of a lower grade than that indicated in Tab 6 to Tab 8 depending on the material class, the structural member gross thickness and design temperature t_D.

For design temperatures $t_D < -55°C$, materials are to be specially considered by the Society on a case-by-case basis.

2.5.5 Single strakes required to be of class III or of grade E/EH or FH are to have breadths not less than (800+5L) mm, but not necessarily greater than 1800 mm.

Figure 1 : Commonly used definitions of temperatures

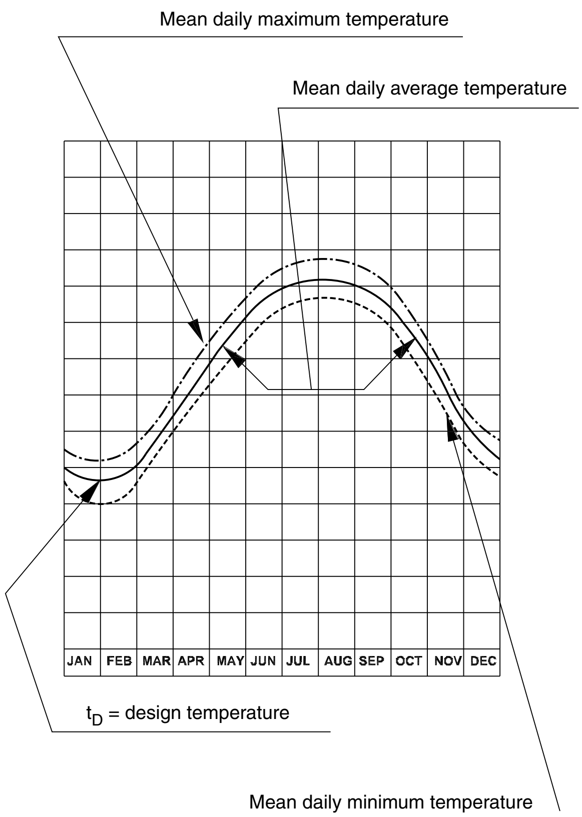


Table 5 : Application of material classes and grades - Structures exposed to low air temperatures

Structural member category	Material class	
	Within 0,4 L amidships	Outside 0,4 L amidships
SECONDARY: Deck plating exposed to weather (in general) Side plating above T_B **(1)** Transverse bulkheads above T_B **(1)**	I	I
PRIMARY: Strength deck plating **(2)** Continuous longitudinal members above strength deck (excluding longitudinal hatch coamings of ships equal to or greater than 90 m in length) Longitudinal bulkhead above T_B **(1)** Topside tank bulkhead above T_B **(1)**	II	I
SPECIAL: Sheerstrake at strength deck **(3)** Stringer plate in strength deck **(3)** Deck strake at longitudinal bulkhead Continuous longitudinal hatch coamings of ships equal to or greater than 90 m in length **(4)**	III	II

(1) T_B is the draught in light ballast condition, defined in Ch 5, Sec 1, [2.4.3]
(2) Plating at corners of large hatch openings to be considered on a case-by-case basis. Class III or grade E/EH to be applied in positions where high local stresses may occur
(3) To be not less than grade E/EH within 0,4 L amidships in ships greater than 250 m in length
(4) To be not less than grade D/DH.
Note 1: Plating materials for sternframes, rudder horns, rudders and shaft brackets are to be of grades not lower than those corresponding to the material classes in [2.4].

Table 6 : Material grade requirements for class I at low temperatures

Gross thickness, in mm	−20°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	A	AH	B	AH	D	DH	D	DH
10 < t ≤ 15	B	AH	D	DH	D	DH	D	DH
15 < t ≤ 20	B	AH	D	DH	D	DH	E	EH
20 < t ≤ 25	D	DH	D	DH	D	DH	E	EH
25 < t ≤ 30	D	DH	D	DH	E	EH	E	EH
30 < t ≤ 35	D	DH	D	DH	E	EH	E	EH
35 < t ≤ 45	D	DH	E	EH	E	EH	N.A.	FH
45 < t ≤ 50	E	EH	E	EH	N.A.	FH	N.A.	FH

Note 1: see [2.1.1] for definitions of NSS and HSS.
Note 2: N.A. = Not applicable.

Table 7 : Material grade requirements for class II at low temperatures

Gross thickness, in mm	−20°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	B	AH	D	DH	D	DH	E	EH
10 < t ≤ 20	D	DH	D	DH	E	EH	E	EH
20 < t ≤ 30	D	DH	E	EH	E	EH	N.A.	FH
30 < t ≤ 40	E	EH	E	EH	N.A.	FH	N.A.	FH
40 < t ≤ 45	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
45 < t ≤ 50	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.

Note 1: see [2.1.1] for definitions of NSS and HSS.
Note 2: N.A. = Not applicable.

Table 8 : Material grade requirements for class III at low temperatures

Gross thickness, in mm	−20°C / −25°C		−26°C / −35°C		−36°C / −45°C		−46°C / −55°C	
	NSS	HSS	NSS	HSS	NSS	HSS	NSS	HSS
t ≤ 10	D	DH	D	DH	E	EH	E	EH
10 < t ≤ 20	D	DH	E	EH	E	EH	N.A.	FH
20 < t ≤ 25	E	EH	E	EH	N.A.	FH	N.A.	FH
25 < t ≤ 30	E	EH	E	EH	N.A.	FH	N.A.	FH
30 < t ≤ 35	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
35 < t ≤ 40	E	EH	N.A.	FH	N.A.	FH	N.A.	N.A.
40 < t ≤ 50	N.A.	FH	N.A.	FH	N.A.	N.A.	N.A.	N.A.

Note 1: see [2.1.1] for definitions of NSS and HSS.
Note 2: N.A. = Not applicable.

2.6 Grades of steel within refrigerated spaces

2.6.1 For structural members within or adjacent to refrigerated spaces, when the design temperature is below 0°C, the materials are to be of grade not lower than those indicated in Tab 9, depending on the design temperature, the structural member gross thickness and its category (as defined in Tab 3).

2.6.2 Unless a temperature gradient calculation is carried out to assess the design temperature and the steel grade in the structural members of the refrigerated spaces, the temperatures to be assumed are specified below:

- temperature of the space on the uninsulated side, for plating insulated on one side only, either with uninsulated stiffening members (i.e. fitted on the uninsulated side of plating) or with insulated stiffening members (i.e. fitted on the insulated side of plating)
- mean value of temperatures in the adjacent spaces, for plating insulated on both sides, with insulated stiffening members, when the temperature difference between the adjacent spaces is generally not greater than 10°C (when the temperature difference between the adjacent spaces is greater than 10°C, the temperature value is established by the Society on a case-by-case basis)
- in the case of non-refrigerated spaces adjacent to refrigerated spaces, the temperature in the non-refrigerated spaces is to be conventionally taken equal to 0°C.

2.6.3 Situations other than those mentioned in [2.6.1] and [2.6.2] or special arrangements are to be considered by the Society on a case-by-case basis.

2.6.4 Irrespective of the provisions of [2.6.1], [2.6.2] and Tab 9, steel having grades lower than those required in [2.4], Tab 3 and Tab 4 and in relation to the class and the gross thickness of the structural member considered may not be used.

Table 9 : Material grade requirements for members within or adjacent to refrigerated spaces

Design temperature, in °C	Gross thickness, in mm	Structural member category	
		Secondary	Primary or Special
$-10 \le t_D < 0$	t ≤ 20	B / AH	B / AH
	20 < t ≤ 25	B / AH	D / DH
	t > 25	D / DH	E / EH
$-25 \le t_D < -10$	t ≤ 15	B / AH	D / DH
	15 < t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH
$-40 \le t_D < -25$	t ≤ 25	D / DH	E / EH
	t > 25	E / EH	E / EH

3 Steels for forging and casting

3.1 General

3.1.1 Mechanical and chemical properties of steels for forging and casting to be used for structural members are to comply with the applicable requirements of NR216 Materials and Welding.

3.1.2 Steels of structural members intended to be welded are to have mechanical and chemical properties deemed appropriate for this purpose by the Society on a case-by-case basis.

3.1.3 The steels used are to be tested in accordance with the applicable requirements of NR216 Materials and Welding.

3.2 Steels for forging

3.2.1 For the purpose of testing, which is to be carried out in accordance with the applicable requirements of NR216 Materials and Welding, the above steels for forging are assigned to class 1 (see NR216 Materials and Welding, Ch 2, Sec 3, [1.2]).

3.2.2 Rolled bars may be accepted in lieu of forged products, after consideration by the Society on a case-by-case basis.

In such case, compliance with the requirements of NR216 Materials and Welding, Ch 2, Sec 1, relevant to the quality and testing of rolled parts accepted in lieu of forged parts, may be required.

3.3 Steels for casting

3.3.1 Cast parts intended for stems, sternframes, rudders, parts of steering gear and deck machinery in general may be made of C and C-Mn weldable steels of quality 1, having tensile strength R_m equal to 400 N/mm² or 440 N/mm², in accordance with the applicable requirements of NR216 Materials and Welding, Ch 2, Sec 4.

Items which may be subjected to high stresses may be required to be of quality 2 steels of the above types.

3.3.2 For the purpose of testing, which is to be carried out in accordance with NR216 Materials and Welding, Ch 2, Sec 4, [1.11], the above steels for casting are assigned to class 1 irrespective of their quality.

3.3.3 The welding of cast parts to main plating contributing to hull strength members is considered by the Society on a case-by-case basis.

The Society may require additional properties and tests for such casting, in particular impact properties which are appropriate to those of the steel plating on which the cast parts are to be welded and non-destructive examinations.

3.3.4 Heavily stressed cast parts of steering gear, particularly those intended to form a welded assembly and tillers or rotors mounted without key, are to be subjected to non-destructive examination to check their internal structure.

4 Aluminium alloy structures

4.1 General

4.1.1 The characteristics of aluminium alloys are to comply with the requirements of NR216 Materials and Welding, Ch 3, Sec 2.

Series 5000 aluminium-magnesium alloys or series 6000 aluminium-magnesium-silicon alloys are generally to be used (see NR216 Materials and Welding, Ch 3, Sec 2, [2]).

4.1.2 In the case of structures subjected to low service temperatures or intended for other specific applications, the alloys to be employed are defined in each case by the Society, which states the acceptability requirements and conditions.

4.2 Extruded plating

4.2.1 Extrusions with built-in plating and stiffeners, referred to as extruded plating, may be used.

4.2.2 In general, the application is limited to decks, bulkheads, superstructures and deckhouses and any other element not contributing to the hull girder strength. Other uses may be permitted by the Society on a case-by-case basis.

4.2.3 Extruded plating is preferably to be oriented so that the stiffeners are parallel to the direction of main stresses.

4.2.4 Connections between extruded plating and primary members are to be given special attention.

4.3 Influence of welding on mechanical characteristics

4.3.1 Welding heat input lowers locally the mechanical strength of aluminium alloys hardened by work hardening (series 5000 other than condition 0 or H111) or by heat treatment (series 6000).

4.3.2 Consequently, where necessary, a drop in the mechanical characteristics of welded structures with respect to those of the parent material is to be considered in the heat-affected zone.

The heat-affected zone may be taken to extend 25 mm on each side of the weld axis.

4.3.3 Aluminium alloys of series 5000 in 0 condition (annealed) or in H111 condition (annealed flattened) are not subject to a drop in mechanical strength in the welded areas.

4.3.4 Aluminium alloys of series 5000 other than condition 0 or H111 are subject to a drop in mechanical strength in the welded areas.

The mechanical characteristics to consider are normally those of condition 0 or H111.

Higher mechanical characteristics may be taken into account, provided they are duly justified.

4.3.5 Aluminium alloys of series 6000 are subject to a drop in mechanical strength in the vicinity of the welded areas.

The mechanical characteristics to be considered are normally indicated by the supplier.

4.4 Material factor k

4.4.1 The material factor k for aluminium alloys is to be obtained from the following formula:

$$k = \frac{235}{R'_{lim}}$$

where:

R'_{lim} : Minimum guaranteed yield stress of the parent metal in welded condition $R'_{p0,2}$, in N/mm², but not to be taken greater than 70% of the minimum guaranteed tensile strength of the parent metal in welded condition R'_m, in N/mm²

$R'_{p0,2} = \eta_1 \, R_{p0,2}$

$R'_m = \eta_2 \, R_m$

$R_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of the parent metal in delivery condition

R_m : Minimum guaranteed tensile stress, in N/mm², of the parent metal in delivery condition.

η_1 and η_2 are given in Tab 10.

4.4.2 In the case of welding of two different aluminium alloys, the material factor k to be considered for the scantlings is the greater material factor of the aluminium alloys of the assembly.

4.4.3 For welded constructions in hardened aluminium alloys (series 5000 other than condition 0 or H111 and series 6000), greater characteristics than those in welded condition may be considered, provided that welded connections are located in areas where stress levels are acceptable for the alloy considered in annealed or welded condition.

Table 10 : Aluminium alloys for welded construction

Aluminium alloy	η_1	η_2
Alloys without work-hardening treatment (series 5000 in annealed condition 0 or annealed flattened condition H111)	1	1
Alloys hardened by work hardening (series 5000 other than condition 0 or H111)	$R'_{p0,2}/R_{p0,2}$	R'_m / R_m
Alloys hardened by heat treatment (series 6000) **(1)**	$R'_{p0,2}/R_{p0,2}$	0,6

(1) When no information is available, coefficient η is to be taken equal to the metallurgical efficiency coefficient β defined in Tab 11.

Note 1:

$R'_{p0,2}$: Minimum guaranteed yield stress, in N/mm², of material in welded condition (see [4.3]).

R'_m : Minimum guaranteed tensile stress, in N/mm², of material in welded condition (see [4.3]).

Table 11 : Aluminium alloys Metallurgical efficiency coefficient β

Aluminium alloy	Temper condition	Gross thickness	β
6005 A (Open sections)	T5 or T6	$t \le 6$ mm	0,45
		$t > 6$ mm	0,40
6005 A (Closed sections)	T5 or T6	all	0,50
6061 (Sections)	T6	all	0,53
6082 (Sections)	T6	all	0,45

5 Other materials and products

5.1 General

5.1.1 Other materials and products such as parts made of iron castings, where allowed, products made of copper and copper alloys, rivets, anchors, chain cables, cranes, masts, derrick posts, derricks, accessories and wire ropes are generally to comply with the applicable requirements of NR216 Materials and Welding.

5.1.2 The use of plastics or other special materials not covered by these Rules is to be considered by the Society on a case-by-case basis. In such cases, the Society states the requirements for the acceptance of the materials concerned.

5.1.3 Materials used in welding processes are to comply with the applicable requirements of NR216 Materials and Welding.

5.2 Iron cast parts

5.2.1 As a rule, the use of grey iron, malleable iron or spheroidal graphite iron cast parts with combined ferritic/perlitic structure is allowed only to manufacture low stressed elements of secondary importance.

5.2.2 Ordinary iron cast parts may not be used for windows or sidescuttles; the use of high grade iron cast parts of a suitable type is to be considered by the Society on a case-by-case basis.

Section 2 Net Scantling Approach

Symbols

t_C : Rule corrosion addition, in mm, see Article [3]
w_N : Net section modulus, in cm^3, of ordinary stiffeners
w_G : Gross section modulus, in cm^3, of ordinary stiffeners.

1 Application criteria

1.1 General

1.1.1 The scantlings obtained by applying the criteria specified in Part B are net scantlings, i.e. those which provide the strength characteristics required to sustain the loads, excluding any addition for corrosion. Exceptions are the scantlings of:

- bow and inner doors in Ch 8, Sec 5
- side doors and stern doors in Ch 8, Sec 6
- rudder structures and hull appendages in Part B, Chapter 9
- massive pieces made of steel forgings, steel castings or iron castings,

which are gross scantlings, i.e. they include additions for corrosion.

1.1.2 The required strength characteristics are:

- thickness, for plating including that which constitutes primary supporting members
- section modulus, shear area, moments of inertia and local thickness, for ordinary stiffeners and, as the case may be, primary supporting members
- section modulus, moments of inertia and single moment for the hull girder.

1.1.3 The ship is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Tab 2, to the net scantlings.

2 Net strength characteristic calculation

2.1 Designer's proposal based on gross scantlings

2.1.1 General criteria

If the Designer provides the gross scantlings of each structural element without providing the corrosion additions, the structural checks are to be carried out on the basis of the net strength characteristics, derived as specified in [2.1.2] to [2.1.6].

2.1.2 Plating

The net thickness is to be obtained by deducting t_c from the gross thickness.

2.1.3 Ordinary stiffeners

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the stiffener profile. For bulb profiles, an equivalent angle profile, as specified in Ch 4, Sec 3, [3.1.2], may be considered.

The net strength characteristics are to be calculated for the net transverse section. As an alternative, the net section modulus may be obtained from the following formula:

$$w_N = w_G(1 - \alpha t_C) - \beta t_C$$

where α and β are the coefficients defined in Tab 1.

Table 1 : Coefficients α and β

Type of ordinary stiffeners	α	β
Flat bars	0,035	2,8
Flanged profiles	0,060	14,0
Bulb profiles: $w_G \le 200$ cm^3 $w_G > 200$ cm^3	 0,070 0,035	 0,4 7,4

2.1.4 Primary supporting members analysed through an isolated beam structural model

The net transverse section is to be obtained by deducting t_C from the gross thickness of the elements which constitute the primary supporting members.

The net strength characteristics are to be calculated for the net transverse section.

2.1.5 Primary supporting members analysed through a three dimensional model or a complete ship model

The net thickness of plating which constitutes primary supporting members is to be obtained by deducting 0,5 t_c from the gross thickness.

2.1.6 Hull girder net strength characteristics

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having net scantlings calculated on the basis of the corrosion additions t_C , according to [2.1.2] to [2.1.4].

2.2 Designer's proposal based on net scantlings

2.2.1 Net strength characteristics and corrosion additions

If the Designer provides the net scantlings of each structural element, the structural checks are to be carried out on the basis of the proposed net strength characteristics.

The Designer is also to provide the corrosion additions or the gross scantlings of each structural element. The proposed corrosion additions are to be not less than the values specified in [3].

2.2.2 Hull girder net strength characteristic

For the hull girder, the net hull transverse sections are to be considered as being constituted by plating and stiffeners having the net scantlings proposed by the Designer.

It is to be checked whether:

$Z_{NAD} \geq 0,9\ Z_{GD}$

where:

Z_{NAD} : Net midship section modulus, in m^3, calculated on the basis of the net scantlings proposed by the Designer

Z_{GD} : Gross midship section modulus, in m^3, calculated on the basis of the gross scantlings proposed by the Designer.

Where the above condition is not satisfied, the hull girder normal and shear stresses, to be used for the checks of plating, ordinary stiffeners and primary supporting members analysed through an isolated beam structural model, are to be obtained by dividing by 0,9 those obtained by considering the hull girder transverse sections with their gross scantlings.

3 Corrosion additions

3.1 Values of corrosion additions

3.1.1 General

The values of the corrosion additions specified in this Article are to be applied in relation to the relevant protective coatings required by the Rules.

The Designer may define values of corrosion additions greater than those specified in [3.1.2].

The values of corrosion additions as given in Tab 2 apply to structure scantlings resulting from loads under normal operation at sea in peace time.

3.1.2 Corrosion additions for steel other than stainless steel

In general, the corrosion addition to be considered for plating forming the boundary between two compartments of different types is the sum of the values specified in Tab 2 for one side exposure to each compartment.

For an internal member within a given compartment, or for plating forming the boundary between two compartments of the same type, the corrosion addition to be considered is twice the value specified in Tab 2 for one side exposure to that compartment.

When, according to Tab 2, a structural element is affected by more than one value of corrosion additions (e.g. a side frame in a dry bulk cargo hold extending above the lower zone), the scantling criteria are generally to be applied considering the value of corrosion addition applicable at the lowest point of the element.

3.1.3 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

3.1.4 Corrosion additions for non-alloyed steel clad with stainless steel

For plates made of non-alloyed steel clad with stainless steel, the corrosion addition t_c is to be taken equal to 0 only for the plate side clad with stainless steel.

3.1.5 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_c is to be taken equal to 0.

Table 2 : Corrosion additions t_c, in mm, for each exposed side

<table>
<tr><th colspan="2">Compartment type</th><th>General (1)</th><th>Special cases</th></tr>
<tr><td colspan="2">Ballast tank</td><td>1,00</td><td>1,25 in upper zone (2)</td></tr>
<tr><td rowspan="3">Fuel oil tank</td><td>Plating of horizontal surfaces</td><td>0,75</td><td>1,00 in upper zone (2)</td></tr>
<tr><td>Plating of non-horizontal surfaces</td><td>0,50</td><td>1,00 in upper zone (2)</td></tr>
<tr><td>Ordinary stiffeners and primary supporting members</td><td>0,75</td><td rowspan="2">1,00 in upper zone (2)</td></tr>
<tr><td colspan="2">Accommodation space</td><td>0,00</td></tr>
<tr><td colspan="2">Compartments other than those mentioned above
Outside sea and air</td><td>0,50</td><td></td></tr>
<tr><td colspan="4">(1) General: corrosion additions t_c are applicable to all members of the considered item with possible exceptions given for upper and lower zones.
(2) Upper zone: area within 1,5 m below the top of the tank. This is to be applied only to tanks with weather deck as the tank top.</td></tr>
</table>

Section 3 Strength Principles

Symbols

E : Young's modulus, in N/mm^2, to be taken equal to:
- for steels in general:
  $E = 2{,}06 \cdot 10^5$ N/mm^2
- for stainless steels:
  $E = 1{,}95 \cdot 10^5$ N/mm^2
- for aluminium alloys:
  $E = 7{,}0 \cdot 10^4$ N/mm^2

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as the case may be

ℓ : Span, in m, of an ordinary stiffener or a primary supporting member, as the case may be, measured between the supporting members (see Fig 2 to Fig 5)

ℓ_b : Length, in m, of brackets (see Fig 4 and Fig 5)

h_w : Web height, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_w : Net web thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

b_f : Face plate width, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_f : Net face plate thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener or a primary supporting member, as the case may be

w : Net section modulus, in cm^3, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

I : Net moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, without attached plating, around its neutral axis parallel to the plating (see Fig 4 and Fig 5)

I_B : Net moment of inertia, in cm^4, of an ordinary stiffener or a primary supporting member, as the case may be, with bracket and without attached plating, around its neutral axis parallel to the plating, calculated at mid-length of the bracket (see Fig 4 and Fig 5).

1 General principles

1.1 Structural continuity

1.1.1 The variation in scantlings between the midship region and the fore and aft parts is to be gradual.

1.1.2 Attention is to be paid to the structural continuity:
- in way of changes in the framing system
- at the connections of primary supporting members or ordinary stiffeners
- in way of the ends of the fore and aft parts (see Ch 8, Sec 1 and Ch 8, Sec 2) and machinery space (see Ch 8, Sec 3)
- in way of ends of superstructures (see Ch 8, Sec 4).

1.1.3 Longitudinal members contributing to the hull girder longitudinal strength, according to Ch 6, Sec 1, [2], are to extend continuously over a sufficient distance towards the ends of the ship.

Ordinary stiffeners contributing to the hull girder longitudinal strength are generally to be continuous when crossing primary supporting members. Otherwise, the detail of connections is considered by the Society on a case-by-case basis.

Longitudinals of the bottom, bilge, sheerstrake, deck, upper and lower longitudinal bulkhead and inner side strakes, as well as the latter strakes themselves, the lower strake of the centreline bottom girder and the upper strake of the centreline deck girder, where fitted, are to be continuous through the transverse bulkheads. Alternative solutions may be examined by the Society on a case-by-case basis, provided they are equally effective.

1.1.4 Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

1.1.5 Openings are to be avoided, as far as practicable, in way of highly stressed areas.

Where necessary, the shape of openings is to be specially designed to reduce the stress concentration factors.

Openings are to be generally well rounded with smooth edges.

1.1.6 Primary supporting members are to be arranged in such a way that they ensure adequate continuity of strength. Abrupt changes in height or in cross-section are to be avoided.

1.2 Connections with higher strength steel

1.2.1 The vertical extent of higher strength steel is to comply with the requirements of Ch 6, Sec 2, [4.5].

1.2.2 When a higher strength steel is adopted at deck, members not contributing to the longitudinal strength and welded on the strength deck (e.g. hatch coamings, strengthening of deck openings) are also generally to be made of the same higher strength steel.

1.3 Connections between steel and aluminium

1.3.1 Any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

1.3.2 Any heterogeneous jointing system is considered by the Society on a case-by-case basis.

1.3.3 The use of transition joints made of aluminium/steel-clad plates or profiles is considered by the Society on a case-by-case basis (see NR216 Materials and Welding, Ch 3, Sec 2, [4]).

2 Plating

2.1 Insert plates and doublers

2.1.1 A local increase in plating thickness is generally to be achieved through insert plates. Local doublers, which are normally only allowed for temporary repair, may however be accepted by the Society on a case-by-case basis.

In any case, doublers and insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

2.1.2 Doublers having a width, in mm, greater than:

- 20 times their thickness, for thicknesses equal to or less than 15 mm
- 25 times their thickness, for thicknesses greater than 15 mm,

are to be fitted with slot welds, to be effected according to Ch 11, Sec 1, [2.6].

2.1.3 When doublers fitted on the outer shell and strength deck within 0,6 L amidships are accepted by the Society, their width and thickness are to be such that slot welds are not necessary according to the requirements in [2.1.2]. Outside this area, the possibility of fitting doublers requiring slot welds is to be considered by the Society on a case-by-case basis.

3 Ordinary stiffeners

3.1 General

3.1.1 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus may be obtained, in cm^3, from the following formula:

$$w = w_0 \sin \alpha$$

where:

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the plating

α : Angle between the stiffener web and the attached plating.

3.1.2 Bulb section: equivalent angle profile

A bulb section may be taken as equivalent to an angle profile.

The dimensions of the equivalent angle profile are to be obtained, in mm, from the following formulae:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \alpha\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

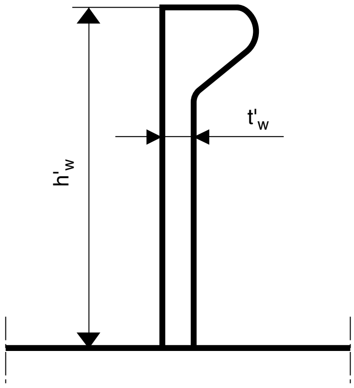
h'_w, t'_w : Height and net thickness of the bulb section, in mm, as shown in Fig 1

α : Coefficient equal to:

$$1{,}1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for } h'_w \le 120$$

$$1 \quad \text{for } h'_w > 120$$

Figure 1 : Dimensions of a bulb section



3.2 Span of ordinary stiffeners

3.2.1 General

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 2 to Fig 5.

Figure 2 : Ordinary stiffener without brackets

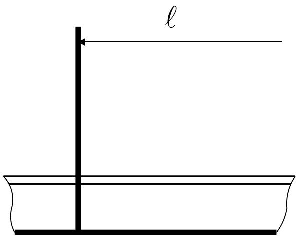


Figure 3 : Ordinary stiffener with a stiffener at one end

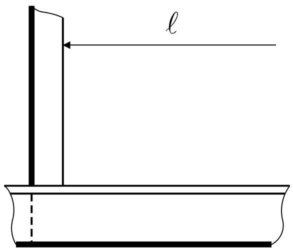


Figure 4 : Ordinary stiffener with end bracket

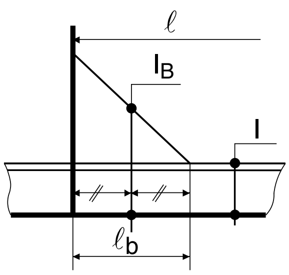
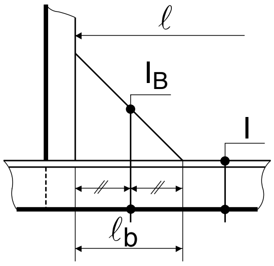


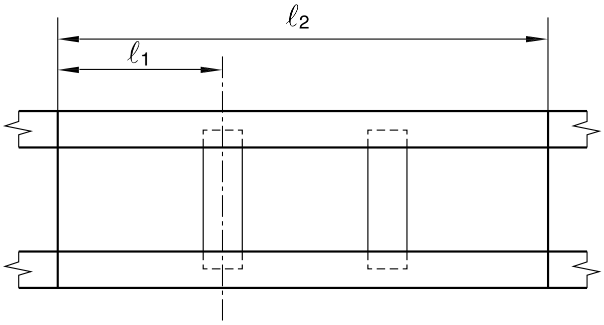
Figure 5 : Ordinary stiffener with a bracket and a stiffener at one end



3.2.2 Open floors

The span ℓ of transverse ordinary stiffeners connected by struts is to be taken as the greater of 1,4 ℓ_1 and 0,7 ℓ_2, where ℓ_1 and ℓ_2 are the spans defined in Fig 6.

Figure 6 : Span of ordinary stiffeners in the case of open floors



3.3 Width of attached plating

3.3.1 The width of the attached plating to be considered for the yielding check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the ordinary stiffener:

  $b_P = s$

- where the plating extends on one side of the ordinary stiffener (i.e. ordinary stiffeners bounding openings):

  $b_P = 0,5\ s$

3.3.2 Buckling check and ultimate strength check

The attached plating to be considered for the buckling and ultimate strength check of ordinary stiffeners is defined in Ch 7, Sec 2, [4.1] and Ch 7, Sec 2, [5.2], respectively.

3.4 Geometric properties

3.4.1 Built section

The geometric properties of built sections as shown in Fig 7 may be calculated as indicated in the following formulae. These formulae are applicable provided that:

$A_a \geq t_f b_f$

$\frac{h_w}{t_p} \geq 10$

$\frac{h_w}{t_f} \geq 10$

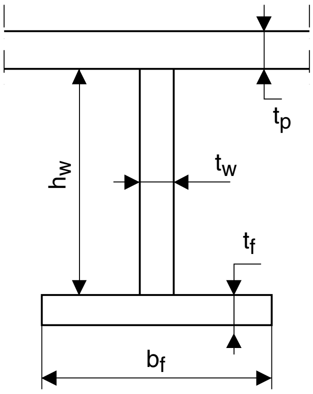
where:

A_a : Net sectional area, in mm², of the attached plating.

The net shear sectional area of a built section with attached plating is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{h_w t_w}{100}$$

Figure 7 : Dimensions of a built section



The net section modulus of a built section with attached plating is to be obtained, in cm³, from the following formula:

$$w = \frac{h_w t_f b_f}{1000} + \frac{t_W h_W^2}{6000}\left(1 + \frac{A_a - t_f b_f}{A_a + \frac{t_W h_W}{2}}\right)$$

The distance from the face plate to the neutral axis is to be obtained, in cm, from the following formula:

$$v = \frac{h_W(A_a + 0,5 t_W h_W)}{10(A_a + t_f b_f + t_W h_W)}$$

The net moment of inertia of a built section with attached plating is to be obtained, in cm⁴, from the following formula:

$I = w\ v$

3.4.2 Corrugations

The net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$$w = \frac{td}{6}(3b + c)10^{-3}$$

where:

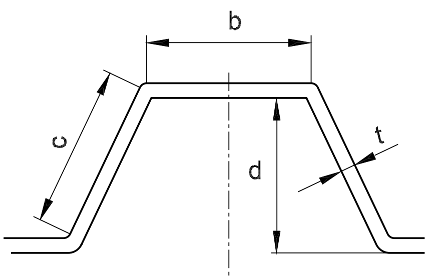
t : Net thickness of the plating of the corrugation, in mm

d, b, c : Dimensions of the corrugation, in mm, shown in Fig 8.

Where the web continuity is not ensured at ends of the bulkhead, the net section modulus of a corrugation is to be obtained, in cm³, from the following formula:

$w = 0,5\ b\ t\ d\ \ 10^{-3}$

Figure 8 : Dimensions of a corrugation



3.5 End connections

3.5.1 Where ordinary stiffeners are continuous through primary supporting members, they are to be connected to the web plating so as to ensure proper transmission of loads, e.g. by means of one of the connection details shown in Fig 9 to Fig 12.

Connection details other than those shown in Fig 9 to Fig 12 may be considered by the Society on a case-by-case basis. In some cases, the Society may require the details to be supported by direct calculations submitted for review.

Figure 9 : End connection of ordinary stiffener - Without collar plate

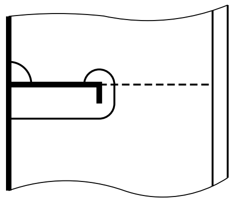


Figure 10 : End connection of ordinary stiffener - Collar plate

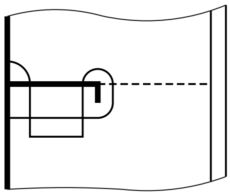


Figure 11 : End connection of ordinary stiffener - One large collar plate

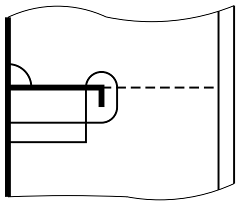
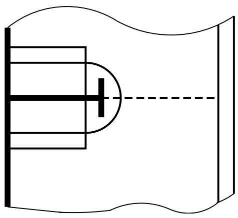


Figure 12 : End connection of ordinary stiffener - Two large collar plates

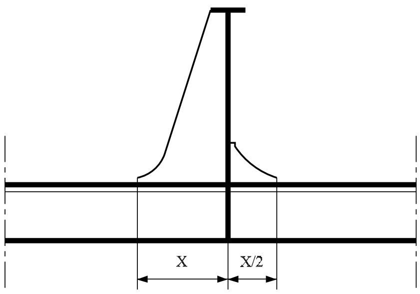


3.5.2 Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity. Their net section modulus and their net sectional area are to be not less than those of the ordinary stiffeners.

The net thickness of brackets is to be not less than that of ordinary stiffeners. Brackets with net thickness, in mm, less than 15 L_b , where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. As a Rule, the net sectional area, in cm^2, of the flanged edge or face plate is to be at least equal to 10 L_b . Other dimensions of the net sectional area of the flanged edge or face plate may be accepted if deemed equivalent or validated by experience.

3.5.3 Where necessary, the Society may require backing brackets to be fitted, as shown in Fig 13, in order to improve the fatigue strength of the connection (see also [4.7.4]).

Figure 13 : End connection of ordinary stiffener - Backing bracket



4 Primary supporting members

4.1 Span of primary supporting members

4.1.1 The span of primary supporting members is to be determined in accordance with [3.2].

4.2 Width of attached plating

4.2.1 General

The width of the attached plating to be considered for the yielding check of primary supporting members analysed through beam structural models is to be obtained, in m, from the following formulae:

- where the plating extends on both sides of the primary supporting member:

  $b_P = \text{Min}\ (s\ ;\ 0{,}2\ \ell)$

- where the plating extends on one side of the primary supporting member (i.e. primary supporting members bounding openings):

  $b_P = 0{,}5\ \text{Min}\ (s\ ;\ 0{,}2\ \ell)$

4.2.2 Corrugated bulkheads

The width of attached plating of corrugated bulkhead primary supporting members is to be determined as follows:

- when primary supporting members are parallel to the corrugations and are welded to the corrugation flanges, the width of the attached plating is to be calculated in accordance with [4.2.1] and is to be taken not greater than the corrugation flange width
- when primary supporting members are perpendicular to the corrugations, the width of the attached plating is to be taken equal to the width of the primary supporting member face plate.

4.3 Geometric properties

4.3.1 Standard roll sections

The geometric properties of primary supporting members made of standard roll sections may be determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

4.3.2 Built sections

The geometric properties of primary supporting members made of built sections (including primary supporting members of double skin structures, such as double bottom floors and girders) are generally determined in accordance with [3.4.1], reducing the web height h_w by the depth of the cut-out for the passage of ordinary stiffeners, if any (see [4.6.1]).

Additional requirements relevant to the net shear sectional area are provided in [4.3.3].

4.3.3 Net shear sectional area in the case of web large openings

Where large openings are fitted in the web of primary supporting members (e.g. where a pipe tunnel is fitted in the double bottom, see Fig 14), their influence is to be taken into account by assigning an equivalent net shear sectional area to the primary supporting member.

This equivalent net shear sectional area is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{A_{Sh1}}{1 + \dfrac{0{,}0032\,\ell^2 A_{Sh1}}{I_1}} + \frac{A_{Sh2}}{1 + \dfrac{0{,}0032\,\ell^2 A_{Sh2}}{I_2}}$$

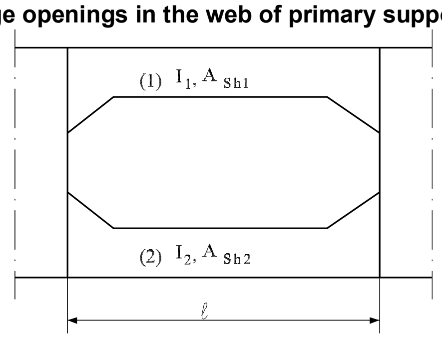
where (see Fig 14):

I_1, I_2 : Net moments of inertia, in cm⁴, of deep webs (1) and (2), respectively, with attached plating around their neutral axes parallel to the plating

A_{Sh1}, A_{Sh2} : Net shear sectional areas, in cm², of deep webs (1) and (2), respectively, to be calculated according to [4.3.2]

ℓ : Span, in cm, of deep webs (1) and (2).

Figure 14 : Large openings in the web of primary supporting members



4.4 Bracketed end connections

4.4.1 The following requirements in [4.4.2] to [4.4.7] may be replaced by equivalent arrangements based on direct analysis of bending stress and shear stress in way of connections. In such a situation, case-by-case analysis or approval of details booklet is requested.

4.4.2 Arm lengths of end brackets are to be equal, as far as practicable.

With the exception of primary supporting members of transversely framed single sides (see Ch 4, Sec 5, [3.2]), the height of end brackets is to be not less than that of the primary supporting member.

4.4.3 The net thickness of the end bracket web is generally to be not less than that of the primary supporting member web.

4.4.4 The net scantlings of end brackets are generally to be such that the net section modulus of the primary supporting member with end brackets is not less than that of the primary supporting member at mid-span.

4.4.5 Brackets with net thickness, in mm, less than 15 L_b, where L_b is the length, in m, of the free edge of the end bracket, are to be flanged or stiffened by a welded face plate. The width, in mm, of the face plate of end brackets is to be not less than 50 (L_b + 1). Other dimensions of width of the face plate may be accepted if deemed equivalent or validated by experience.

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

4.4.6 Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.

As a guidance, the following prescriptions may be applied:

- where the length L_b is greater than 1,5 m, the web of the bracket is to be stiffened
- the net sectional area, in cm^2, of web stiffeners is to be not less than 16,5 ℓ, where ℓ is the span, in m, of the stiffener
- tripping flat bars are to be fitted to prevent lateral buckling of web stiffeners. Where the width of the symmetrical face plate is greater than 400 mm, additional backing brackets are to be fitted.

4.4.7 In addition to the above requirements, the net scantlings of end brackets are to comply with the applicable requirements given in Ch 4, Sec 4 to Ch 4, Sec 7.

4.5 Bracketless end connections

4.5.1 In the case of bracketless crossing between primary supporting members (see Fig 15), the net thickness of the common part of the web is to be not less than the value obtained, in mm, from the following formula:

$$t = 15{,}75\frac{w}{\Omega}$$

where:

w : The lesser of w_1 and $w_{2,MAX}$

w_1 : Gross section modulus, in cm^3, of member 1

$w_{2,MAX}$: The greater value, in cm^3, of the gross section moduli of members 2 and 3

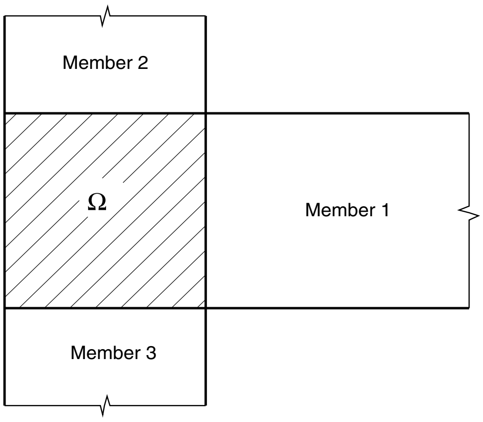
Ω : Area, in cm^2, of the common part of members 1, 2 and 3.

In the absence of one of members 2 and 3 shown in Fig 15, the value of the relevant gross section modulus is to be taken equal to zero.

4.5.2 In no case may the net thickness calculated according to [4.5.1] be less than the smallest web net thickness of the members forming the crossing.

4.5.3 In general, the continuity of the face plates is to be ensured.

Figure 15 : Bracketless end connections of primary supporting members



4.6 Cut-outs and holes

4.6.1 Cut-outs for the passage of ordinary stiffeners are to be as small as possible and well rounded with smooth edges.

In general, the depth of cut-outs is to be not greater than 50% of the depth of the primary supporting member.

4.6.2 Where openings such as lightening holes are cut in primary supporting members, they are to be equidistant from the face plate and corners of cut-outs. Other arrangement may be considered on a case-by-case basis.

4.6.3 Openings may not be fitted in way of toes of end brackets.

4.6.4 Over half of the span of primary supporting members, the length of openings is to be not greater than the distance between adjacent openings.

At the ends of the span, the length of openings is to be not greater than 25% of the distance between adjacent openings.

4.6.5 In the case of large openings as shown in Fig 16, the secondary stresses in primary supporting members are to be considered for the reinforcement of the openings.

The secondary stresses may be calculated in accordance with the following procedure.

Members (1) and (2) are subjected to the following forces, moments and stresses:

$$F = \frac{M_A + M_B}{2d}$$

$$m_1 = \left|\frac{M_A - M_B}{2}\right| K_1$$

$$m_2 = \left|\frac{M_A - M_B}{2}\right| K_2$$

$$\sigma_{F1} = 10\frac{F}{S_1}$$

$$\sigma_{F2} = 10\frac{F}{S_2}$$

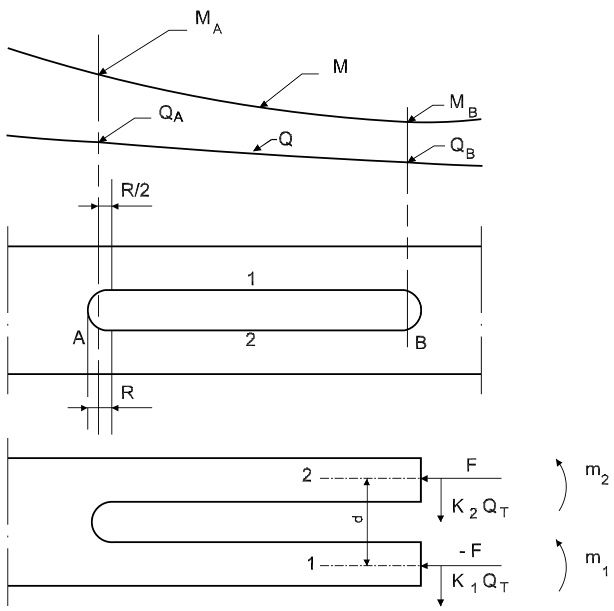
$$\sigma_{m1} = \frac{m_1}{w_1}10^3$$

$$\sigma_{m2} = \frac{m_2}{w_2}10^3$$

$$\tau_1 = 10\frac{K_1 Q_T}{S_{w1}}$$

$$\tau_2 = 10\frac{K_2 Q_T}{S_{w2}}$$

Figure 16 : Large openings in primary supporting members - Secondary stresses



where:

M_A, M_B : Bending moments, in kN·m, in sections A and B of the primary supporting member

m_1, m_2 : Bending moments, in kN·m, in (1) and (2)

d : Distance, in m, between the neutral axes of (1) and (2)

σ_{F1}, σ_{F2} : Axial stresses, in N/mm², in (1) and (2)

σ_{m1}, σ_{m2} : Bending stresses, in N/mm², in (1) and (2)

Q_T : Shear force, in kN, equal to Q_A or Q_B, whichever is greater

τ_1, τ_2 : Shear stresses, in N/mm², in (1) and (2)

w_1, w_2 : Net section moduli, in cm³, of (1) and (2)

S_1, S_2 : Net sectional areas, in cm², of (1) and (2)

S_{w1}, S_{w2} : Net sectional areas, in cm², of webs in (1) and (2)

I_1, I_2 : Net moments of inertia, in cm⁴, of (1) and (2) with attached plating

$$K_1 = \frac{I_1}{I_1 + I_2}$$

$$K_2 = \frac{I_2}{I_1 + I_2}$$

The combined stress σ_C calculated at the ends of members (1) and (2) is to be obtained from the following formula:

$$\sigma_c = \sqrt{(\sigma_F + \sigma_m)^2 + 3\tau^2}$$

The combined stress σ_C is to comply with the checking criteria in Ch 7, Sec 3, [2.6] or Ch 7, Sec 3, [3.3], as applicable. Where these checking criteria are not complied with, the cut-out is to be reinforced according to one of the solutions shown in Fig 17 to Fig 19:

- continuous face plate (solution 1), see Fig 17
- straight face plate (solution 2), see Fig 18
- compensation of the opening (solution 3), see Fig 19
- combination of the above solutions.

Other arrangements may be accepted provided they are supported by direct calculations submitted to the Society for review.

Figure 17 : Stiffening of large openings in primary supporting members - Solution 1

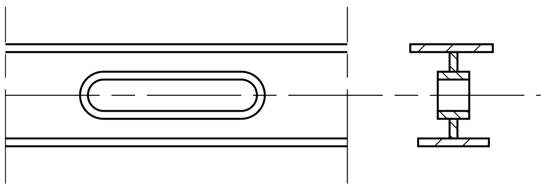


Figure 18 : Stiffening of large openings in primary supporting members - Solution 2

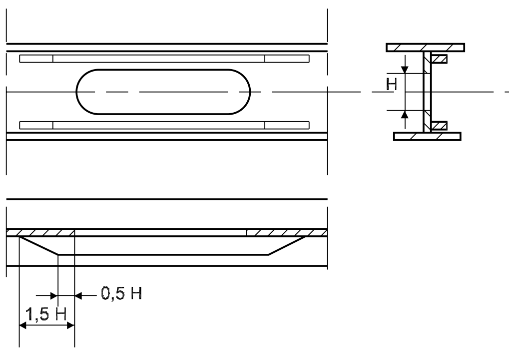
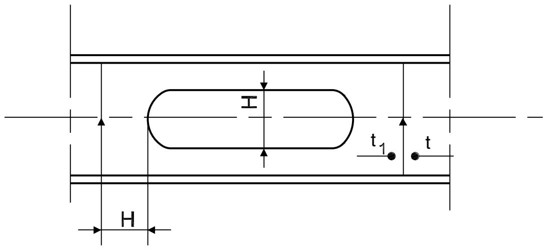


Figure 19 : Stiffening of large openings in primary supporting members - Solution 3

Inserted plate



4.7 Stiffening arrangement

4.7.1 Webs of primary supporting members are generally to be stiffened where the height, in mm, is greater than 100 t, where t is the web net thickness, in mm, of the primary supporting member.

In general, the web stiffeners of primary supporting members are to be spaced not more than 110 t.

4.7.2 Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, their net sectional area at the web stiffener mid-height is to be not less than the value obtained, in cm^2, from the following formula:

$$A = 0{,}1\ k_1\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s\ \ell$$

where:

k_1 : Coefficient depending on the web connection with the ordinary stiffener, to be taken as:

- k_1 = 0,300 for connections without collar plate (see Fig 9)
- k_1 = 0,225 for connections with a collar plate (see Fig 10)
- k_1 = 0,200 for connections with one or two large collar plates (see Fig 11 and Fig 12)

p_S, p_W : Still water and wave pressure, respectively, in kN/m^2, acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

γ_{S2}, γ_{W2} : Partial safety factors, defined in Ch 7, Sec 2, Tab 1 for yielding check (general).

4.7.3 The net section modulus of web stiffeners of non-watertight primary supporting members is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 2{,}5\ s^2\ t\ S_s^2$$

where:

s : Length, in m, of web stiffeners

t : Web net thickness, in mm, of the primary supporting member

S_s : Spacing, in m, of web stiffeners.

Moreover, web stiffeners located in areas subject to compression stresses are to be checked for buckling in accordance with Ch 7, Sec 2, [4].

4.7.4 Tripping brackets (see Fig 20) welded to the face plate are generally to be fitted:

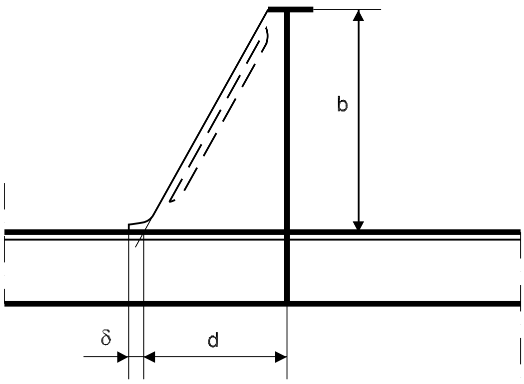
- in way of ordinary stiffeners and spaced not more than 4 m
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

However, when d, calculated according to [4.7.6] with net thickness of tripping bracket equal to the minimum of thicknesses of ordinary stiffener and primary member webs, is less than 100 mm, the tripping bracket may be omitted.

Where the width of the symmetrical face plate is greater than 400 mm, backing brackets are to be fitted in way of the tripping brackets.

4.7.5 In general, the width of the primary supporting member face plate is to be not less than one tenth of the depth of the web, where tripping brackets are spaced as specified in [4.7.4].

Figure 20 : Primary supporting member: web stiffener in way of ordinary stiffener



4.7.6 The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$d = 0,38\ b$

$$d = 0,85b\sqrt{\frac{s_t}{t}}$$

where:

b	:	Height, in m, of tripping brackets, shown in Fig 20
s_t	:	Spacing, in m, of tripping brackets
t	:	Net thickness, in mm, of tripping brackets.

It is recommended that the bracket toe should be designed as shown in Fig 20.

4.7.7 Tripping brackets with a net thickness, in mm, less than 15 L_b are to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flanged edge or the face plate is to be not less than 10 L_b, where L_b is the length, in m, of the free edge of the bracket. Other dimensions of the net sectional area of the flanged edge or face plate may be accepted if deemed equivalent or validated by experience.

Where the depth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge.

Section 4 Bottom Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed single and double bottom structures.

1.2 General arrangement

1.2.1 In general the bottom is to be longitudinally framed.

1.2.2 The bottom structure is to be checked by the Designer to make sure that it withstands the loads resulting from the dry-docking of the ship.

1.2.3 The bottom is to be locally stiffened where concentrated loads are envisaged.

1.2.4 Girders or floors are to be fitted under each line of pillars, when deemed necessary by the Society on the basis of the loads carried by the pillars.

1.2.5 Adequate tapering is to be provided between double bottom and adjacent single bottom structures. Similarly, adequate continuity is to be provided in the case of height variation in the double bottom. Where such a height variation occurs within 0,6 L amidships, the inner bottom is generally to be maintained continuous by means of inclined plating.

1.2.6 Provision is to be made for the free passage of water from all parts of the bottom to the suctions, taking into account the pumping rate required.

1.2.7 When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

1.3 Drainage and openings for air passage

1.3.1 Holes are to be cut into floors and girders to ensure the free passage of air and liquids from all parts of the double bottom.

1.3.2 Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as practicable.

2 Longitudinally framed single bottom

2.1 General

2.1.1 Single bottom ships are to be fitted with a centre girder formed by a vertical continuous or intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.2 In general, girders are to be fitted spaced not more than 2,5 m apart and formed by a vertical intercostal web plate and a horizontal face plate continuous over the floors.

Intercostal web plates are to be aligned and welded to floors.

2.1.3 Centre and side girders are to be extended as far aft and forward as practicable.

2.1.4 Where side girders are fitted in lieu of the centre girder, the scarfing is to be adequately extended and additional stiffening of the centre bottom may be required.

2.1.5 Longitudinal girders are to be fitted in way of each line of pillars.

2.1.6 Floors are to be made with a welded face plate between the collision bulkhead and 0,25L from the fore end.

2.2 Floors

2.2.1 In general, the floor spacing is to be not greater than 5 frame spacings.

2.3 Longitudinal ordinary stiffeners

2.3.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

3 Transversely framed single bottom

3.1 General

3.1.1 The requirements in [2.1] apply also to transversely framed single bottoms.

3.2 Floors

3.2.1 Floors are to be fitted at every frame.

3.2.2 The height, in m, of floors at the centreline is to be not less than B/16. In the case of ships with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

4 Longitudinally framed double bottom

4.1 General

4.1.1 The centre girder is to be continuous and extended over the full length of ship and the spacing of adjacent longitudinal girders is generally to be not greater than 6,5 m.

4.2 Double bottom height

4.2.1 The double bottom height is to be sufficient to ensure access to all parts and, in way of the centre girder, is to be not less than 0,7 m.

4.2.2 Where the height of the double bottom varies, the variation is generally to be made gradually and over an adequate length; the knuckles of inner bottom plating are to be located in way of plate floors.

Where this is impossible, suitable longitudinal structures such as partial girders, longitudinal brackets etc., fitted across the knuckle are to be arranged.

4.2.3 In ships without a flat bottom, the height of double bottom specified in [4.2.1] may be required to be adequately increased such as to ensure sufficient access to the areas towards the sides.

4.3 Floors

4.3.1 The spacing of plate floors, in m, is generally to be not greater than 0,05L or 3,8 m, whichever is the lesser.

Additional plate floors are to be fitted in way of transverse watertight bulkheads.

4.3.2 Plate floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

4.3.3 Where the double bottom height exceeds 0,9 m, watertight floors are to be fitted with stiffeners having a net section modulus not less than that required for tank bulkhead vertical stiffeners.

4.4 Bottom and inner bottom longitudinal ordinary stiffeners

4.4.1 Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.

4.5 Brackets to centreline girder and margin plate

4.5.1 In general, intermediate brackets are to be fitted connecting either the margin plate or the centre girder to the nearest bottom and inner bottom ordinary stiffeners.

4.5.2 Such brackets are to be stiffened at the edge with a flange having a width not less than 1/10 of the local double bottom height.

If necessary, the Society may require a welded flat bar to be arranged in lieu of the flange.

4.5.3 Where the side shell is transversely stiffened, margin plate brackets are to be fitted at every frame.

4.6 Duct keel

4.6.1 Where a duct keel is arranged, the centre girder may be replaced by two girders conveniently spaced, generally no more than 2 m apart.

4.6.2 The structures in way of the floors are to ensure sufficient continuity of the latter.

4.7 Bilge wells

4.7.1 Bilge wells arranged in the double bottom are to be limited in depth and formed by steel plates having a net thickness not less than the greater of that required for watertight floors and that required for the inner bottom.

4.7.2 In ships subject to subdivision requirements, such bilge wells are to be fitted so that the distance of their bottom from the shell plating is not less than 460 mm.

4.7.3 Where there is no margin plate, well arrangement is considered by the Society on a case by case basis.

5 Transversely framed double bottom

5.1 General

5.1.1 The requirements in [4.1], [4.2], [4.5], [4.6] and [4.7] apply also to transversely framed double bottoms.

5.2 Floors

5.2.1 Plate floors are to be fitted at every frame forward of 0,75L from the aft end.

Plate floors are also to be fitted:

- in way of transverse watertight bulkheads
- in way of double bottom steps.

Elsewhere, plate floors may be arranged at a distance not exceeding 3 m.

5.2.2 In general, plate floors are to be continuous between the centre girder and the margin plate.

5.2.3 Open floors are to be fitted in way of intermediate frames.

5.2.4 Where the double bottom height exceeds 0,9 m, plate floors are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the floor depth and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3 Girders

5.3.1 Side girders are to be arranged in such a way that their distance to adjacent girders or margin plate does not generally exceed 4,5 m.

5.3.2 Where the double bottom height exceeds 0,9 m, longitudinal girders are to be fitted with vertical stiffeners spaced not more than 1,5 m apart.

These stiffeners may consist of flat bars with a width equal to one tenth of the girder height and a net thickness, in mm, not less than $0,8L^{0,5}$.

5.3.3 In way of open floors, side girders are to be provided with stiffeners having a web height which is generally to be not less than 150 mm.

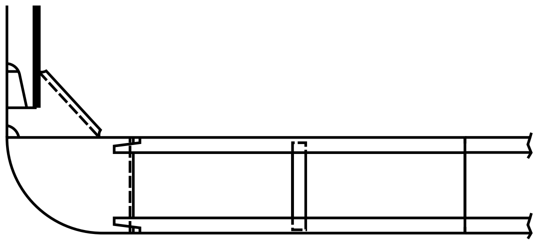
5.4 Open floors

5.4.1 At each frame between plate floors, open floors are to be arranged consisting of a frame connected to the bottom plating and a reverse frame connected to the inner bottom plating (see Fig 1).

5.4.2 Open floors are to be attached to the centreline girder and to the margin plate by means of flanged brackets having a width of flange not less than 1/10 of the local double bottom height.

5.4.3 Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 1 : Open floor



6 Bilge keel

6.1 Arrangement, scantlings and connections

6.1.1 Material

The material of the bilge keel and that of the ground bar is to be at least of the same yield stress as the material of the bilge plating to which they are attached.

In addition, when the bilge keel extends over a length greater than 0,15 L, the material of the ground bar and that of the bilge keel are to be, at least, of the same grade and of the same material class as the material of the bilge plating to which they are attached.

Exceptions will be specially considered by the Society on the basis of justification to be provided by the Designer, if it is shown that the bilge keel is able to resist the loads imposed on it.

6.1.2 Design

The design of single web bilge keels is to be such that failure of the web occurs before failure of the ground bar. This may be achieved by ensuring that the following conditions are both satisfied:

- the web thickness of the bilge keel does not exceed that of the ground bar
- the yield stress of the material of the bilge keel does not exceed that of the ground bar.

Other design principles which ensure that the bilge keel fails first without causing damage to the hull will be specially considered by the Society.

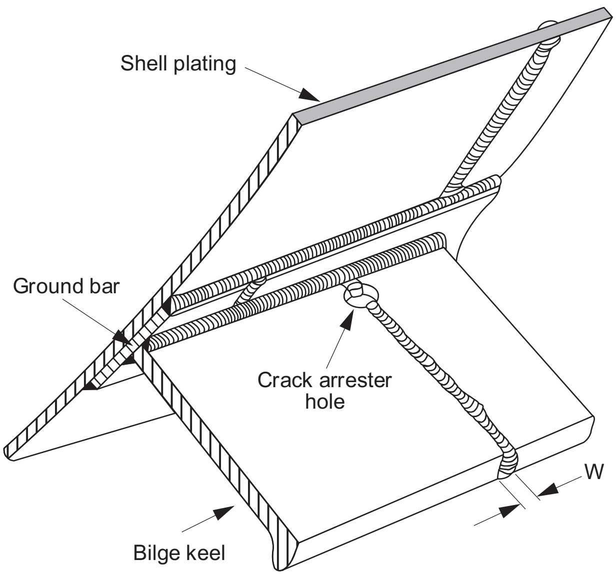
In general, scallops and cut-outs are not to be used. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm (see Fig 2). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Bilge keels of a design different from that shown in Fig 2 are to be specially considered by the Society.

The design of box type bilge keels will be examined on a case-by-case basis, taking into account the following requirements:

- such designs and their connections to the shell are to account for the possibility that they may lead to damage to the hull, as well as the degree of inspection that will be possible
- such designs are to be watertight
- the thickness of the longitudinal members enclosing the bilge keel is not to exceed that of the surrounding plating
- as a rule, internal stiffening members are not to be attached to the shell.

Figure 2 : Single web bilge keel arrangement



6.1.3 Ground bars

Single web bilge keels are not to be welded directly to the shell plating. A ground bar, or doubler, is to be fitted on the shell plating as shown in Fig 2 to Fig 4. In general, the ground bar is to be continuous.

The gross thickness of the ground bar is not to be less than the gross thickness of the bilge plating or 14 mm, whichever is the lesser.

In the case of box type bilge keels:

- For designs directly attached to the shell plating (i.e. without doubler), insert plates having well-rounded corners and gross thickness at least 50 percent greater than the gross thickness of the surrounding plating are to be fitted at the ends.
- Other arrangements for attachment to the hull will be specially considered by the Society on the basis of justification to be provided by the Designer. This justification is to account for the possibility of crack initiation at the attachments to the shell.

Figure 3 : Single web bilge keel design

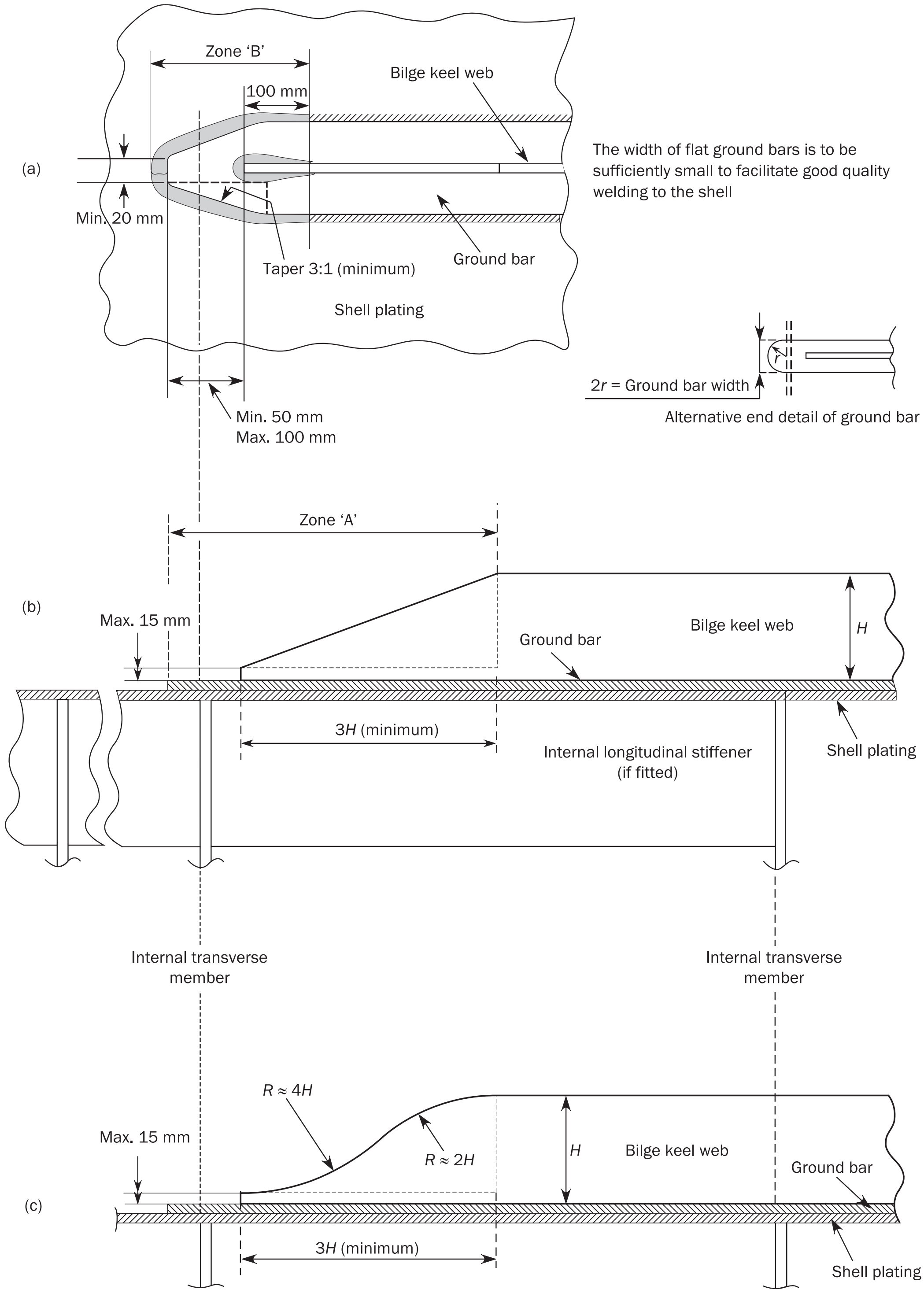
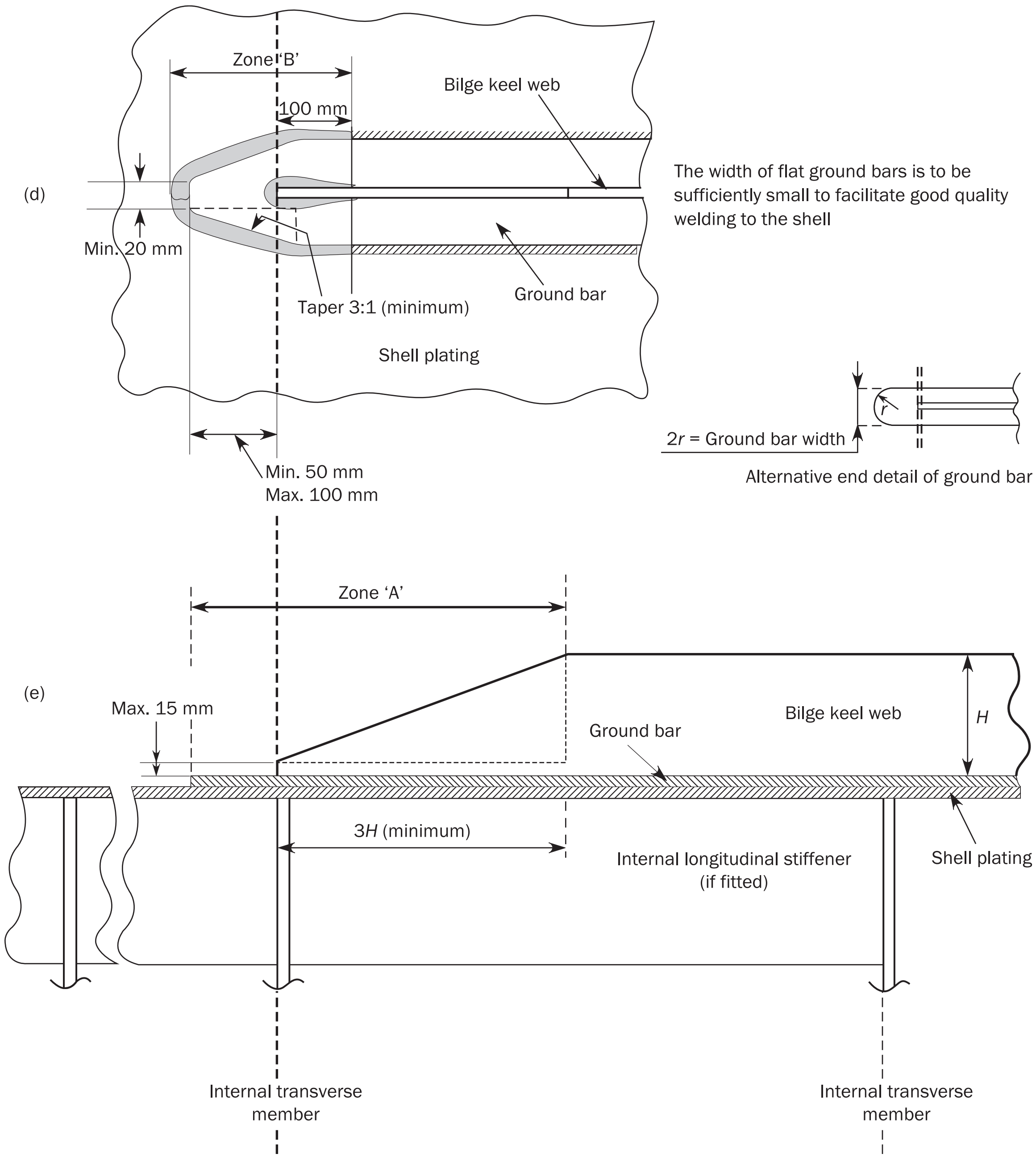


Figure 4 : Single web bilge keel design



6.1.4 End details

The ground bar and bilge keel ends are to be tapered or rounded. Tapering is to be gradual with a minimum ratio of 3:1, see Fig 3 items (a) and (b), and Fig 4items (d) and (e).

Rounded ends are to be as shown in Fig 3 item (c). Cutouts on the bilge keel web within zone A (see Fig 3, item (b) and Fig 4 item (e) are not permitted.

The end of the bilge keel web is to be not less than 50 mm and not greater than 100 mm from the end of the ground b ar, see Fig 3, item (a) and Fig 4, item (d).

Ends of the bilge keel and ground bar are to be supported by either transverse or longitudinal members inside the hull, as indicated as follows:

- transverse support member is to be fitted at mid-length between the end of the bilge keel web and the end of the ground bar, see Fig 3 items (a), (b) and (c)
- longitudinal stiffener is to be fitted in line with the bilge keel web, it is to extend to at least the nearest transverse member forward and aft of zone A (see Fig 3 item (b) and Fig 4 item (e)).

Alternative end arrangements may be considered by the Society on a case-by-case basis.

For box type bilge keels, end details will be examined on a case-by-case basis, paying due attention to structural continuity at the ends with respect to the stiffening members of the hull.

Section 5 Side Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed side structures.

1.1.2 The transversely framed side structures are built with transverse frames possibly supported by side girders (see [5.3.1]).

1.1.3 The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by side vertical primary supporting members.

1.2 General arrangement

1.2.1 Unless otherwise specified, side girders are to be fitted aft of the collision bulkhead up to 0,2L aft of the fore end, in line with fore peak girders.

1.2.2 Side vertical primary supporting members are to be fitted in way of hatch end beams.

1.3 Sheerstrake

1.3.1 The width of the sheerstrake is to be not less than the value obtained, in m, from the following formula:

$$b = 0,715 + 0,425\frac{L}{100}$$

For strength deck, the width of the sheerstrake is to be not less than the value given in Ch 4, Sec 1, [2.4.4].

1.3.2 The sheerstrake may be either welded to the stringer plate or rounded. If it is rounded, the radius, in mm, is to be not less than $17t_S$, where t_S is the net thickness, in mm, of the sheerstrake.

1.3.3 The upper edge of the welded sheerstrake is to be rounded and free of notches.

1.3.4 The transition from a rounded sheerstrake to an angled sheerstrake associated with the arrangement of superstructures at the ends of the ship is to be carefully designed so as to avoid any discontinuities.

Plans showing details of this transition are to be submitted for approval to the Society.

2 Longitudinally framed single side

2.1 Longitudinal ordinary stiffeners

2.1.1 Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

2.2 Primary supporting members

2.2.1 In general, the side vertical primary supporting member spacing may not exceed 5 frame spacings.

2.2.2 In general, the side vertical primary supporting members are to be bracketed to the double bottom transverse floors.

3 Transversely framed single side

3.1 Frames

3.1.1 Transverse frames are to be fitted at every frame.

3.1.2 Frames are generally to be continuous when crossing primary members.

Otherwise, the detail of the connection is to be examined by the Society on a case by case basis.

3.1.3 In general, the net section modulus of ‘tween deck frames is to be not less than that required for frames located immediately above.

3.2 Primary supporting members

3.2.1 In 'tweendecks of more than 4 m in height, side girders or side vertical primary supporting members or both may be required by the Society.

3.2.2 Side girders are to be flanged or stiffened by a welded face plate.

The width of the flanged edge or face plate is to be not less than 22t, where t is the web net thickness, in mm, of the girder.

3.2.3 The height of end brackets is to be not less than half the height of the primary supporting member.

4 Longitudinally framed double side

4.1 General

4.1.1 Adequate continuity of strength is to be ensured in way of breaks or changes in width of the double side.

In particular, scarfing of the inner side is to be ensured beyond the cargo hold region.

4.1.2 Knuckles of the inner side are to be adequately stiffened by longitudinal stiffeners. Equivalent arrangement may be considered by the Society on a case by case basis.

4.2 Primary supporting members

4.2.1 The height of side vertical primary supporting members may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

4.2.2 Side vertical primary supporting members supported by a strut and two diagonals converging on the former are to be considered by the Society on a case by case basis.

5 Transversely framed double side

5.1 General

5.1.1 The requirements in [4.1] also apply to transversely framed double side.

5.1.2 Transverse frames may be connected to the vertical ordinary stiffeners of the inner side by means of struts.

Struts are generally to be connected to transverse frames and vertical ordinary stiffeners of the inner side by means of vertical brackets.

5.2 Frames

5.2.1 Transverse frames are to be fitted at every frame.

5.3 Primary supporting members

5.3.1 Unless otherwise specified, transverse frames are to be supported by side girders if $D \geq 6{,}0$ m.

These girders are to be supported by side vertical primary supporting members spaced no more than 3,8 m apart.

5.3.2 In the case of ships having $4{,}5\text{m} < D < 6{,}0\text{m}$, side vertical primary supporting members are to be fitted, in general not more than 5 frame spacings apart.

6 Frame connections

6.1 General

6.1.1 End connections of frames are to be bracketed.

Other arrangement may be accepted on a case by case basis, when deemed equivalent.

6.1.2 'Tweendeck frames are to be bracketed at the top and welded or bracketed at the bottom to the deck.

In the case of bulb profiles, a bracket may be required to be fitted at bottom.

6.1.3 Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

6.1.4 Arrangement and scantlings of bracketed ends other than those shown in [6.2] [6.3]may be accepted on a case by case basis, based on strength analysis.

6.2 Upper brackets of frames

6.2.1 The arm length of upper brackets connecting frames to deck beams is to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w + 30}{t}}$$

where:

φ : Coefficient equal to:

- for unflanged brackets:
  $\varphi = 48$
- for flanged brackets:
  $\varphi = 43,5$

w : Required net section modulus of the stiffener, in cm^3, given in [6.2.2] and [6.2.3] and depending on the type of connection

t : Bracket net thickness, in mm.

6.2.2 For connections of perpendicular stiffeners located in the same plane (see Fig 1) or connections of stiffeners located in perpendicular planes (see Fig 2), the required net section modulus is to be taken equal to:

$w = w_2$ if $w_2 \leq w_1$

$w = w_1$ if $w_2 > w_1$

where w_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 1 and Fig 2.

Figure 1 : Connections of perpendicular stiffeners in the same plane

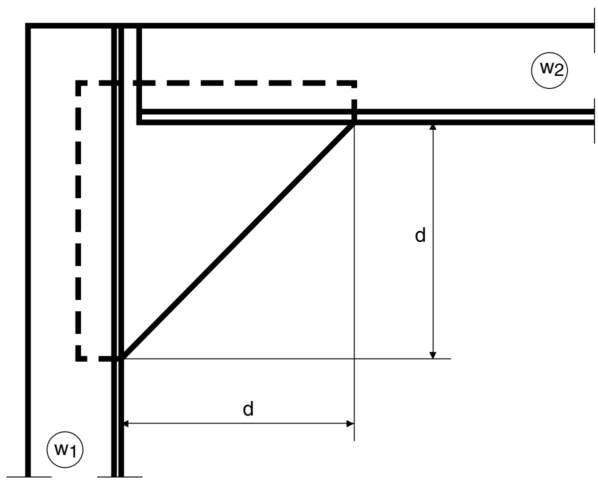
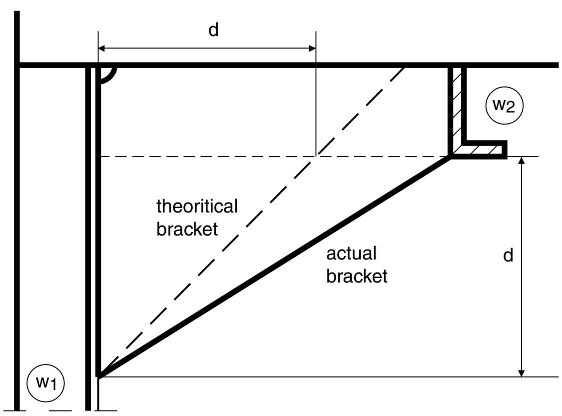


Figure 2 : Connections of stiffeners located in perpendicular planes



6.2.3 For connections of frames to deck beams (see Fig 3), the required net section modulus is to be taken equal to:

- for bracket "A":

  $w_A = w_1$ if $w_2 \le w_1$

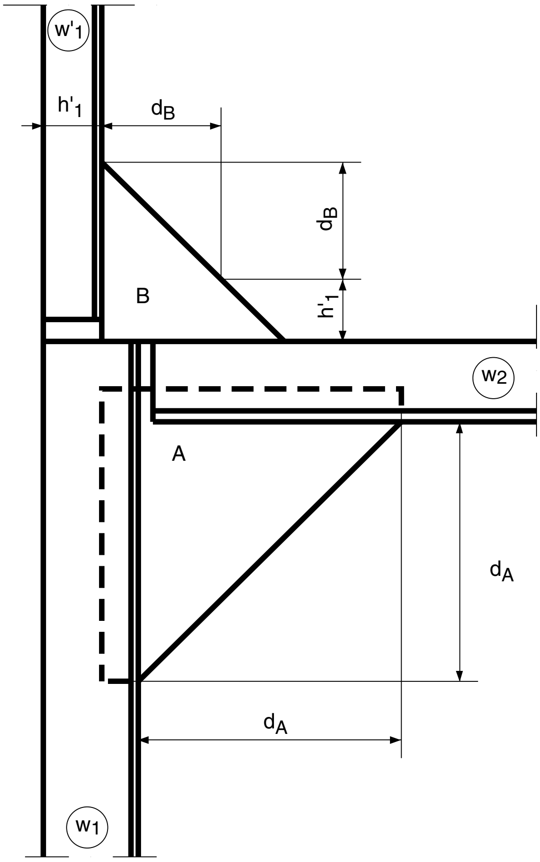
  $w_A = w_2$ if $w_2 > w_1$

- for bracket "B":

  $w_B = w'_1$ need not be greater than w_1

where w_1 , w'_1 and w_2 are the required net section moduli of stiffeners, as shown in Fig 3.

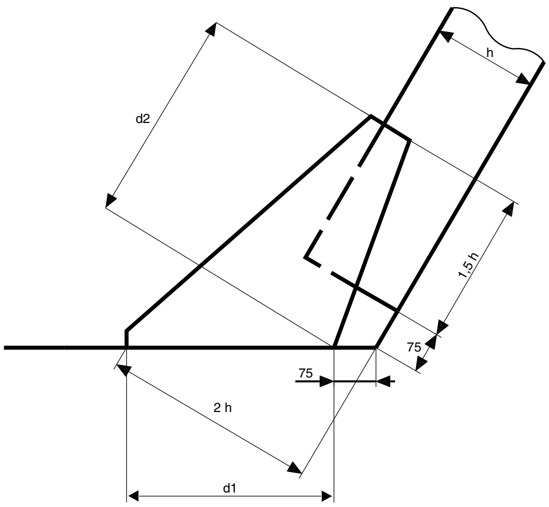
Figure 3 : Connections of frames to deck beams



6.3 Lower brackets of frames

6.3.1 In general, frames are to be bracketed to the inner bottom or to the face plate of floors as shown in Fig 4.

Figure 4 : Lower brackets of main frames



6.3.2 The arm lengths d_1 and d_2 of lower brackets of frames are to be not less than the value obtained, in mm, from the following formula:

$$d = \varphi\sqrt{\frac{w+30}{t}}$$

where:

φ : Coefficient equal to:
- for unflanged brackets:
  $\varphi = 50$
- for flanged brackets:
  $\varphi = 45$

w : Required net section modulus of the frame, in cm^3

t : Bracket net thickness, in mm.

6.3.3 Where the bracket net thickness, in mm, is less than $15L_b$, where L_b is the length, in m, of the bracket free edge, the free edge of the bracket is to be flanged or stiffened by a welded face plate.

The net sectional area, in cm^2, of the flange or the face plate is to be not less than $10L_b$.

7 Openings in the shell plating

7.1 Position of openings

7.1.1 Openings in the shell plating are to be located at a vertical distance from the decks at side not less than:
- two times the opening diameter, in case of circular opening
- the opening minor axis, in case of elliptical openings.

See also Ch 4, Sec 6, Fig 1.

7.2 Local strengthening

7.2.1 Openings in the ship sides, e.g. for cargo ports, are to be well rounded at the corners and located well clear of superstructure ends or any openings in the deck areas at sides of hatchways.

7.2.2 Openings for sea intakes are to be well rounded at the corners and, within 0,6 L amidships, located outside the bilge strakes. Where arrangements are such that sea intakes are unavoidably located in the curved zone of the bilge strakes, such openings are to be elliptical with the major axis in the longitudinal direction. Openings for stabiliser fins are considered by the Society on a case by case basis. The thickness of sea chests is generally to be not less than that of the local shell plating.

7.2.3 Openings in [7.2.1] and [7.2.2] and, when deemed necessary by the Society, other openings of considerable size are to be adequately compensated by means of insert plates of increased thickness or doublers sufficiently extended in length. Such compensation is to be partial or total depending on the stresses occurring in the area of the openings.

Circular openings on the sheerstrake need not be compensated where their diameter does not exceed 20% of the sheerstrake minimum width, defined in [1.3], or 380 mm, whichever is the lesser, and where they are located away from openings on deck at the side of hatchways or superstructure ends.

Section 6 Deck Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinally or transversely framed deck structures.

1.2 General arrangement

1.2.1 The deck supporting structure consists of ordinary stiffeners (beams or longitudinals), longitudinally or transversely arranged, supported by primary supporting members which may be sustained by pillars.

1.2.2 Where beams are fitted in a hatched deck, these are to be effectively supported by at least two longitudinal girders located in way of hatch side girders to which they are to be connected by brackets and/or clips.

1.2.3 In ships greater than 120 m in length, the zones outside the line of openings of the strength deck and other decks contributing to longitudinal strength are, in general, to be longitudinally framed.

Where a transverse framing type is adopted for such ships, it is considered by the Society on a case-by-case basis.

1.2.4 Adequate continuity of strength is to be ensured in way of:

- stepped or knuckled decks contributing to longitudinal strength
- changes in the framing system.

Details of structural arrangements are to be submitted for review to the Society.

1.2.5 Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

1.2.6 Inside the line of openings, a transverse structure is generally to be adopted for cross-deck structures, beams are to be adequately supported by girders and, in ships greater than 120 m in length, extend up to the second longitudinal from the hatch side girders toward the bulwark.

Where this is impracticable, intercostal stiffeners are to be fitted between the hatch side girder and the second longitudinal.

Other structural arrangements may be accepted, subject to their strength verification. In particular, their buckling strength against the transverse compression loads is to be checked. Where needed, deck transverses may be required to be fitted.

1.2.7 Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

1.2.8 Pillars or other supporting structures are generally to be fitted under heavy concentrated weights.

1.2.9 Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case-by-case basis.

1.2.10 Where devices for vehicle lashing arrangements and/or corner fittings for containers are directly attached to deck plating, provision is to be made for the fitting of suitable additional reinforcements of the sizes required by the load carried.

1.2.11 Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

1.3 Construction of watertight decks

1.3.1 Watertight decks are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Stringer plate

1.4.1 As a Rule, the width of the stringer plate is to be not less than the value obtained, in m, from the following formula:

$$b = 0{,}35 + 0{,}5\frac{L}{100}$$

However, the stringer plate is also to comply with the requirements in Ch 4, Sec 1, [2.4.4] and Ch 4, Sec 1, [2.5.5].

1.4.2 Stringer plates of lower decks not extending over the full ship's length are to be gradually tapered or overlapped by adequately sized brackets.

2 Longitudinally framed deck

2.1 General

2.1.1 Deck longitudinals are to be continuous, as far as practicable, in way of deck transverses and transverse bulkheads.

Other arrangements may be considered, provided adequate continuity of longitudinal strength is ensured.

2.1.2 In general, the spacing of deck transverses is not to exceed 5 frame spacings.

2.2 Longitudinal ordinary stiffeners

2.2.1 In ships equal to or greater than 120 m in length, strength deck longitudinal ordinary stiffeners are to be continuous through the watertight bulkheads and/or deck transverses.

2.2.2 Frame brackets, in ships with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

3 Transversely framed deck

3.1 General

3.1.1 In general, deck beams are to be fitted at each frame.

4 Pillars

4.1 General

4.1.1 Pillars are to be fitted, as far as practicable, in the same vertical line.

4.1.2 In general, pillars are to be fitted below winches, cranes, windlasses and steering gear, in the engine room and at the corners of deckhouses.

4.1.3 In tanks, solid or open section pillars are generally to be fitted. Pillars located in spaces intended for products which may produce explosive gases are to be of open section type.

4.1.4 Tight or non-tight bulkheads may be considered as pillars, provided that their arrangement complies with Ch 4, Sec 7, [4].

4.2 Connections

4.2.1 Heads and heels of pillars are to be attached to the surrounding structure by means of brackets, insert plates so that the loads are well distributed.

Insert plates may be replaced by doubling plates, except in the case of pillars which may also work under tension such as those in tanks.

In general, the net thickness of doubling plates is to be not less than 1,5 times the net thickness of the pillar.

4.2.2 Pillars are to be attached at their heads and heels by continuous welding.

4.2.3 Pillars are to be connected to the inner bottom at the intersection of girders and floors.

4.2.4 Where pillars connected to the inner bottom are not located in way of intersections of floors and girders, partial floors or girders or equivalent structures suitable to support the pillars are to be arranged.

4.2.5 Manholes may not be cut in the girders and floors below the heels of pillars.

4.2.6 Where pillars are fitted in tanks, head and heel brackets may be required if tensile stresses are expected.

4.2.7 Where side pillars are not fitted in way of hatch ends, vertical stiffeners of bulkheads supporting hatch side girders or hatch end beams are to be bracketed at their ends.

5 Hatch supporting structures

5.1 General

5.1.1 Hatch side girders and hatch end beams of reinforced scantlings are to be fitted in way of cargo hold openings.

In general, hatched end beams and deck transverses are to be in line with bottom and side transverse structures, so as to form a reinforced ring.

5.1.2 Clear of openings, adequate continuity of strength of longitudinal hatch coamings is to be ensured by underdeck girders.

5.1.3 The details of connection of deck transverses to longitudinal girders and web frames are to be submitted to the Society for approval.

6 Openings in the strength deck

6.1 Position of openings and local strengthening

6.1.1 Openings in the strength deck are to be kept to a minimum and spaced as far apart from one another and from breaks of effective superstructures as practicable. Openings are generally to be cut outside the hatched areas; in particular, they are to be cut as far as practicable from hatchway corners.

The dashed areas in Fig 1 are those where openings are generally to be avoided. The meaning of the symbols in Fig 1 is as follows:

c, e : Longitudinal and transverse dimensions of hatched area:

$c = 0{,}07\,\ell + 0{,}10\,b$ without being less than $0{,}25\,b$

$e = 0{,}25\,(B - b)$

a : Transverse dimension of openings

g : Transverse dimension of the area where openings are generally to be avoided in way of the connection between deck and side (as shown in Fig 1), deck and longitudinal bulkheads, deck and large deck girders:

- in the case of circular openings: $g = 2\,a$
- in the case of elliptical openings: $g = a$

Figure 1 : Position of openings in the strength deck

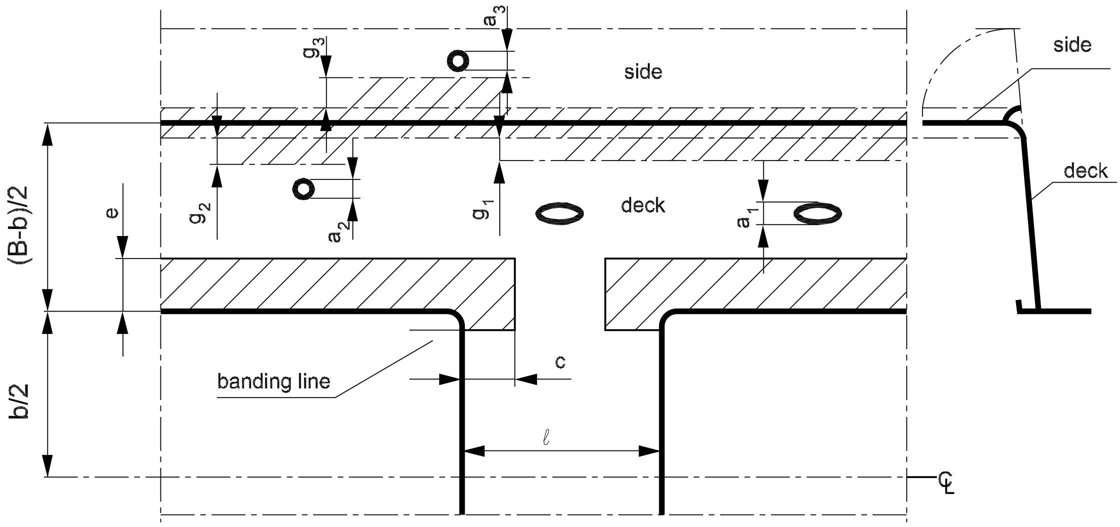
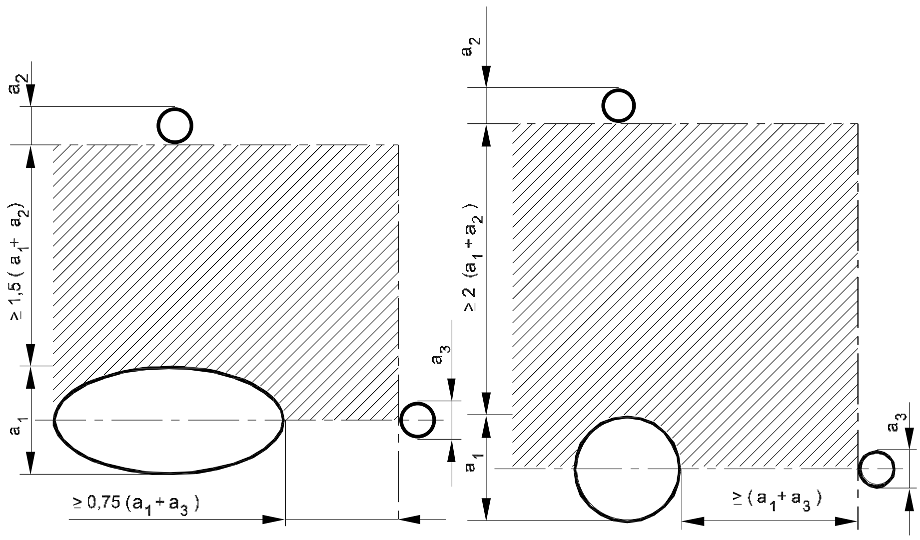


Figure 2 : Circular openings in the strength deck



6.1.2 No compensation is required where the openings are:

- circular of less than 350 mm in diameter and at a distance from any other opening in compliance with Fig 2
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

6.1.3 Other criteria proposed by the shipyard may be accepted by the Society, if considered as equivalent with respect to [6.1.1] and [6.1.2].

6.2 Corners of hatchways

6.2.1 For hatchways located within the central part, insert plates, whose thickness is to be determined according to [6.2.3], are generally to be fitted in way of corners where the plating cut-out has a circular profile.

The radius of circular corners is to be not less than:

- 5% of the hatch width, where a continuous longitudinal deck girder is fitted below the hatch coaming
- 8% of the hatch width, where no continuous longitudinal deck girder is fitted below the hatch coaming.

Corner radiusing, in the case of the arrangement of two or more hatchways athwartship, is considered by the Society on a case-by-case basis.

6.2.2 For hatchways located in the positions specified in [6.2.1], insert plates are, in general, not required in way of corners where the plating cut-out has an elliptical or parabolic profile and the half axes of elliptical openings, or the half lengths of the parabolic arch, are not less than:

- 1/20 of the hatchway width or 600 mm, whichever is the lesser, in the transverse direction
- twice the transverse dimension, in the fore and aft direction.

6.2.3 Where insert plates are required, their thickness is obtained, in mm, from the following formula:

$$t_{INS} = \left(0{,}8 + 0{,}4\frac{\ell}{b}\right)t$$

without being taken less than t or greater than 1,6 t

where:

ℓ : Width, in m, in way of the corner considered, of the cross deck strip between two consecutive hatchways, measured in the longitudinal direction (see Fig 1)

b : Width, in m, of the hatchway considered, measured in the transverse direction (see Fig 1)

t : Actual thickness, in mm, of the deck at the side of the hatchways.

For the extreme corners of end hatchways, the thickness of insert plates is to be 60% greater than the actual thickness of the adjacent deck plating. A lower thickness may be accepted by the Society on the basis of calculations showing that stresses at hatch corners are lower than permissible values.

6.2.4 Where insert plates are required, the arrangement shown in Sheet 3.1 of Ch 11, App 2 of is to be complied with.

6.2.5 For hatchways located in positions other than those in [6.2.1], a reduction in the thickness of the insert plates in way of corners may be considered by the Society on a case-by-case basis.

6.2.6 Other reinforcements deemed equivalent by the Society or alternative arrangements justified by direct calculations may be accepted.

7 Openings in decks other than the strength deck

7.1 General

7.1.1 The requirements for such openings are similar to those in [6.1] for the strength deck. However, circular openings need not to be compensated.

7.1.2 Corners of hatchway openings are to be rounded, as specified in [6.2] for the strength deck; insert plates may be omitted, however, when deemed acceptable by the Society.

Section 7 Bulkhead Structure

1 General

1.1 Application

1.1.1 The requirements of this Section apply to longitudinal or transverse bulkhead structures which may be plane or corrugated.

1.1.2 Bulkheads may be horizontally or vertically stiffened.

Horizontally framed bulkheads consist of horizontal ordinary stiffeners supported by vertical primary supporting members.

Vertically framed bulkheads consist of vertical ordinary stiffeners which may be supported by horizontal girders.

1.2 General arrangement

1.2.1 The number and location of watertight bulkheads are to be in accordance with the relevant requirements given in Ch 2, Sec 1.

1.2.2 Transverse corrugated bulkheads having horizontal corrugations are to be fitted with vertical primary supporting members of number and size sufficient to ensure the required vertical stiffness of the bulkhead.

1.2.3 Where an inner bottom terminates on a bulkhead, the lowest strake of the bulkhead forming the watertight floor of the double bottom is to extend at least 300 mm above the inner bottom.

1.2.4 Longitudinal bulkheads are to terminate at transverse bulkheads and are to be effectively tapered to the adjoining structure at the ends and adequately extended in the machinery space, where applicable.

1.2.5 Where the longitudinal watertight bulkheads contribute to longitudinal strength, the plating thickness is to be uniform for a distance of at least 0,1D from the deck and bottom.

1.2.6 The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

1.2.7 The height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 8 cm per metre.

1.3 Watertight bulkheads of trunks, tunnels, etc.

1.3.1 Watertight trunks, tunnels, duct keels and ventilators are to be of the same strength as watertight bulkheads at corresponding levels. The means used for making them watertight, and the arrangements adopted for closing openings in them, are to be to the satisfaction of the Society.

1.4 Openings in watertight bulkheads

1.4.1 Openings may not be cut in the collision bulkhead below the watertight deck.

The number of openings in the collision bulkhead above the watertight deck is to be kept to the minimum compatible with the design and proper working of the ship.

All such openings are to be fitted with means of closing to weathertight standards.

1.4.2 Certain openings below the watertight deck are permitted in the other bulkheads, but these are to be kept to a minimum compatible with the design and proper working of the ship and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected. Ch 2, Sec 1, Tab 2 is to be referred to.

1.5 Watertight doors

1.5.1 The net thickness of watertight doors is to be not less than that of the adjacent bulkhead plating, taking account of their actual spacing.

1.5.2 Where vertical stiffeners are cut in way of watertight doors, reinforced stiffeners are to be fitted on each side of the door and suitably overlapped; cross-bars are to be provided to support the interrupted stiffeners.

1.5.3 Watertight doors are to be framed and capable of being secured watertight by handle-operated wedges which are suitably spaced and operable at both sides.

2 Plane bulkheads

2.1 General

2.1.1 Where a bulkhead does not extend up to the uppermost continuous deck (such as the after peak bulkhead), suitable strengthening is to be provided in the extension of the bulkhead.

2.1.2 Bulkheads are to be stiffened in way of deck girders.

2.1.3 The stiffener webs of hopper and topside tank watertight bulkheads are generally to be aligned with the webs of inner hull longitudinal stiffeners.

2.1.4 A primary supporting member is to be provided in way of any vertical knuckle in longitudinal bulkheads. The distance between the knuckle and the primary supporting member is to be taken not greater than 70 mm.

2.1.5 Plate floors are to be fitted in the double bottom in way of plane transverse bulkheads.

2.1.6 A doubling plate of the same net thickness as the bulkhead plating is to be fitted on the after peak bulkhead in way of the sterntube, unless the net thickness of the bulkhead plating is increased by at least 60%.

2.2 End connections of ordinary stiffeners

2.2.1 The crossing of ordinary stiffeners through a watertight bulkhead is to be watertight.

2.2.2 In general, end connections of ordinary stiffeners are to be bracketed (see [2.3]). However, stiffeners of watertight bulkheads in upper ‘tweendecks may be sniped, provided the scantling of such stiffeners are modified accordingly.

2.2.3 Where hull lines do not enable compliance with the requirements of [2.2.2], sniped ends may be accepted, provided the scantlings of stiffeners are modified accordingly.

2.2.4 Where sniped ordinary stiffeners are fitted, the snipe angle is to be not greater than 30° and their ends are to be extended, as far as practicable, to the boundary of the bulkhead.

2.3 Bracketed ordinary stiffeners

2.3.1 Where bracketed ordinary stiffeners are fitted, the arm lengths of end brackets of ordinary stiffeners, as shown in Fig 1 and Fig 2, are to be not less than the following values, in mm:

- for arm length a:
  - brackets of horizontal stiffeners and bottom bracket of vertical stiffeners: $a = 100\,\ell$
  - upper bracket of vertical stiffeners: $a = 80\,\ell$
- for arm length b, the greater of:

$$b = 80\sqrt{\frac{w+20}{t}}$$

$$b = \alpha\frac{ps\ell}{t}$$

where:

ℓ : Span, in m, of the stiffener measured between supports

w : Net section modulus, in cm^3, of the stiffener

t : Net thickness, in mm, of the bracket

p : Design pressure, in kN/m^2, calculated at mid-span

α : Coefficient equal to:

$\alpha = 4,9$ for tank bulkheads

$\alpha = 3,6$ for watertight bulkheads.

2.3.2 The connection between the stiffener and the bracket is to be such that the net section modulus of the connection is not less than that of the stiffener.

2.3.3 Scantlings of bracketed ends other than those calculated in [2.3.1] may be accepted by the Society on a case-by-case basis, based on strength analysis.

Figure 1 : Bracket at upper end of ordinary stiffener on plane bulkhead

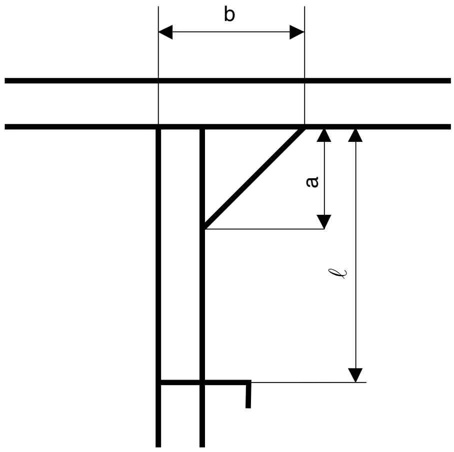
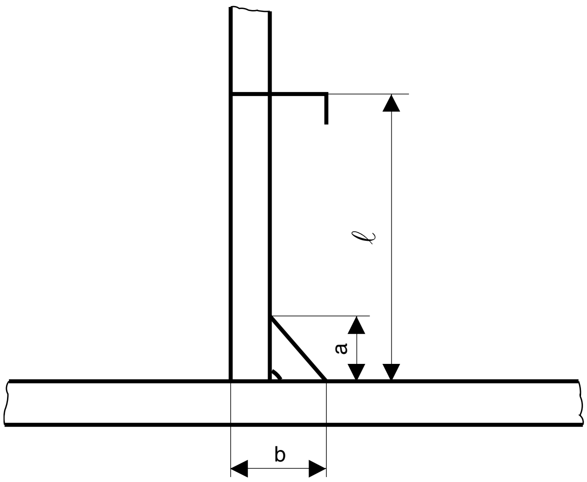


Figure 2 : Bracket at lower end of ordinary stiffener on plane bulkhead



3 Corrugated bulkheads

3.1 General

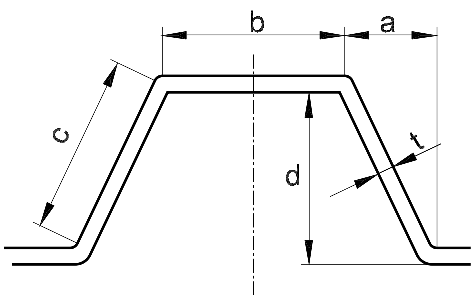
3.1.1 The main dimensions a, b, c and d of corrugated bulkheads are defined in Fig 3.

3.1.2 Unless otherwise specified, the following requirement is to be complied with:

$a \leq 1{,}2\ d$

Moreover, in some cases, the Society may prescribe an upper limit for the ratio b/t.

Figure 3 : Corrugated bulkhead



3.1.3 In general, the bending internal radius is to be not less than the following values, in mm:

- for normal strength steel: $R_i = 2,5\ t$
- for high tensile steel: $R_i = 3,0\ t$

where t is the net thickness, in mm, of the corrugated plate.

3.1.4 When butt welds in a direction parallel to the bend axis are provided in the zone of the bend, the welding procedures are to be submitted to the Society for approval, as a function of the importance of the structural element.

Moreover, when the gross thickness of the bulkhead plating is greater than 20 mm, the Society may require the use of steel grade E or EH.

3.1.5 In general, where girders or vertical primary supporting members are fitted on corrugated bulkheads, they are to be arranged symmetrically.

3.2 Structural arrangement

3.2.1 The strength continuity of corrugated bulkheads is to be ensured at ends of corrugations.

3.2.2 Where corrugated bulkheads are cut in way of primary members, attention is to be paid to ensure correct alignment of corrugations on each side of the primary member.

3.2.3 In general, where vertically corrugated transverse bulkheads are welded on the inner bottom, plate floors are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.4 In general, where vertically corrugated longitudinal bulkheads are welded on the inner bottom, girders are to be fitted in way of the flanges of corrugations.

However, other arrangements ensuring adequate structural continuity may be accepted by the Society.

3.2.5 In general, the upper and lower parts of horizontally corrugated bulkheads are to be flat over a depth equal to 0,1 D.

3.2.6 Where stools are fitted at the lower part of transverse bulkheads, the net thickness of adjacent plate floors is to be not less than that of the stool plating.

3.3 Bulkhead stool

3.3.1 In general, plate diaphragms or web frames are to be fitted in bottom stools in way of the double bottom longitudinal girders or plate floors, as the case may be.

3.3.2 Brackets or deep webs are to be fitted to connect the upper stool to the deck transverses or hatch end beams, as the case may be.

3.3.3 The continuity of the corrugated bulkhead with the stool plating is to be adequately ensured. In particular, the upper strake of the lower stool is to be of the same net thickness and yield stress as those of the lower strake of the bulkhead.

4 Non-tight bulkheads

4.1 Non-tight bulkheads not acting as pillars

4.1.1 Non-tight bulkheads not acting as pillars are to be provided with vertical stiffeners with a maximum spacing equal to:

- 0,9 m for transverse bulkheads
- two frame spacings, with a maximum of 1,5 m, for longitudinal bulkheads.

4.2 Non-tight bulkheads acting as pillars

4.2.1 Non-tight bulkheads acting as pillars “(i.e. those that are designed to sustain the loads transmitted by a deck structure) are to be provided with vertical stiffeners with a maximum spacing equal to:

- two frame spacings, when the frame spacing does not exceed 0,75 m
- one frame spacing, when the frame spacing is greater than 0,75 m.

4.2.2 Each vertical stiffener, in association with a width of plating equal to 35 times the plating net thickness, is to comply with the applicable requirements for pillars in Ch 7, Sec 3, the load supported being determined in accordance with the same requirements.

4.2.3 In the case of non-tight bulkheads supporting longitudinally framed decks, vertical girders are to be provided in way of deck transverses.

5 Wash bulkheads

5.1 General

5.1.1 The requirements in [5.2] apply to transverse and longitudinal wash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

5.2 Openings

5.2.1 The total area of openings in a transverse wash bulkhead is generally to be between 10% and 30% of the total bulkhead area.

In the upper, central and lower portions of the bulkhead (the depth of each portion being 1/3 of the bulkhead height), the areas of openings, expressed as percentages of the corresponding areas of these portions, are to be within the limits given in Tab 1.

5.2.2 In any case, the distribution of openings is to fulfil the strength requirements specified in [4.2].

5.2.3 In general, openings may not be cut within 0,15 D from bottom and from deck.

Table 1 : Areas of openings in transverse wash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10 %	15 %
Central	10 %	50 %
Lower	2 %	10 %

Part B
Hull and Stability

CHAPTER 5
DESIGN LOADS

Section 1 General

Section 2 Hull Girder Loads

Section 3 Ship Motions and Accelerations

Section 4 Load Cases

Section 5 Sea Pressures

Section 6 Internal Pressures and Forces

Appendix 1 Inertial Pressure for Typical Tank Arrangement

Symbols used in this Chapter

F : Froude's number:

$F = 0.164\ V_{max} / L^{0.5}$

V_{max} : Maximum ahead service speed, in knots

T_1 : Draught, in m, defined in Pt B, Ch 5, Sec 1, [2.4.3] or Pt B, Ch 5, Sec 1, [2.5.3], as the case may be

g : Gravity acceleration, in m/s^2:

$g = 9{,}81$ m/s^2,

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6].

Section 1 General

1 Definitions

1.1 Cargo

1.1.1 Cargo are liquids and dry units (e.g. containers, vehicles, etc.) carried inside compartments and on decks.

1.2 Still water loads

1.2.1 Still water loads are those acting on the ship at rest in calm water.

1.3 Wave loads

1.3.1 Wave loads are those due to wave pressures and ship motions, which can be assumed to have the same wave encounter period.

1.4 Dynamic loads

1.4.1 Dynamic loads are those that have a duration much shorter than the period of the wave loads.

1.5 Local loads

1.5.1 Local loads are pressures and forces which are directly applied to the individual structural members: plating panels, ordinary stiffeners and primary supporting members.

- Still water local loads are constituted by the hydrostatic external sea pressures and the static pressures and forces induced by the weights carried in the ship spaces.
- Wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations applied to the weights carried in the ship spaces.
- Dynamic local loads are constituted by the impact and sloshing pressures.

1.5.2 For the structures which constitute the boundary of spaces not intended to carry liquids and which do not belong to the outer shell, the still water and wave pressures in flooding conditions are also to be considered.

1.6 Hull girder loads

1.6.1 Hull girder loads are (still water, wave and dynamic) forces and moments which result as effects of local loads acting on the ship as a whole and considered as a beam.

1.7 Loading condition

1.7.1 A loading condition is a distribution of weights carried in the ship spaces arranged for their storage.

1.8 Load case

1.8.1 A load case is a state of the ship structures subjected to a combination of hull girder and local loads.

2 Application criteria

2.1 Fields of application

2.1.1 General

The wave induced and dynamic loads defined in this Chapter corresponds to an operating life of the ship equal to 30 years.

Loads for an operating life different from 30 years are considered by the Society on a case-by-case basis.

2.1.2 Requirements applicable to all types of ships

The still water, wave induced and dynamic loads defined in this Chapter are to be used for the determination of the hull girder strength and structural scantlings in the central part (see Ch 1, Sec 1) of ships, according to the requirements in Part B, Chapter 6 and Part B, Chapter 7.

2.1.3 Requirements applicable to specific ship types

The design loads applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.1.4 Load direct calculation

As an alternative to the formulae in Ch 5, Sec 2 and Ch 5, Sec 3, the Society may accept the values of wave induced loads and dynamic loads derived from direct calculations, when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

2.2 Hull girder loads

2.2.1 The still water, wave and dynamic hull girder loads to be used for the determination of:

- the hull girder strength, according to the requirements of Part B, Chapter 6, and
- the structural scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Ch 5, Sec 5 and Ch 5, Sec 6, according to the requirements in Part B, Chapter 7,

are specified in Ch 5, Sec 2.

2.3 Local loads

2.3.1 Load cases

The local loads defined in [1.5] are to be calculated in each of the mutually exclusive load cases described in Ch 5, Sec 4.

Dynamic loads are to be taken into account and calculated according to the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6.

2.3.2 Ship motions and accelerations

The wave local loads are to be calculated on the basis of the reference values of ship motions and accelerations specified in Ch 5, Sec 3.

2.3.3 Calculation and application of local loads

The criteria for calculating:

- still water local loads, and
- wave local loads on the basis of the reference values of ship motions and accelerations,

are specified in Ch 5, Sec 5 for sea pressures and in Ch 5, Sec 6 for internal pressures and forces.

2.3.4 Flooding conditions

The still water and wave pressures in flooding conditions are specified in Ch 5, Sec 6, [6]. The pressures in flooding conditions applicable to specific ship types are to be defined in accordance with the requirements in Part D.

2.4 Load definition criteria to be adopted in structural analyses based on plate or isolated beam structural models

2.4.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of:

- plating, according to Ch 7, Sec 1
- ordinary stiffeners, according to Ch 7, Sec 2
- primary supporting members for which a three-dimensional structural model is not required, according to Ch 7, Sec 3, [2].

2.4.2 Full load and operational load distributions

When calculating the local loads for the structural scantling of an element which separates two adjacent compartments, the latter may not be considered simultaneously loaded. The local loads to be used are those obtained considering the two compartments individually loaded.

For elements of the outer shell, the local loads are to be calculated considering separately:

- the still water and wave external sea pressures, considered as acting alone without any counteraction from the ship interior
- the still water and wave differential pressures (internal pressure minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded.

2.4.3 Draught associated with full load and operational load

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the full load or operational load distribution considered according to the criteria in [2.4.2]. The ship draught is to be taken as the distance measured vertically on the hull transverse section at the middle of the length L, from the moulded base line to the waterline in:

- full load condition, when:
  - one or more compartments are considered as being loaded and the ballast tanks are considered as being empty
  - the still water and wave external pressures are considered as acting alone without any counteraction from the ship's interior

- operational load condition, when one or more ballast tanks are considered as being loaded and the other compartments are considered as being empty. In the absence of more precise information, the ship's draught in light ballast condition may be obtained, in m, from the following formulae:

  $T_B = 0,03\ L \leq 7,5$ m

2.5 Load definition criteria to be adopted in structural analyses based on three- dimensional structural models

2.5.1 Application

The requirements of this sub-article apply for the definition of local loads to be used in the scantling checks of primary supporting members for which a three-dimensional structural model is required, according to Ch 7, Sec 3, [3].

2.5.2 Loading conditions

For all ship types for which analyses based on three-dimensional models are required according to Ch 7, Sec 3, [3], the most severe loading conditions for the structural elements under investigation are to be considered. These loading conditions are to be selected among those envisaged in the ship loading manual.

Further criteria applicable to specific ship types are specified in Part D.

2.5.3 Draught associated with each loading condition

Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the loading condition considered according to the criteria in [2.5.2].

Section 2 Hull Girder Loads

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

C : Wave parameter:

$$C = (118 - 0,36L)\frac{L}{1000} \quad \text{for } 65\,m \le L < 90\,m$$

$$C = 10,75 - \left(\frac{300 - L}{100}\right)^{1,5} \quad \text{for } 90\,m \le L < 300\,m$$

$$C = 10,75 \quad \text{for } 300\,m \le L \le 350\,m$$

$$C = 10,75 - \left(\frac{L - 350}{150}\right)^{1,5} \quad \text{for } L > 350\,m$$

H : Wave parameter:

$$H = 8,13 - \left(\frac{250 - 0,7L}{125}\right)^3$$

without being taken greater than 8,13

H_A : Wave parameter:

$$H_A = \frac{CL}{200}$$

without being taken greater than 0,8 C

F_{CH} : Characteristic Froude number:

$$F_{CH} = 0,164\frac{V_{CH}}{\sqrt{L}}$$

V_{CH} : Characteristic ship speed; to be taken as the greatest between V_{cruise} and 0,75 V_{max}

V_{cruise} : Cruise speed, in knots.

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the following characteristics:

L / B > 5

B / D < 2,5

$C_B \ge 0,4$

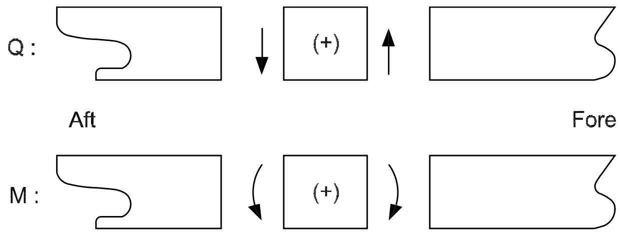
Ships not having one or more of these characteristics and ships of unusual type or design are considered by the Society on a case-by-case basis.

1.2 Sign conventions of vertical bending moments and shear forces

1.2.1 The sign conventions of bending moments and shear forces at any ship transverse section are as shown in Fig 1, namely:

- the vertical bending moment M is positive when it induces tensile stresses in the strength deck (hogging bending moment); it is negative in the opposite case (sagging bending moment)
- the vertical shear force Q is positive in the case of downward resulting forces preceding and upward resulting forces following the ship transverse section under consideration; it is negative in the opposite case.

Figure 1 : Sign conventions for shear forces Q and bending moments M



2 Still water loads

2.1 General

2.1.1 Still water load calculation

For all ships, the longitudinal distributions of still water bending moment and shear force are to be calculated, for each of the loading conditions in [2.1.2], on the basis of realistic data related to the amount of ballast, fuel, lubricating oil and fresh water.

The actual hull lines and lightweight distribution are to be taken into account in the calculations. The lightweight distribution may be replaced, if the actual values are not available, by a statistical distribution of weights accepted by the Society.

The designer is to supply the data necessary to verify the calculations of still water loads.

Ships with large openings are specially considered by the Society on a case-by-case basis.

2.1.2 Loading conditions

Still water loads are to be calculated at least for the design loading conditions corresponding to full load condition (end of life) and minimum operational load condition (at delivery) on which the approval of hull structural scantlings is based (see Ch 5, Sec 1, [1.2]). If other loading conditions are expected to be more severe than the above conditions, corresponding still water loads are also to be calculated.

For all ships, the following loading conditions are to be considered:

- homogeneous loading conditions at maximum draught
- operational load conditions
- special loadings (e.g. light load conditions at less than the maximum draught, etc., where applicable)
- short voyage or harbour conditions, where applicable
- loading and unloading transitory conditions, where applicable
- docking condition afloat
- ballast exchange at sea, if applicable.

2.2 Still water bending moments

2.2.1 The design still water bending moments $M_{SW,H}$ and $M_{SW,S}$ at any hull transverse section are the maximum still water bending moments calculated, in hogging and sagging conditions, respectively, at that hull transverse section for the loading conditions specified in [2.1.2].

Where no sagging bending moments act in the hull section considered, the value of $M_{SW,S}$ is to be taken as specified in Part B, Chapter 6 and Part B, Chapter 7.

2.2.2 If the design still water bending moments are not defined, at a preliminary design stage, at any hull transverse section, the longitudinal distributions shown in Fig 2 may be considered.

In Fig 2, M_{SW} is the design still water bending moment amidships, in hogging or sagging conditions, whose absolute values are to be taken not less than those obtained, in kN.m, from the following formulae:

- hogging conditions:

  $M_{SWM,H} = 175\ C\ L^2\ B\ (C_B + 0{,}7)\ 10^{-3} - M_{WV,H}$

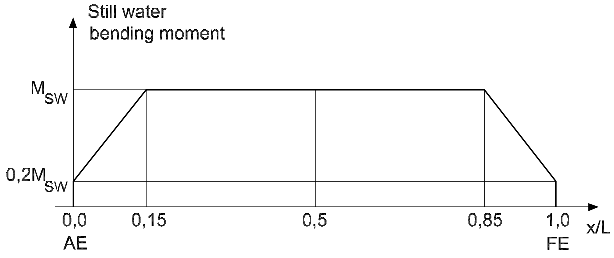
- sagging conditions:

  $M_{SWM,S} = 175\ C\ L^2\ B\ (C_B + 0{,}7)\ 10^{-3} + M_{WV,S}$

where $M_{WV,H}$ and $M_{WV,S}$ are the vertical wave bending moments, in kN.m, defined in [3.1].

The final structural checks are, in any case, to be carried out on the basis of the design still water bending moments as specified [2.2.1].

Figure 2 : Preliminary still water bending moment distribution



2.3 Still water shear force

2.3.1 The design still water shear force Q_{SW} at any hull transverse section is the maximum positive or negative shear force calculated, at that hull transverse section, for the loading conditions specified in [2.1.2].

3 Wave loads

3.1 Vertical wave bending moments

3.1.1 The vertical wave bending moments at any hull transverse section are obtained, in kN.m, from the following formulae:

- hogging conditions:

  $M_{WV,H} = 150\ F_M\ C\ L^2\ B\ C_B\ (1 + C_A)\ 10^{-3}$

- sagging conditions:

  $M_{WV,S} = -\ 85\ F_M\ C\ L^2\ B\ (C_B + 0{,}7)\ (1 + C_A)\ 10^{-3}$

where:

F_M : Distribution factor defined in Tab 1 and Fig 3

C_A : Coefficient equal to:

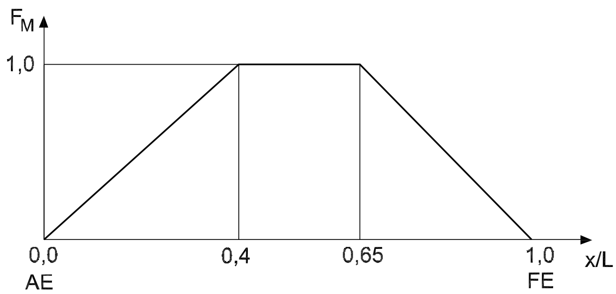
$$C_A = \frac{7{,}1 H_A (1 + 1{,}26 F_{CH})^2}{L}$$

3.1.2 The effects of bow flare impact are to be taken into account, for the cases specified in [4.1.1], according to [4.2.1].

Table 1 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \leq x < 0{,}4\ L$	$2{,}5\frac{x}{L}$
$0{,}4\ L \leq x \leq 0{,}65\ L$	1,00
$0{,}65\ L < x \leq L$	$2{,}86\left(1 - \frac{x}{L}\right)$

Figure 3 : Distribution factor F_M



3.2 Horizontal wave bending moment

3.2.1 The horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

$M_{WH} = 0{,}42\ F_M\ H_A\ L^2\ T\ C_B$

where F_M is the distribution factor defined in [3.1.1].

3.3 Wave torque

3.3.1 The wave torque at any hull transverse section is to be calculated considering the ship in two different conditions:

- condition 1: ship direction forming an angle of 60° with the prevailing sea direction
- condition 2: ship direction forming an angle of 120° with the prevailing sea direction.

The values of the wave torques in these conditions, calculated with respect to the section centre of torsion, are obtained, in kN.m, from the following formula:

$$M_{WT} = \frac{HL}{4}(F_{TM}C_M + F_{TQ}C_Q d)$$

where:

F_{TM}, F_{TQ} : Distribution factors defined in Tab 2 for ship conditions 1 and 2 (see also Fig 4 and Fig 5)

C_M : Wave torque coefficient:

$C_M = 0{,}38\ B^2\ C_W^2$

C_Q : Horizontal wave shear coefficient:

$C_Q = 2{,}8\ T\ C_B$

C_W : Waterplane coefficient, to be taken not greater than the value obtained from the following formula:

$C_W = 0{,}165 + 0{,}95\ C_B$

where C_B is to be assumed not less than 0,6. In the absence of more precise determination, C_W may be taken equal to the value provided by the above formula

d : Vertical distance, in m, from the centre of torsion to a point located 0,6 T above the baseline.

Table 2 : Distribution factors F_{TM} and F_{TQ}

Ship condition	Distribution factor F_{TM}	Distribution factor F_{TQ}
1	$1 - \cos\frac{2\pi x}{L}$	$\sin\frac{2\pi x}{L}$
2	$1 - \cos\frac{2\pi(L-x)}{L}$	$\sin\frac{2\pi(L-x)}{L}$

Figure 4 : Ship condition 1 - Distribution factors F_{TM} and F_{TQ}

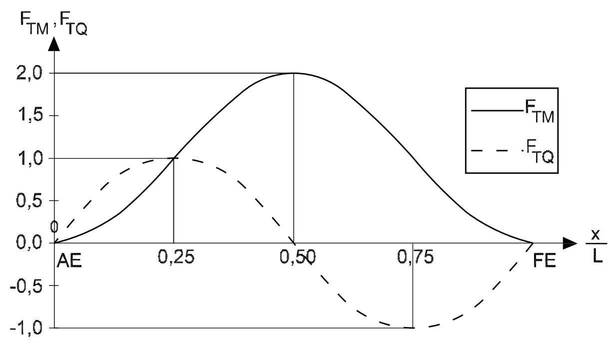
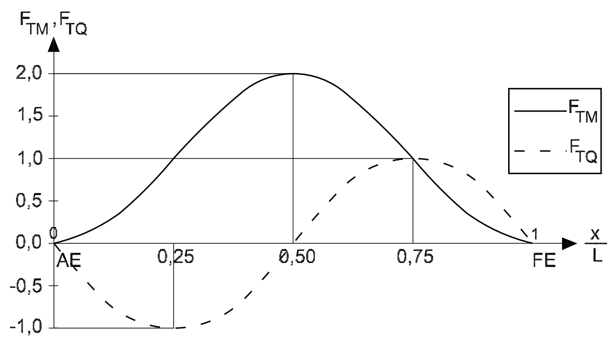


Figure 5 : Ship condition 2 - Distribution factors F_{TM} and F_{TQ}



3.4 Vertical wave shear force

3.4.1 The vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$Q_{WV} = 30\ F_Q\ C\ L\ B\ (C_B + 0{,}7)\ 10^{-2}$

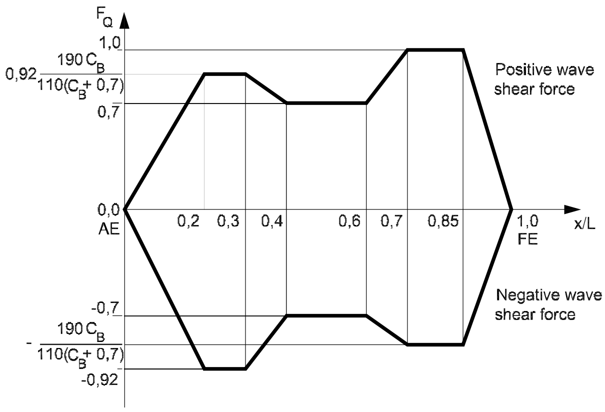
where:

F_Q : Distribution factor defined in Tab 3 for positive and negative shear forces (see also Fig 6).

Table 3 : Distribution factor F_Q

Hull transverse section location	Distribution factor F_Q	
	Positive wave shear force	Negative wave shear force
$0 \le x < 0{,}2\ L$	$4{,}6A\frac{x}{L}$	$-4{,}6\frac{x}{L}$
$0{,}2\ L \le x \le 0{,}3\ L$	0,92 A	– 0,92
$0{,}3\ L < x < 0{,}4\ L$	$(9{,}2A-7)\left(0{,}4-\frac{x}{L}\right)+0{,}7$	$-2{,}2\left(0{,}4-\frac{x}{L}\right)-0{,}7$
$0{,}4\ L \le x \le 0{,}6\ L$	0,70	– 0,70
$0{,}6\ L < x < 0{,}7\ L$	$3\left(\frac{x}{L}-0{,}6\right)+0{,}7$	$-(10A-7)\left(\frac{x}{L}-0{,}6\right)-0{,}7$
$0{,}7\ L \le x \le 0{,}85\ L$	1,00	– A
$0{,}85\ L < x \le L$	$6{,}67\left(1-\frac{x}{L}\right)$	$-6{,}67A\left(1-\frac{x}{L}\right)$
Note 1: $A = \dfrac{190C_B}{110(C_B+0{,}7)}$		

Figure 6 : Distribution factor F_Q



4 Dynamic loads due to bow flare impact

4.1 Application

4.1.1 The effects of bow flare impact are to be considered where all the following conditions occur:

- $V_{cruise} \ge 17{,}5$ knots
- $\dfrac{100FA_S}{LB} > 1$

where:

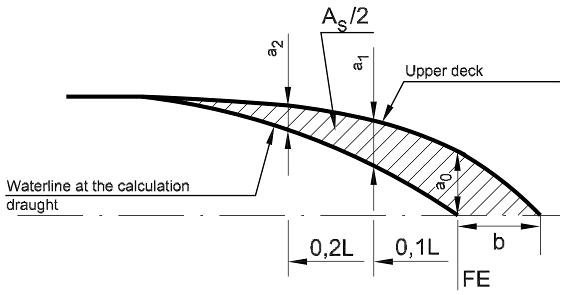
A_S : Twice the shaded area shown in Fig 7, to be obtained, in m², from the following formula:

$A_S = b\ a_0 + 0{,}1\ L\ (a_0 + 2\ a_1 + a_2)$

b, a_0, a_1, a_2 : Distances, in m, shown in Fig 7.

For multideck ships, the upper deck shown in Fig 7 is to be taken as the deck (including superstructures) which extends up to the extreme forward end of the ship and has the largest breadth forward of 0,2 L from the fore end.

Figure 7 : Area A_S



4.1.2 When the effects of bow flare impact are to be considered, according to [4.1.1], the sagging wave bending moment is to be increased as specified in [4.2.1] and [4.2.2].

4.1.3 The Society may require the effects of bow flare impact to be considered also when one of the conditions in [4.1.1] does not occur, if deemed necessary on the basis of the ship's characteristics.

In such cases, the increase in sagging wave bending moment is defined on a case-by-case basis.

4.2 Increase in sagging wave bending moment

4.2.1 General

The sagging wave bending moment at any hull transverse section, defined in [3.1], is to be multiplied by the coefficient F_D obtained from the formulae in Tab 4, which takes into account the dynamic effects of bow flare impact.

Where at least one of the conditions in [4.1.1] does not occur, the coefficient F_D may be taken equal to 1.

Table 4 : Coefficient F_D

Hull transverse section location	Coefficient F_D
$0 \le x < 0,4\ L$	1,0
$0,4\ L \le x < 0,5\ L$	$1 + 10(C_D - 1)\left(\frac{x}{L} - 0,4\right)$
$0,5\ L \le x \le L$	C_D
Note 1: $C_D = 262,5\dfrac{A_S}{CLB(C_B + 0,7)} - 0,6$ without being taken greater than 1,2 nor less than 1,0. A_S : Area, in m², defined in [4.1.1].	

4.2.2 Direct calculations

As an alternative to the formulae in [4.2.1], the Society may accept the evaluation of the effects of bow flare impact from direct calculations, when justified on the basis of the ship's characteristics. The calculations are to be submitted to the Society for approval.

Section 3 Ship Motions and Accelerations

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

a_B : Motion and acceleration parameter:

$$a_B = 0,76F + 1,875\frac{h_W}{L}$$

h_W : Wave parameter, in m:

$$h_W = 11,44 - \left|\frac{L-250}{110}\right|^3 \quad \text{for} \quad L < 350 \text{ m}$$

$$h_W = \frac{200}{\sqrt{L}} \quad \text{for} \quad L \geq 350 \text{ m}$$

a_{SU} : Surge acceleration, in m/s², defined in [2.1]

a_{SW} : Sway acceleration, in m/s², defined in [2.2]

a_H : Heave acceleration, in m/s², defined in [2.3]

α_R : Roll acceleration, in rad/s², defined in [2.4]

α_P : Pitch acceleration, in rad/s², defined in [2.5]

α_Y : Yaw acceleration, in rad/s², defined in [2.6]

T_{SW} : Sway period, in s, defined in [2.2]

T_R : Roll period, in s, defined in [2.4]

T_P : Pitch period, in s, defined in [2.5]

A_R : Roll amplitude, in rad, defined in [2.4]

A_P : Pitch amplitude, in rad, defined in [2.5].

1 General

1.1

1.1.1 Ship motions and accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 2, [10].

1.1.2 Ship motions and accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Section, are half of the crest to through amplitudes.

1.1.3 As an alternative to the formulae in this Section, the Society may accept the values of ship motions and accelerations derived from direct calculations or obtained from model tests, when justified on the basis of the ship's characteristics. In general, the values of ship motions and accelerations to be calculated are those which can be reached with a probability of 10^{-5}. In any case, the model tests or the calculations, including the assumed sea scatter diagrams and spectra, are to be submitted to the Society for approval.

2 Ship absolute motions and accelerations

2.1 Surge

2.1.1 The surge acceleration a_{SU} is to be taken equal to 0,5 m/s².

2.2 Sway

2.2.1 The sway period and acceleration are obtained from the formulae in Tab 1.

Table 1 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$\dfrac{0,8\sqrt{L}}{1,22F+1}$	$0,775\, a_B\, g$

2.3 Heave

2.3.1 The heave acceleration is obtained, in m/s², from the following formula:

$a_H = a_B\, g$

2.4 Roll

2.4.1 The roll amplitude, period and acceleration are obtained from the formulae in Tab 2.

Table 2 : Roll amplitude, period and acceleration

Amplitude A_R, in rad	Period T_R, in s	Acceleration α_R, in rad/s²
$a_B\sqrt{E}$ without being taken greater than 0,35	$2{,}2\dfrac{\delta}{\sqrt{GM}}$	$A_R\left(\dfrac{2\pi}{T_R}\right)^2$

Note 1:

$E = 1{,}39\dfrac{GM}{\delta^2}B_{WS}$ to be taken not less than 1,0

GM : Distance, in m, from the ship's centre of gravity to the transverse metacentre, for the loading considered; when GM is not known, the following values may be assumed: $GM = 0{,}07\ B_{WS}$

δ : Roll radius of gyration, in m, for the loading considered; when δ is not known, it may be taken equal to: $\delta = 0{,}35\ B_{WS}$

2.5 Pitch

2.5.1 The pitch amplitude, period and acceleration are obtained from the formulae in Tab 3.

Table 3 : Pitch amplitude, period and acceleration

Amplitude A_P, in rad	Period T_P, in s	Acceleration α_P, in rad/s²
$0{,}328a_B\left(1{,}32-\dfrac{h_W}{L}\right)\left(\dfrac{0{,}6}{C_B}\right)^{0{,}75}$	$0{,}575\sqrt{L}$	$A_P\left(\dfrac{2\pi}{T_P}\right)^2$

2.6 Yaw

2.6.1 The yaw acceleration is obtained, in rad/s², from the following formula:

$$\alpha_Y = 1{,}581\frac{a_B g}{L}$$

3 Ship relative motions and accelerations

3.1 Definitions

3.1.1 Ship relative motions

The ship relative motions are the vertical oscillating translations of the sea waterline on the ship side. They are measured, with their sign, from the waterline at draught T_1.

3.1.2 Accelerations

At any point, the accelerations in X, Y and Z direction are the acceleration components which result from the ship motions defined in [2.1] to [2.6].

3.2 Ship conditions

3.2.1 General

Ship relative motions and accelerations are to be calculated considering the ship in the following conditions:

- upright ship condition
- inclined ship condition.

3.2.2 Upright ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Z plane, i.e. surge, heave and pitch.

3.2.3 Inclined ship condition

In this condition, the ship encounters waves which produce ship motions in the X-Y and Y-Z planes, i.e. sway, roll and yaw.

3.3 Ship relative motions

3.3.1 The reference value of the relative motion in the upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 4.

Table 4 : Reference value of the relative motion h_1 in the upright ship condition

Location	Reference value of the relative motion h_1 in the upright ship condition, in m
$x = 0$	$0{,}7\left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$
$0 < x < 0{,}3\ L$	$h_{1,AE} - \frac{h_{1,AE} - h_{1,M}}{0{,}3}\frac{x}{L}$
$0{,}3\ L \le x \le 0{,}7\ L$	$0{,}42\ C\ (C_B + 0{,}7)$ without being taken greater than the minimum of T_1 and $D - 0{,}9\ T$
$0{,}7\ L < x < L$	$h_{1,M} + \frac{h_{1,FE} - h_{1,M}}{0{,}3}\left(\frac{x}{L} - 0{,}7\right)$
$x = L$	$\left(\frac{4{,}35}{\sqrt{C_B}} - 3{,}25\right)h_{1,M}$

Note 1:
C : Wave parameter defined in Ch 5, Sec 2
$h_{1,AE}$: Reference value h_1 calculated for $x = 0$
$h_{1,M}$: Reference value h_1 calculated for $x = 0{,}5\ L$
$h_{1,FE}$: Reference value h_1 calculated for $x = L$.

3.3.2 The reference value, in m, of the relative motion in the inclined ship condition is obtained, at any hull transverse section, from the following formula:

$$h_2 = 0{,}5 h_1 + A_R \frac{B_W}{2}$$

where:

h_1 : Reference value, in m, of the relative motion in the upright ship, calculated according to [3.3.1]

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

3.4 Accelerations

3.4.1 The reference values of the longitudinal, transverse and vertical accelerations at any point are obtained from the formulae in Tab 5 for upright and inclined ship conditions.

Table 5 : Reference values of the accelerations a_X, a_Y and a_Z

Direction		Upright ship condition	Inclined ship condition
X - Longitudinal	a_{X1} and a_{X2} in m/s²	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p (z - T_1)]^2}$	$a_{X2} = 0$
Y - Transverse	a_{Y1} and a_{Y2} in m/s²	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R (z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z - Vertical	a_{Z1} and a_{Z2} in m/s²	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{Z2} = \sqrt{0,25 a_H^2 + \alpha_R^2 y^2}$

Note 1:

$K_X = 1{,}2\left(\frac{x}{L}\right)^2 - 1{,}1\frac{x}{L} + 0{,}2$ without being taken less than 0,018

Section 4 Load Cases

Symbols

h_1 : Reference value of the ship relative motion in the upright ship condition, defined in Ch 5, Sec 3, [3.3]
h_2 : Reference value of the ship relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3]
a_{X1}, a_{Y1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4]
a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4]
M_{WV} : Reference value of the vertical wave bending moment, defined in Ch 5, Sec 2, [3.1]
M_{WH} : Reference value of the horizontal wave bending moment, defined in Ch 5, Sec 2, [3.2]
M_{WT} : Reference value of the wave torque, defined in Ch 5, Sec 2, [3.3]
Q_{WV} : Reference value of the vertical wave shear force, defined in Ch 5, Sec 2, [3.4].

1 General

1.1 Load cases for structural analyses based on partial ship models

1.1.1 The load cases described in this Section are those to be used for structural element analyses which do not require complete ship modelling. They are:

- the analyses of plating (see Ch 7, Sec 1)
- the analyses of ordinary stiffeners (see Ch 7, Sec 2)
- the analyses of primary supporting members through isolated beam structural models or three-dimensional structural models (see Ch 7, Sec 3)
- the fatigue analysis of the structural details of the above elements (see Ch 7, Sec 4).

1.1.2 These load cases are the mutually exclusive load cases “a”, “b”, “c” and “d” described in Article [2].

Load cases “a” and “b” refer to the ship in upright conditions (see Ch 5, Sec 3, [3.2]), i.e. at rest or having surge, heave and pitch motions.

Load cases “c” and “d” refer to the ship in inclined conditions (see Ch 5, Sec 3, [3.2]), i.e. having sway, roll and yaw motions.

1.2 Load cases for structural analyses based on complete ship models

1.2.1 When primary supporting members are to be analysed through complete ship models according to Ch 7, Sec 3, [1.1.2], specific load cases are to be considered.

These load cases are to be defined considering the ship as sailing in regular waves with different length, height and heading angle, each wave being selected in order to maximise a design load parameter. The procedure for the determination of these load cases is specified in Ch 7, App 3.

2 Load cases

2.1 Upright ship conditions (load cases “a” and “b”)

2.1.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 1 for load case “a” and Fig 2 for load case “b”) a relative motion of the sea waterline (both positive and negative) symmetric on the ship sides and induces wave vertical bending moment and shear force in the hull girder. In load case “b”, the wave is also considered to induce heave and pitch motions.

2.1.2 Local loads

The external pressure is obtained by adding to or subtracting from the still water head a wave head corresponding to the relative motion.

The internal loads are the still water loads induced by the weights carried, including those carried on decks. For load case “b”, those induced by the accelerations are also to be taken into account.

2.1.3 Hull girder loads

The hull girder loads are:

- the vertical still water bending moment and shear force
- the vertical wave bending moment and the shear force.

Figure 1 : Wave loads in load case "a"

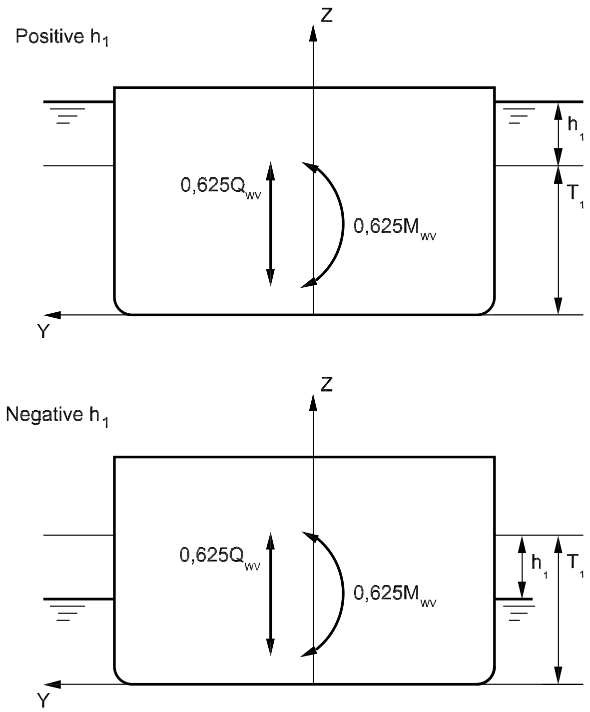
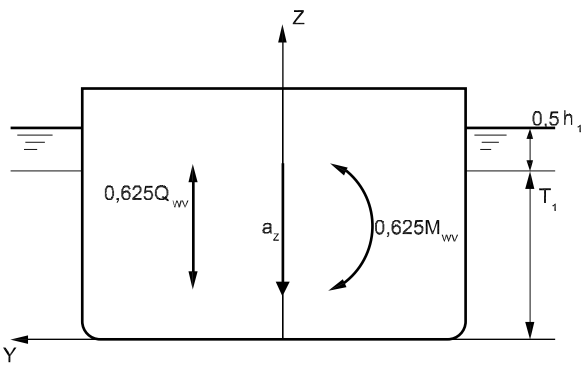


Figure 2 : Wave loads in load case "b"



2.2 Inclined ship conditions (load cases "c" and "d")

2.2.1 Ship condition

The ship is considered to encounter a wave which produces (see Fig 3 for load case "c" and Fig 4 for load case "d"):

- sway, roll and yaw motions
- a relative motion of the sea waterline anti-symmetric on the ship sides,

and induces:

- vertical wave bending moment and shear force in the hull girder
- horizontal wave bending moment in the hull girder
- in load case "c", torque in the hull girder.

2.2.2 Local loads

The external pressure is obtained by adding or subtracting from the still water head a wave head linearly variable from positive values on one side of the ship to negative values on the other.

The internal loads are the still water loads induced by the weights carried, including those carried on decks, and the wave loads induced by the accelerations.

Figure 3 : Wave loads in load case "c"

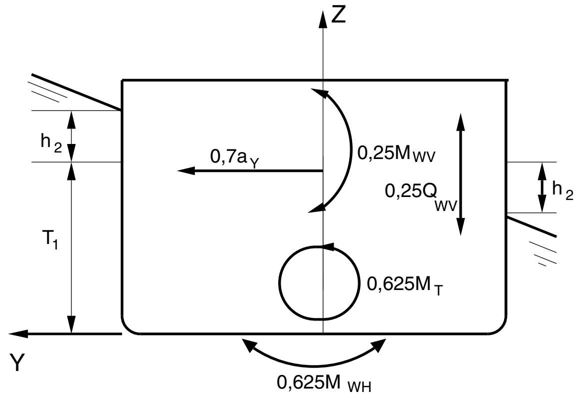
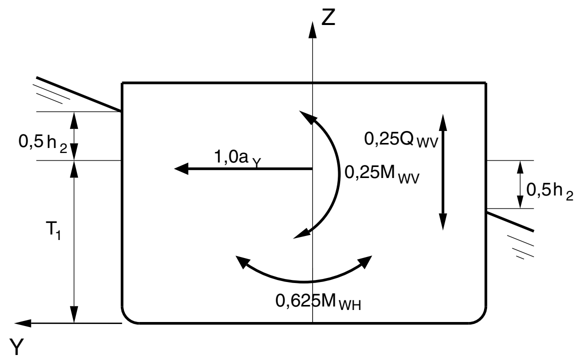


Figure 4 : Wave loads in load case "d"



2.2.3 Hull girder loads

The hull girder loads are:

- the still water bending moment and shear force
- the vertical wave bending moment and shear force
- the horizontal wave bending moment
- the wave torque (for load case "c").

2.3 Summary of load cases

2.3.1 The wave local and hull girder loads to be considered in each load case are summarised in Tab 1 and Tab 2, respectively. These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 1 : Wave local loads in each load case

Ship condition	Load case	Relative motions		Accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value	Combination factor
Upright	"a"	h_1	1,0	a_{X1} ; 0; a_{Z1}	0,0
	"b" **(1)**	h_1	0,5	a_{X1} ; 0; a_{Z1}	1,0
Inclined	"c" **(2)**	h_2	1,0	0; a_{Y2} ; a_{Z2}	0,7
	"d" **(2)**	h_2	0,5	0; a_{Y2} ; a_{Z2}	1,0

(1) For a ship moving with a positive heave motion:
- h_1 is positive
- the acceleration a_{X1} is directed towards the positive part of the X axis
- the acceleration a_{Z1} is directed towards the negative part of the Z axis

(2) For a ship rolling with a negative roll angle:
- h_2 is positive for the points located in the positive part of the Y axis and, vice-versa, it is negative for the points located in the negative part of the Y axis
- the acceleration a_{Y2} is directed towards the positive part of the Y axis
- the acceleration a_{Z2} is directed towards the negative part of the Z axis for the points located in the positive part of the Y axis and, vice-versa, it is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

Table 2 : Wave hull girder loads in each load case

Ship condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment		Torque	
		Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor	Reference value	Comb. factor
Upright	"a"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_T	0,0
	"b"	0,625 M_{WV}	1,0	0,625 Q_{WV}	1,0	0,625 M_{WH}	0,0	0,625 M_T	0,0
Inclined	"c"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_T	1,0
	"d"	0,625 M_{WV}	0,4	0,625 Q_{WV}	0,4	0,625 M_{WH}	1,0	0,625 M_T	0,0
Note 1: The sign of the hull girder loads, to be considered in association with the wave local loads for the scantling of plating, ordinary stiffeners and primary supporting members contributing to the hull girder longitudinal strength, is defined in Part B, Chapter 7.									

Section 5 Sea Pressures

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

ρ : Sea water density, taken equal to 1,025 t/m^3

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3].

1 Still water pressure

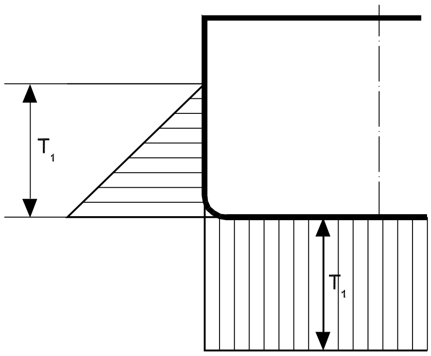
1.1 Pressure on sides and bottom

1.1.1 The still water pressure at any point of the hull is obtained from the formulae in Tab 1 (see also Fig 1).

Table 1 : Still water pressure

Location	Still water pressure p_S, in kN/m^2
Points at and below the waterline ($z \le T_1$)	$\rho\ g\ (T_1 - z)$
Points above the waterline ($z > T_1$)	0

Figure 1 : Still water pressure



2 Wave pressure

2.1 Upright ship conditions (load cases "a" and "b")

2.1.1 Pressure on sides and bottom

The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 4 (see also Fig 2 for load case "a" and Fig 3 for load case "b").

Figure 2 : Wave pressure in load case "a"

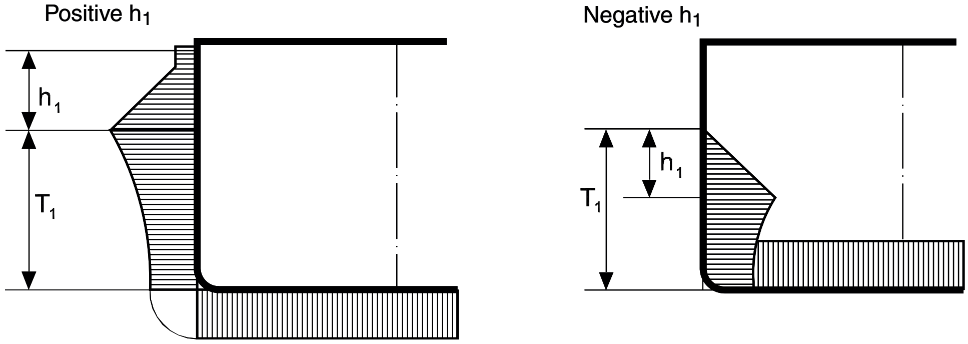
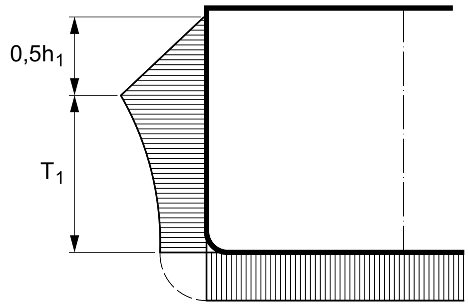


Figure 3 : Wave pressure in load case “b”



2.2 Inclined ship conditions (load cases “c” and “d”)

2.2.1 The wave pressure at any point of the sides and bottom is obtained from the formulae in Tab 5 (see also Fig 4 for load case “c” and Fig 5 for load case “d”).

Figure 4 : Wave pressure in load case “c”

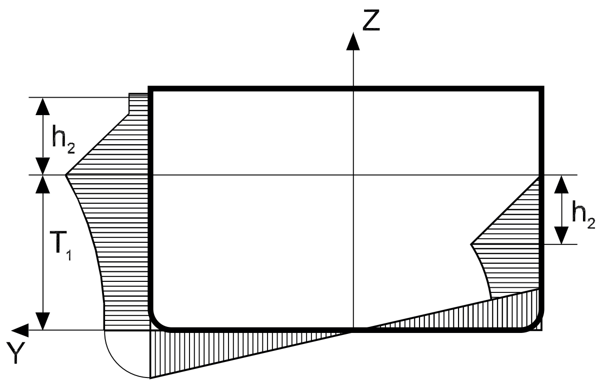
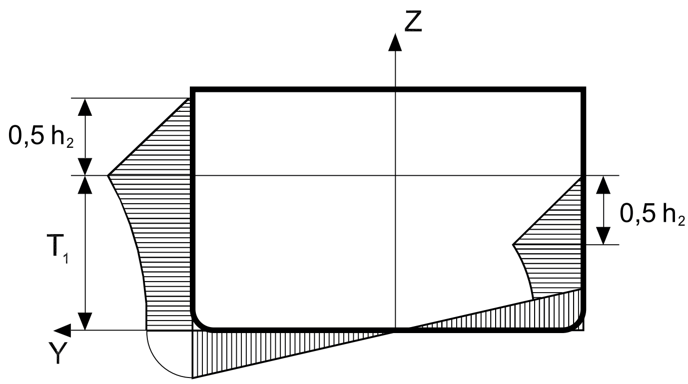


Figure 5 : Wave pressure in load case “d”



3 Exposed decks

3.1 Application

3.1.1 The pressures defined in [3.2] for exposed decks are to be considered independently of the pressures due to dry uniform cargoes, dry unit cargoes or wheeled cargoes, if any, as defined in Ch 5, Sec 6, [2], Ch 5, Sec 6, [3] and Ch 5, Sec 6, [4] respectively.

3.2 Sea pressures on exposed decks

3.2.1 Still water pressure

The still water pressure on exposed decks p_S, in kN/m², is to be taken equal to $10.\varphi_1.\varphi_2$, where φ_1 is defined in Tab 2 and φ_2 in Tab 3.

3.2.2 Green sea loads

The wave pressure on exposed decks due to green sea is obtained from the formulae in Tab 3 and Tab 5.

Table 2 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Watertight deck and below	1,00
Top of lowest tier	0,75
Top of second tier	0,56
Top of third tier	0,42
Top of fourth tier	0,32
Top of fifth tier	0,25
Top of sixth tier	0,20
Top of seventh tier	0,15
Top of eighth tier and above	0,10

Table 3 : Wave pressure on exposed decks in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	
	Crest	Through
$0 \le x \le 0,5\ L$	$17,5\varphi_1\varphi_2$	0
$0,5\ L < x < 0,75\ L$	$\left\{17,5 + \left[\frac{19,6\sqrt{H_F} - 17,5}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\}\varphi_1\varphi_2$	0
$0,75\ L \le x \le L$	$19,6\varphi_1\varphi_2\sqrt{H}$	0

Note 1:

$$H = C_{F1}\left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T_1)$$ without being taken less than 0,8

φ_1 : Coefficient defined in Tab 2

φ_2 : Coefficient taken equal to:

- $\varphi_2 = 1$ if $L \ge 120$ m
- $\varphi_2 = L/120$ if $L < 120$ m

H_F : Value of H calculated at $x = 0,75\ L$

C_{F1} : Combination factor, to be taken equal to:

- $C_{F1} = 1,0$ for load case “a”
- $C_{F1} = 0,5$ for load case “b”

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 4 : Wave pressure on sides and bottom in upright ship conditions (load cases “a” and “b”)

Location	Wave pressure p_W, in kN/m²	
	Crest	Trough
Bottom and sides below the waterline ($z \le T_1$)	$\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$	$-\rho g h e^{\frac{-2\pi(T_1 - z)}{L}}$ without being taken less than $\rho\, g\, (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho\, g\, (T_1 + h - z)$ without being taken, for case “a” only, less than $0,15\ \varphi_1\ \varphi_2\ L$	0,0

Note 1:

$h = C_{F1}\ h_1$

C_{F1} : Combination factor, to be taken equal to:

- $C_{F1} = 1,0$ for load case “a”
- $C_{F1} = 0,5$ for load case “b”.

Table 5 : Wave pressure on sides, bottom and exposed decks in inclined ship conditions (load cases “c” and “d”)

Location	Wave pressure p_W, in kN/m² (negative roll angle) **(1)**	
	$y \geq 0$	$y < 0$
Bottom and sides below the waterline ($z \leq T_1$)	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$	$\beta C_{F2} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{L}} + A_R y e^{\frac{-\pi(T_1 - z)}{L}}\right]$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g \left[T_1 + \beta C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken, for case “c” only, less than 0,15 φ_1 φ_2 L	0
Exposed decks	$0{,}4 \rho g \left[T_1 + \beta C_{F2}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$ without being taken, for case “c” only, less than 0,15 φ_1 φ_2 L	0

(1) In the formulae giving the wave pressure p_W, the ratio (y / B_W) is not to be taken greater than 0,5.

Note 1:

φ_1 : Coefficient defined in Tab 2

φ_2 : Coefficient defined in Tab 3

C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case “c”
- C_{F2} = 0,5 for load case “d”

β : coefficient, to be taken as the minimum of:
- 1
- $T_1 / \left(0{,}5 h_1 + A_R \frac{B_W}{2}\right)$
- $(D - 0{,}9T) / \left(0{,}5 h_1 + A_R \frac{B_W}{2}\right)$

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

4 Sea chests

4.1 Design pressure

4.1.1 The pressure to be considered for the scantling of sea chests is the maximum between:
- sea pressure as calculated in Articles [1] and [2] for sides and bottom
- pressure defined by the designer to consider the hazard of an overpressure due to the inlet grating cleaning system, to be taken not less than 200 kN/m².

Section 6 Internal Pressures and Forces

Symbols

For the symbols not defined in this Section, refer to the list at the beginning of this Chapter.

ρ_L : Density, in t/m^3, of the liquid carried

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction

z_L : Z co-ordinate, in m, of the highest point of the liquid:

$z_L = z_{TOP} + 0{,}5\ (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}

p_{PV} : Setting pressure, in bar, of safety valves

M : Mass, in t, of a dry unit cargo carried

a_{X1} , a_{Y1} , a_{Z1} : Reference values of the accelerations in the upright ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity:

- of the compartment, in general
- of any dry unit cargo, in the case of this type of cargo

a_{X2} , a_{Y2} , a_{Z2} : Reference values of the accelerations in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity:

- of the compartment, in general
- of any dry unit cargo, in the case of this type of cargo

C_{FA} : Combination factor, to be taken equal to:

- $C_{FA} = 0{,}7$ for load case “c”
- $C_{FA} = 1{,}0$ for load case “d”

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank, excluding any small hatchways

d_{AP} : Distance from the top of air pipe to the top of compartment, in m

d_0 : Distance, in m, to be taken equal to:

$d_0 = 0{,}02\ L$ for $65\ m \le L < 120\ m$

$d_0 = 2{,}4$ for $L \ge 120$ m.

1 Liquids

1.1 Still water pressure

1.1.1 Still water pressure

The still water pressure to be used in combination with the inertial pressure in [1.2] is the greater of the values obtained, in kN/m^2, from the following formulae:

$p_S = \rho_L\ g\ (z_L - z)$

$p_S = \rho_L\ g\ (z_{TOP} - z) + 100\ p_{PV}$

1.2 Inertial pressure

1.2.1 Inertial pressure

The inertial pressure is obtained from the formulae in Tab 1, or from Ch 5, App 1 for typical tank arrangements.

Moreover, the inertial pressure is to be taken such that:

$p_S + p_W \ge 0$

where p_S is defined in [1.1].

Table 1 : Liquids - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$\rho_L\ [0{,}5\ a_{X1}\ \ell_B + a_{Z1}\ (z_{TOP} - z)]$
Inclined (negative roll angle)	"c"	$\rho_L\ [a_{TY}\ (y - y_H) + a_{TZ}\ (z - z_H) + g\ (z - z_{TOP})]$
	"d"	

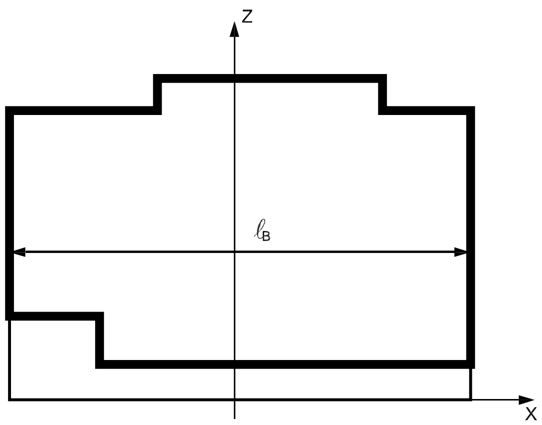
Note 1:

ℓ_B : Longitudinal distance, in m, between the transverse tank boundaries, without taking into account small recesses in the lower part of the tank (see Fig 1)

a_{TY} , a_{TZ} : Y and Z components, in m/s², of the total acceleration vector defined in [1.2.2] for load case "c" and load case "d"

y_H , z_H : Y and Z co-ordinates, in m, of the highest point of the tank in the direction of the total acceleration vector, defined in [1.2.3] for load case "c" and load case "d".

Figure 1 : Upright ship conditions - Distance ℓ_B



1.2.2 Total acceleration vector

The total acceleration vector is the vector obtained from the following formula:

$$\vec{A_T} = \vec{A} + \vec{G}$$

where:

A : Acceleration vector whose absolute values of X, Y and Z components are the longitudinal, transverse and vertical accelerations defined in Ch 5, Sec 3, [3.4]

G : Gravity acceleration vector.

The Y and Z components of the total acceleration vector and the angle it forms with the z direction are defined in Tab 2.

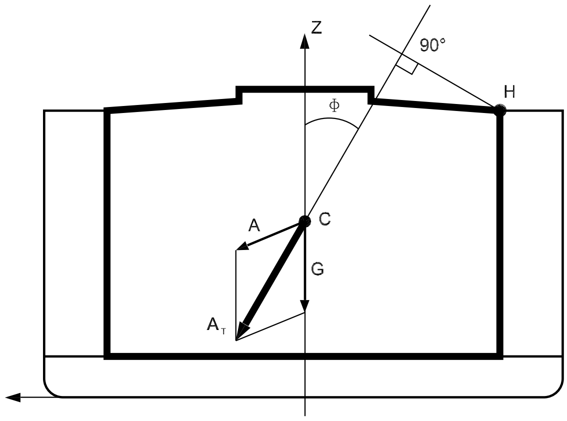
Table 2 : Inclined ship conditions Y and Z components of the total acceleration vector and angle Φ it forms with the z direction

Components (negative roll angle)		Angle Φ, in rad
a_{TY}, in m/s²	a_{TZ}, in m/s²	
$0{,}7\ C_{FA}\ a_{Y2}$	$-0{,}7\ C_{FA}\ a_{Z2} - g$	$\operatorname{atan}\dfrac{a_{TY}}{a_{TZ}}$

1.2.3 Highest point of the tank in the direction of the total acceleration vector

The highest point of the tank in the direction of the total acceleration vector A_T, defined in [1.2.2], is the point of the tank boundary whose projection on the direction forming the angle Φ with the vertical direction is located at the greatest distance from the tank's centre of gravity. It is to be determined for the inclined ship condition, as indicated in Fig 2, where A and G are the vectors defined in [1.2.2] and C is the tank's centre of gravity.

Figure 2 : Inclined ship conditions Highest point H of the tank in the direction of the total acceleration vector



2 Dry uniform loads

2.1 Still water and inertial pressures

2.1.1 General

The still water and inertial pressures are obtained, in kN/m², as specified in Tab 3.

Table 3 : Dry uniform loads Still water and inertial pressure

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is generally specified by the Designer; in any case, it may not be taken less than 10 kN/m². When the value of p_S is not specified by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_{W,Z} = p_S \frac{a_{Z1}}{g}$ in z direction
Inclined (negative roll angle)	"c"	$p_{W,Y} = p_S \frac{C_{FA} a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p_S \frac{C_{FA} a_{Z2}}{g}$ in z direction

3 Dry unit cargoes

3.1 Still water and inertial forces

3.1.1 The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 4 taking into account the elastic characteristics of the lashing arrangement and/or the structure which contains the unit.

Table 4 : Dry unit - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water		$F_S = M g$
Upright (positive heave motion)	"a"	No inertial force
	"b"	$F_{W,X} = M a_{X1}$ in x direction $F_{W,Z} = M a_{Z1}$ in z direction
Inclined (negative roll angle)	"c"	$F_{W,Y} = M C_{FA} a_{Y2}$ in y direction
	"d"	$F_{W,Z} = M C_{FA} a_{Z2}$ in z direction

4 Vehicles and helicopters

4.1 Still water and inertial forces

4.1.1 Tyred vehicles and helicopters

The forces transmitted through the tyres are to be considered as a pressure uniformly distributed over the tyre print. With the exception of dimensioning of plating, such forces may be considered as concentrated in the tyre print centre.

The designer is to provide the following information for each tyred vehicle or helicopter:

- the number of axles and the relative arrangement of axles
- the number of wheels on axles and their arrangement
- the maximum mass of the vehicle or helicopter
- the distribution of load per axle
- the dimensions of the tyre prints
- the tyre pressures, if the dimensions of the tyre prints is not specified.

The above information is to be specified for all relevant operating and non-operating conditions.

In the case of vehicles having a Safe Working Load or maximum rated lifting capacity (for example, forklifts and movable cranes), the maximum mass and distribution of load per axle are to be specified with respect to these values.

The still water and inertial forces transmitted to the hull structures are to be determined on the basis of the forces obtained, in kN, as specified in Tab 5.

4.1.2 Non-tyred rolling vehicles

The requirements of [4.1.1] also apply to tracked vehicles; in this case the print to be considered is that below each wheel or wheelwork.

4.1.3 Other vehicles

For other vehicles on fixed supports, all the forces transmitted are to be considered as concentrated at the contact area centre.

Table 5 : Vehicles and helicopters Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water **(1) (2)**		$F_S = M\,g$
Upright (positive heave motion)**(1)**	"a"	No inertial force
	"b"	$F_{W,Z} = \alpha\,M\,a_{Z1}$ in z direction
Inclined (negative roll angle)**(2)**	"c"	$F_{W,Y} = M\,C_{FA}\,a_{Y2}$ in y direction
	"d"	$F_{W,Z} = M\,C_{FA}\,a_{Z2}$ in z direction
Harbour		$F_{W,X} = 0{,}035\,M\,g$ in x direction $F_{W,Y} = 0{,}087\,M\,g$ in y direction $F_{W,Z} = 0{,}100\,M\,g$ in z direction

(1) This condition defines the force, applied by one wheel, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, as defined in Part B, Chapter 7, where:

α : Coefficient taken equal to 0,5

M : Mass, in t, taken equal to:

$$M = \frac{Q_A}{n_W}$$

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered.

(2) This condition is to be considered for the racking analysis, as defined in Ch 7, App 2, with M taken equal to the mass, in t, of wheeled loads located on the structural member under consideration.

5 Accommodation and ammunition storage

5.1 Still water and inertial pressures

5.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 6 and Tab 7.

5.1.2 In addition to the pressures defined in [5.1.1], the effect of significant concentrated loads must be taken into account, when deemed necessary by the Society.

Table 6 : Accommodations and ammunition storage - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		The value of p_S is defined in Tab 7 depending on the type of the accommodation compartment
Upright (positive heave motion)	"a"	No inertial force
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually
	"d"	

Table 7 : Still water deck pressure in operational and accommodation compartments

Type of operational and accommodation compartments	p_S, in kN/m²
Operational rooms (COC, COP, TLC, ECG, ADT, GE, RADAR room, EMPAR, METEO)	6,5
Cabins, hospitals, kitchens, baggage rooms	3,0
Galleys, restaurant, meeting rooms, briefing rooms, corridors, lounges	5,0
Other storages	10,0
Ammunition storages	**(1)**
(1) The value of p_S is to be specified by the Designer; in any case, it may not be less than 15,0 kN/m². This value may also be assumed for the scantling checks where, at a preliminary design stage, the value of p_S is not yet defined by the Designer.	

5.1.3 Manoeuvring areas are always to be considered as exposed areas, and as such, subject to the relevant loads in Ch 5, Sec 5.

5.1.4 For ammunition storages, the case of fire-extinguishing by flooding as per Pt C, Ch 4, Sec 6 is to be taken into consideration, in addition to Tab 7. Loads on decks and side walls are to be checked according to [1]. In case the water-spraying system is fitted with an automatic closing of the water supply valve when the water level reaches the top of the storage area, this maximum water level is to be clearly specified on relevant drawings and is to be considered for calculation of liquid pressure in Article [1].

Doors and hatches giving access to ammunition storage are to have a strength equivalent to the one of the surrounding structure.

For ammunition storages above the deepest waterline and fitted with scuppers, reduction of pressure may be considered on a case-by-case basis, based on justification provided by the Designer.

6 Machinery

6.1 Still water and inertial pressures

6.1.1 The still water and inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 8.

Table 8 : Machinery - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water		$p_S = 10$
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \frac{a_{Z1}}{g}$
Inclined	"c"	The inertial pressure transmitted to the deck structures in inclined condition may generally be disregarded. Specific cases in which this simplification is not deemed permissible by the Society are considered individually
	"d"	

7 Flooding

7.1 Still water and inertial pressures

7.1.1 Unless otherwise specified, the still water pressure p_{SF}, in kN/m², and the inertial pressure p_{WF}, in kN/m², to be considered as acting on structural watertight elements defined as per Internal Watertight Plan and located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding are obtained from the formulae in Tab 9.

Table 9 : Flooding - Still water and inertial pressures

Still water pressure p_{SF}, in kN/m²	Inertial pressure p_{WF}, in kN/m²
$\rho\, g\, (z_F - z)$ without being taken less than $0{,}4\, g\, d_0$	$0{,}6\, \rho\, a_{Z1}\, (z_F - z)$ without being taken less than $0{,}4\, g\, d_0$

Note 1:
z_F : Z co-ordinate, in m, at the deepest equilibrium waterline at side in way of the transverse section considered, obtained from the damage stability calculations, for which the transient conditions are to be taken into account
d_0 : Distance, in m, to be taken equal to:
$d_0 = 0{,}02\, L$ for $65\text{ m} \le L \le 120\text{ m}$
$d_0 = 2{,}4$ for $L > 120\text{ m}$.

8 Testing

8.1 Still water pressures

8.1.1 The still water pressure to be considered as acting on plates and stiffeners subject to tank testing is obtained, in kN/m², from the formulae in Tab 10.

No inertial pressure is to be considered as acting on plates and stiffeners subject to tank testing.

Table 10 : Testing - Still water pressures

Compartment or structure to be tested	Still water pressure p_{ST}, in kN/m²
Double bottom tanks	The greater of the following: $p_{ST} = 10\, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\, [(z_{TOP} - z) + 2{,}4]$ $p_{ST} = 10\, (z_{BD} - z)$
Double side tanks, fore and after peaks used as tank, cofferdams	The greater of the following: $p_{ST} = 10\, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\, [(z_{TOP} - z) + 2{,}4]$
Tank bulkheads, deep tanks, fuel oil bunkers	The greater of the following: $p_{ST} = 10\, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\, [(z_{TOP} - z) + 2{,}4]$ $p_{ST} = 10\, [(z_{TOP} - z) + 10\, p_{PV}]$
Fore peak not used as tank	The greater of the following: $p_{ST} = 10\, (z_F - z)$ $p_{ST} = 10\, (z_{BD} - z)$
Watertight doors below bulkhead deck	$p_{ST} = 10\, (z_{BD} - z)$
Chain locker (if aft of collision bulkhead)	$p_{ST} = 10\, (z_{TOP} - z)$
Independent tanks and ammunition storage **(1)**	The greater of the following: $p_{ST} = 10\, [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\, [(z_{TOP} - z) + 0{,}9]$
Ballast ducts	Ballast pump maximum pressure

z_{BD} : Z co-ordinate, in m, of the bulkhead deck
z_F : As defined in Tab 9.
(1) Ammunition storage where the extinguishing system is not by flooding need not be subjected to testing

9 Weapons firing dynamic loads

9.1 Dynamic loads

9.1.1 General

The following weapons firing dynamic loads are to be specified by the Designer:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure
- gun recoil dynamic force, for all the possible combinations of elevation and slewing angle of the weapon system.

As guidance, they may be obtained from the formulae specified in [9.2].

9.1.2 Other loads

Weapon firing dynamic loads other than those specified in [9.1.1], such as loads on vertical missile launching systems (VLS) and loads on rocket or missile launching systems with elevation and slewing capabilities, are generally to be specified by the weapon manufacturer. In any event, they are to be considered by the Society on a case-by-case basis.

9.1.3 Additional loads

At the request of the interested parties, additional weapon firing dynamic loads other than those specified in [9.1.1] and [9.1.2], such as collision or hitting against fixed devices fitted in way of the weapon system rail limits, may be considered by the Society on a case-by-case basis, together with the relevant weapon manufacturer specification.

9.2 Guidance values

9.2.1 Missile blast dynamic pressure

As guidance, the missile blast dynamic pressure may be obtained, in kN/m², from the following formula:

$$p_W = \frac{T\left(\sin\alpha + \left(\frac{0,0225}{\sin\alpha}\right)\right)}{A}$$

where (see Fig 3):

T : Total thrust, in kN, of the missile

α : Angle, in degrees, of incidence for missile blast with respect to the considered surface

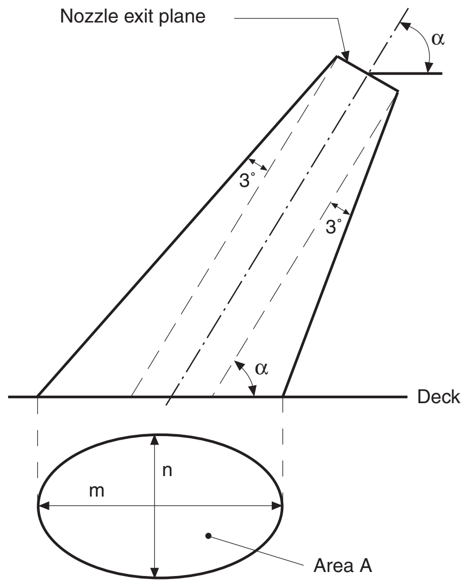
A : Impingement area, in m², of the considered surface bounded by the blast cone, i.e. the cone generated by rotating about the missile axis a line with a 3° divergence from the axis and passing through the circumference of the exit nozzle. The impingement area is to be obtained, in m², from the following formula:

$$A = \alpha m \frac{n}{4}$$

m : Major axis, in m, of the impingement area

n : Minor axis, in m, of the impingement area.

Figure 3 : Missile blast impingement area



9.2.2 Accidental missile ignition dynamic pressure

As guidance, the accidental missile ignition dynamic pressure may be obtained, in kN/m², from the following formula:

$$p_W = \frac{67,4R}{A_B}$$

where:

R : Burning rate, in kg / s, of the missile booster

A_B : Total area, in m², of blow-out opening.

9.2.3 Gun blast dynamic pressure

As guidance, the blast dynamic pressure for one gun may be obtained, in kN/m², from the following formula:

$$p_W = \frac{1380(1+\cos\beta)}{\left(\frac{r}{d}\right)^{1,5}}$$

where (see Fig 4):

β : Angle, in degrees, between the gun barrel axis and the straight line passing through the gun muzzle and the calculation point P

r : Distance, in mm, from the gun muzzle to the calculation point P

d : Gun diameter (calibre), in mm.

When two or more guns firing simultaneously are considered, the blast dynamic pressure is the greater of the values obtained by applying the above formula for each gun, considered as being firing independently from the others.

9.2.4 Gun recoil dynamic force

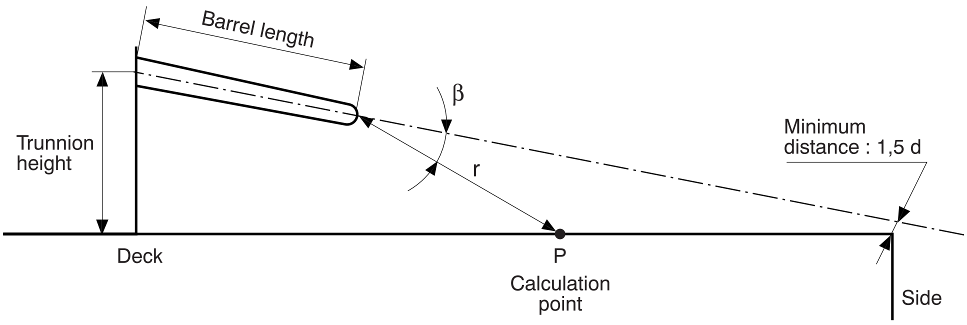
As guidance, the gun recoil dynamic force may be obtained, in kN, from the following formula:

$F_W = 1,3\ F_B$

where:

F_B : Rated brake load, in kN, of the recoil mechanism.

Figure 4 : Angle β and distance r for gun blast dynamic pressure calculation



Appendix 1 Inertial Pressure for Typical Tank Arrangement

1 Inertial ballast pressure

1.1 Introduction

1.1.1 Ch 5, Sec 6, [1] defines the criteria to calculate the inertial pressure p_W induced by ballast water in any type of tank. The relevant formulae are specified in Ch 5, Sec 6, Tab 1 and entail the definition of the highest point of the tank in the direction of the total acceleration vector. As specified in Ch 5, Sec 6, [1.2], this point depends on the geometry of the tank and the values of the acceleration. For typical tank arrangements, the highest point of the tank in the direction of the total acceleration vector can easily be identified and the relevant formulae written using the tank geometric characteristics.

1.1.2 This Appendix provides the formulae for calculating the inertial pressure p_W in the case of typical tank arrangements.

1.2 Formulae for the inertial pressure calculation

1.2.1 For typical tank arrangements, the inertial pressure transmitted to the hull structures at the calculation point P in inclined ship condition may be obtained from the formulae in Tab 1, obtained by applying to those tanks the general formulae in Ch 5, Sec 6, Tab 1.

Figure 1 : Distances b_L and d_H

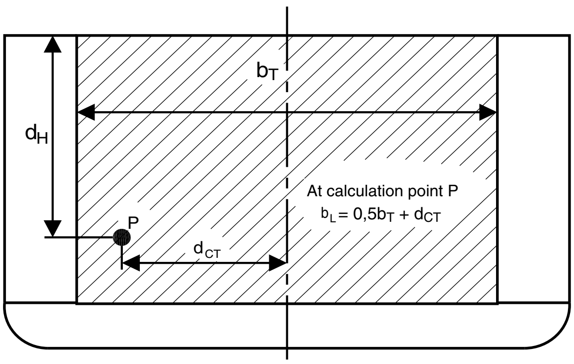


Table 1 : Inertial ballast pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Inclined (negative roll angle)	"c"	$0,7\ C_{FA}\ \rho_L\ (a_{Y2}\ b_L + a_{Z2}\ d_H)$
	"d"	

Note 1:

C_{FA} : Combination factor, to be taken equal to:
- $C_{FA} = 0,7$ for load case "c"
- $C_{FA} = 1,0$ for load case "d"

ρ_L : Density, in t/m³, of the liquid carried

a_{Y2}, a_{Z2} : Reference values of the acceleration in the inclined ship condition, defined in Ch 5, Sec 3, [3.4], calculated in way of the centre of gravity of the tank

b_L, d_H : Transverse and vertical distances, in m, to be taken as indicated in Fig 1 to Fig 4 for various types of tanks; for the cases in Fig 1, where the central area is divided into two or more tanks by longitudinal bulkheads, b_L and d_H for calculation points inside each tank are to be taken as indicated in Fig 3 for the double side.

Figure 2 : Distances b_L and d_H

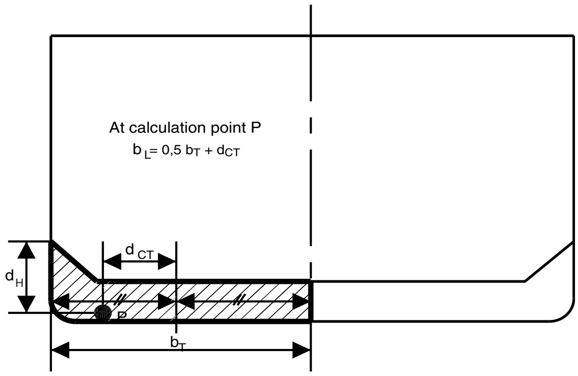


Figure 3 : Distances b_L and d_H

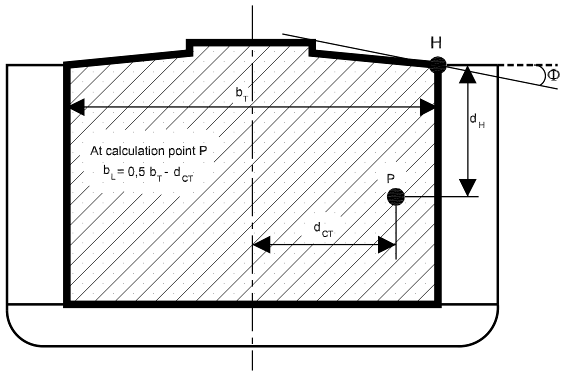
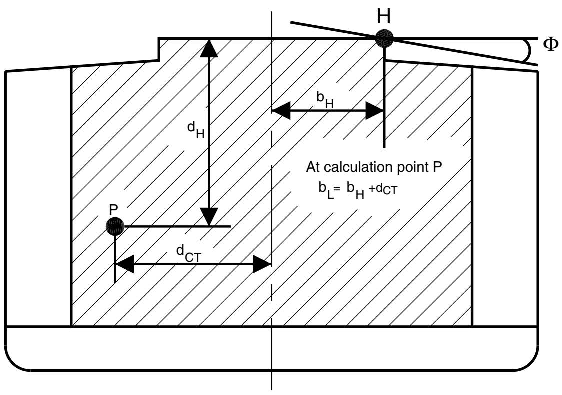


Figure 4 : Distances b_L and d_H



Part B
Hull and Stability

CHAPTER 6
HULL GIRDER STRENGTH

Section 1 Strength Characteristics of the Hull Girder Transverse Sections

Section 2 Yielding Checks

Section 3 Ultimate Strength Check

Appendix 1 Hull Girder Ultimate Strength

Symbols used in this Chapter

E : Young's modulus, in N/mm^2, to be taken equal to:
- for steels in general:
  $E = 2,06.10^5 \ N/mm^2$
- for stainless steels:
  $E = 1,95.10^5 \ N/mm^2$
- for aluminium alloys:
  $E = 7,0.10^4 \ N/mm^2$

M_{SW} : Still water bending moment, in kN.m:
- in hogging conditions:
  $M_{SW} = M_{SW,H}$
- in sagging conditions:
  $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2],

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2], when the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0,

M_{WV} : Vertical wave bending moment, in kN.m:
- in hogging conditions:
  $M_{WV} = M_{WV,H}$
- in sagging conditions:
  $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1],

g : Gravity acceleration, in m/s^2:
$g = 9,81 \ m/s^2$.

Section 1 Strength Characteristics of the Hull Girder Transverse Sections

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1 General

1.1.1 This Section specifies the criteria for calculating the hull girder strength characteristics to be used for the checks in Ch 6, Sec 2 and Ch 6, Sec 3, in association with the hull girder loads specified in Ch 5, Sec 2.

2 Calculation of the strength characteristics of hull girder transverse sections

2.1 Hull girder transverse sections

2.1.1 General

Hull girder transverse sections are to be considered as being constituted by the members contributing to the hull girder longitudinal strength, i.e. all continuous longitudinal members below the strength deck defined in [2.2], taking into account the requirements in [2.1.2] to [2.1.9].

These members are to be considered as having net scantlings (see also Ch 4, Sec 2).

2.1.2 Continuous trunks and continuous longitudinal hatch coamings

Continuous trunks and continuous longitudinal hatch coamings may be included in the hull girder transverse sections, provided they are effectively supported by longitudinal bulkheads or primary supporting members.

2.1.3 Longitudinal ordinary stiffeners or girders welded above the decks

Longitudinal ordinary stiffeners or girders welded above the decks (including the deck of any trunk fitted as specified in [2.1.2]) may be included in the hull girder transverse sections.

2.1.4 Longitudinal girders between hatchways

Where longitudinal girders are fitted between hatchways, the sectional area that can be included in the hull girder transverse sections is obtained, in m^2, from the following formula:

$A_{EFF} = A_{LG}\, a$

where:

A_{LG} : Sectional area, in m^2, of longitudinal girders

a : Coefficient:

- for longitudinal girders effectively supported by longitudinal bulkheads or primary supporting members:

  a = 1

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r \le 60$:

  $$a = 0{,}6\left(\frac{s}{b_1} + 0{,}15\right)^{0{,}5}$$

- for longitudinal girders not effectively supported by longitudinal bulkheads or primary supporting members and having dimensions and scantlings such that $\ell_0 / r > 60$:

  a = 0

ℓ_0 : Span, in m, of longitudinal girders, to be taken as shown in Fig 1

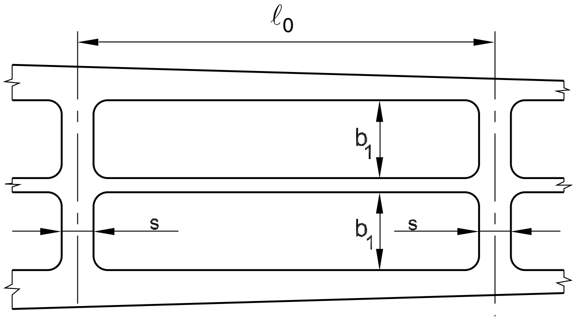
r : Minimum radius of gyration, in m, of the longitudinal girder transverse section

s, b_1 : Dimensions, in m, defined in Fig 1.

2.1.5 Longitudinal bulkheads with vertical corrugations

Longitudinal bulkheads with vertical corrugations may not be included in the hull girder transverse sections.

Figure 1 : Longitudinal girders between hatchways



2.1.6 Members in materials other than steel

Where a member contributing to the longitudinal strength is made in material other than steel with a Young's modulus E equal to 2,06 10^5 N/mm², the steel equivalent sectional area that may be included in the hull girder transverse sections is obtained, in m², from the following formula:

$$A_{SE} = \frac{E}{2{,}06 \cdot 10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.7 Large openings

Large openings are:

- elliptical openings exceeding 2,5 m in length or 1,2 m in breadth
- circular openings exceeding 0,9 m in diameter.

Large openings and scallops, where scallop welding is applied, are always to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.8 Small openings

Smaller openings than those in [2.1.7] in one transverse section in the strength deck or bottom area need not be deducted from the sectional areas included in the hull girder transverse sections, provided that:

$\Sigma b_S \leq 0{,}06\ (B - \Sigma b)$

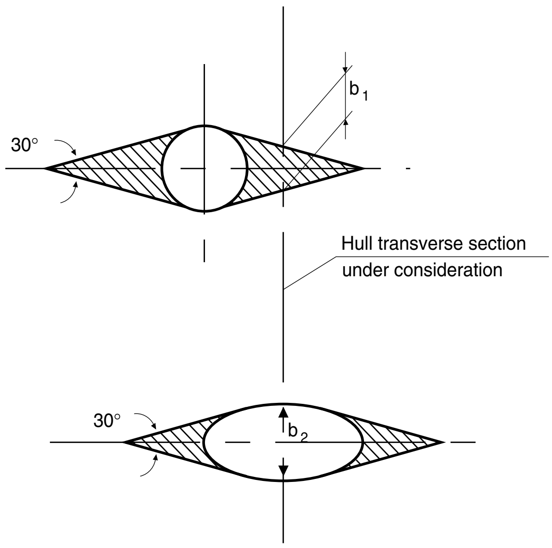
where:

Σb_S : Total breadth of small openings, in m, in the strength deck or bottom area at the transverse section considered, determined as indicated in Fig 2

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 2.

Where the total breadth of small openings Σb_S does not fulfil the above criteria, only the excess of breadth is to be deducted from the sectional areas included in the hull girder transverse sections.

Figure 2 : Calculation of Σb and Σb_S



b_1 and b_2 included in Σ b and Σ bs

2.1.9 Lightening holes, draining holes and single scallops

Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W 10^{-3}, without being greater than 75 mm, where h_W is the web height, in mm, defined in Ch 4, Sec 3.

Otherwise, the excess is to be deducted from the sectional area or compensated.

2.2 Strength deck

2.2.1 The strength deck is, in general, the uppermost continuous deck.

In the case of a superstructure or deckhouses contributing to the longitudinal strength, the strength deck is the deck of the superstructure or the deck of the uppermost deckhouse.

2.2.2 A superstructure extending at least 0,15 L within 0,4 L amidships may generally be considered as contributing to the longitudinal strength. For other superstructures and for deckhouses, their contribution to the longitudinal strength is to be assessed on a case by case basis, through a finite element analysis of the whole ship, which takes into account the general arrangement of the longitudinal elements (side, decks, bulkheads).

The presence of openings in the side shell and longitudinal bulkheads is to be taken into account in the analysis. This may be done in two ways:

- by including these openings in the finite element model
- by assigning to the plate panel between the side frames beside each opening an equivalent thickness, in mm, obtained from the following formula:

$$t_{EQ} = 10^3\left[\ell_P\left(\frac{Gh^2}{12EI_J} + \frac{1}{A_J}\right)\right]^{-1}$$

where (see Fig 3):

ℓ_P : Longitudinal distance, in m, between the frames beside the opening

h : Height, in m, of openings

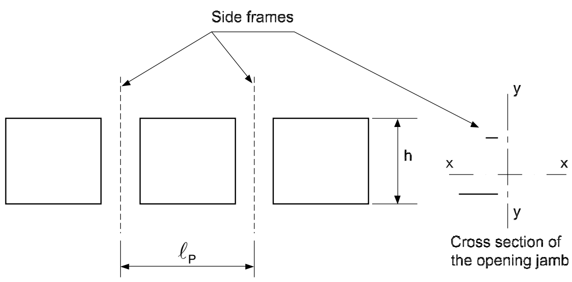
I_J : Moment of inertia, in m^4, of the opening jamb about the transverse axis y-y

A_J : Shear area, in m^2, of the opening jamb in the direction of the longitudinal axis x-x

G : Coulomb's modulus, in N/mm^2, of the material used for the opening jamb, to be taken equal to:

- for steels: $G = 8{,}0 \cdot 10^4$ N/mm²
- for aluminium alloys: $G = 2{,}7 \cdot 10^4$ N/mm².

Figure 3 : Side openings



2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m^3, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m^4, of the hull transverse section defined in [2.1], about its horizontal neutral axis

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [2.1], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.3.2 The section moduli at bottom and at the equivalent deck line are obtained, in m^3, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at the equivalent deck line:

$$Z_{AD} = \frac{I_Y}{V_D}$$

where:

I_Y, N : Defined in [2.3.1]

V_D : Vertical distance to the equivalent deck line, in m:

- when no effective longitudinal members specified in [2.1.2] and [2.1.3] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

  $V_D = z_D - N$

  where:

  z_D : Z co-ordinate, in m, of strength deck, defined in [2.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

- when effective longitudinal members specified in [2.1.2] and [2.1.3] are positioned above a line extending from strength deck at side to a position $(z_D - N)/0,9$ from the neutral axis at the centreline:

$$V_D = (z_T - N)\left(0,9 + 0,2\frac{y_T}{B}\right) \geq z_D - N$$

  where:

  y_T, z_T : Y and Z co-ordinates, in m, of the top of continuous trunk or hatch coaming or longitudinal ordinary stiffeners or girders welded above the strength deck, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]; y_T and z_T are to be measured for the point which maximises the value of V_D

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m^4, are those, calculated about the horizontal and vertical neutral axes, respectively, of the hull transverse sections defined in [2.1].

2.5 First moment

2.5.1 The first moment S, in m^3, at a level z above the baseline is that, calculated with respect to the horizontal neutral axis, of the portion of the hull transverse sections defined in [2.1] located above the z level.

2.6 Structural models for the calculation of normal warping stresses and shear stresses

2.6.1 The structural models that can be used for the calculation of normal warping stresses, induced by torque, and shear stresses, induced by shear forces or torque, are:

- three-dimensional finite element models
- thin walled beam models,

representing the members which constitute the hull girder transverse sections according to [2.1].

Section 2 Yielding Checks

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

M_{WH} : Horizontal wave bending moment, in kN·m, defined in Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN·m, defined in Ch 5, Sec 2, [3.3]

Q_{SW} : Design still water shear force, in kN, defined in Ch 5, Sec 2, [2.3]

Q_{WV} : Vertical wave shear force, to be calculated according to Ch 5, Sec 2, [3.4]:

- if $Q_{SW} \geq 0$, Q_{WV} is the positive wave shear force
- if $Q_{SW} < 0$, Q_{WV} is the negative wave shear force

k : Material factor, as defined in Ch 4, Sec 1, [2.3]

x : X co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

I_Y : Moment of inertia, in m^4, of the hull transverse section about its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

I_Z : Moment of inertia, in m^4, of the hull transverse section about its vertical neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

S : First moment, in m^3, of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.5]

Z_A : Section modulus, in cm^3, at any point of the hull transverse section, to be calculated according to Ch 6, Sec 1, [2.3.1]

Z_{AB},Z_{AD} : Section moduli, in cm^3, at bottom and deck, respectively, to be calculated according to Ch 6, Sec 1, [2.3.2]

C : Wave parameter defined in Ch 5, Sec 2.

1 Application

1.1 General

1.1.1 The requirements of this Section apply to ships having the following characteristics:

- $L < 500$ m
- $L / B > 5$
- $B / D < 2,5$
- $C_B \geq 0,4$

Ships not having one or more of these characteristics and ships of unusual type or design are considered by the Society on a case-by-case basis.

2 Hull girder stresses

2.1 Normal stresses induced by vertical bending moments

2.1.1 The normal stresses induced by vertical bending moments are obtained, in N/mm², from the following formulae:

- at any point of the hull transverse section:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_A} 10^3$$

- at bottom:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AB}} 10^3$$

- at the equivalent deck line:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^3$$

2.1.2 The formulae given in [2.1.1] are valid only when the distribution of vertical bending stress across the hull girder transverse section can be assumed to be linear.

Table 1 : Torque and bending moments

Still water loads		Wave loads					
Vertical bending moment		Torque **(1)**		Vertical bending moment		Horizontal bending moment	
Reference value	Combination factor	Reference value	Combination factor	Reference value	Combination factor	Reference value	Combination factor
M_{SW}	1,0	M_{WT}	1,0	M_{WV}	0,4	M_{WH}	1,0
(1) To be considered only when deemed necessary by the Society (e.g. wave torque is not applicable to frigates).							

2.1.3 The normal stresses in a member made in material other than steel with a Young's modulus E equal to $2{,}06 \cdot 10^5$ N/mm², included in the hull girder transverse sections as specified in Ch 6, Sec 1, [2.1.6], are obtained from the following formula:

$$\sigma_1 = \frac{E}{2{,}06 \cdot 10^5}\sigma_{1S}$$

where:

σ_{1S} : Normal stress, in N/mm², in the member under consideration, calculated according to [2.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in Ch 6, Sec 1, [2.1.6].

2.2 Normal stresses induced by vertical and horizontal bending moments

2.2.1 The normal stresses induced by vertical and horizontal bending moments are to be calculated for the load case constituted by the hull girder loads specified in Tab 1 together with their combination factors. They are to be obtained, in N/mm², from the following formula:

$$\sigma_1 = \frac{M_{SW}}{Z_A} + \frac{0{,}4M_{WV}}{Z_A} + \frac{M_{WH}}{I_Z}y$$

where:

y : Y co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6].

2.3 Shear stresses

2.3.1 The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6].

2.3.2 The hull girder loads to be considered in these analyses are the vertical shear forces Q_{SW} and Q_{WV}.

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force and torque are also to be calculated and taken into account in the calculation of shear stresses.

2.3.3 As an alternative to the above procedure, the shear stresses induced by the vertical shear forces Q_{SW} and Q_{WV} may be obtained through the simplified procedure in [2.4].

2.4 Simplified calculation of shear stresses induced by vertical shear forces

2.4.1 Ships without effective longitudinal bulkheads or with one effective longitudinal bulkhead

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear forces in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = 0,5(Q_{SW} + Q_{WV})\frac{S}{I_Y t_S}$$

where:

t_S : Minimum thickness, in mm, of side plating (see Fig 1) according to Tab 2.

2.4.2 Single side ships with two effective longitudinal bulkheads

In this context, effective longitudinal bulkhead means a bulkhead extending from the bottom to the strength deck.

The shear stresses induced by the vertical shear force in the calculation point are obtained, in N/mm², from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 2

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable (see Fig 2), according to Tab 2.

Table 2 : Shear stresses induced by vertical shear forces

Location	t, in mm	δ
Sides	t_S	$(1 - \Phi) / 2$
Longitudinal bulkheads	t_B	$\Phi / 2$

Note 1:
$\Phi = 0,3 + 0,21\ t_{BM} / t_{SM}$

t_S, t_B : Minimum net thicknesses, in mm, of side and longitudinal bulkhead plating, respectively

t_{SM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side and longitudinal bulkhead plating, respectively. They are calculated as: $\Sigma (\ell_i\ t_i) / \Sigma\ \ell_i$, where ℓ_i and t_i are the length, in m, and the thickness, in mm, of the i^{th} strake of side and longitudinal bulkheads.

Figure 1 : Single side ship without effective longitudinal bulkheads

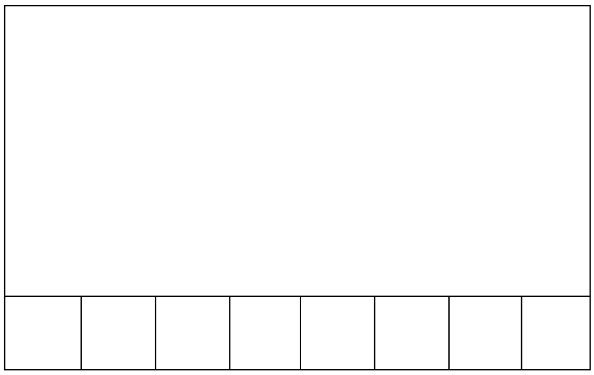
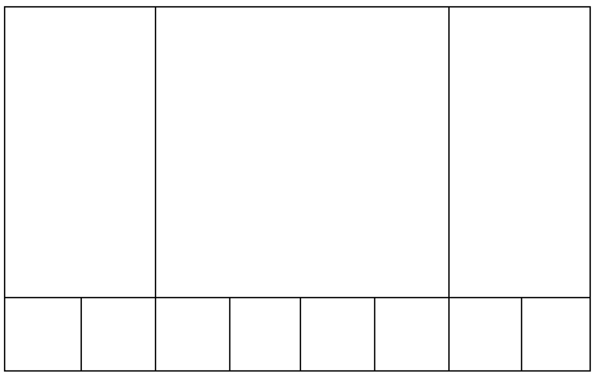


Figure 2 : Single side ship with two effective longitudinal bulkheads



3 Checking criteria

3.1 General

3.1.1 The material factors k are to be defined with respect to the material used at each calculation point, for the members contributing to the longitudinal strength according to Ch 6, Sec 1, [2].

3.2 Normal stresses induced by vertical bending moments

3.2.1 It is to be checked that the normal stresses σ_1 calculated according to [2.1]with vertical wave bending moment M_{WV} increased by 10%, and, when applicable, [2.2] are in compliance with the following formula:

$\sigma_1 \leq \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², obtained from the following formulae:

$$\sigma_{1,\,ALL} = \frac{139}{k} \quad \text{for } \frac{x}{L} \le 0,1$$

$$\sigma_{1,\,ALL} = \frac{194}{k} + \frac{275}{k}\left(\frac{x}{L} - 0,3\right) \quad \text{for } 0,1 < \frac{x}{L} < 0,3$$

$$\sigma_{1,\,ALL} = \frac{194}{k} \quad \text{for } 0,3 \le \frac{x}{L} \le 0,7$$

$$\sigma_{1,\,ALL} = \frac{194}{k} - \frac{275}{k}\left(\frac{x}{L} - 0,7\right) \quad \text{for } 0,7 < \frac{x}{L} < 0,9$$

$$\sigma_{1,\,ALL} = \frac{139}{k} \quad \text{for } \frac{x}{L} \ge 0,9$$

Note 1: For naval ships having a service notation other than **frigate** or **aircraft carrier**, the increased of M_{WV} by 10% may generally be disregarded.

3.3 Shear stresses

3.3.1 It is to be checked that the shear stresses τ_1 calculated according to [2.3] are in compliance with the following formula:

$\tau_1 \le \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²

$\tau_{1,ALL} = 122/k$

4 Section modulus and moment of inertia

4.1 General

4.1.1 The requirements in [4.2] to [4.5] provide for the minimum hull girder section modulus, complying with the checking criteria indicated in [3], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

4.1.2 The material factors k are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to Ch 6, Sec 1, [2]. When material factors for higher strength steels are used, the requirements in [4.5] apply.

4.2 Section modulus within 0,4L amidships

4.2.1 The section moduli Z_{AB} and Z_{AD} within 0,4 L amidships are to be not less than the value obtained, in m³, from the following formula:

$$Z_R = \frac{M_{SW} + nM_{WV}}{\sigma_{1,\,ALL}} 10^{-3}$$

where:

- n = 1,1 for service notation **frigate** or **aircraft carrier**
- n = 1,0 for the other service notations.

In addition, the section moduli Z_{AB} and Z_{AD} at the midship section are to be not less than the value obtained, in m³, from the following formula:

$$Z_{R\Delta} = \frac{M_{WV,\,H} + M_{WV,\,S}}{2\sigma_{\Delta,\,ALL}} 10^{-3}$$

where:

$\sigma_{\Delta,ALL}$: Allowable normal stress, in N/mm² to be taken equal to:

- 122 N/mm² for steel with R_{eH} = 235 N/mm²
- 155 N/mm² for steel with R_{eH} = 315 N/mm²
- 166 N/mm² for steel with R_{eH} = 355 N/mm² or 390 N/mm².

4.2.2 Where the total breadth Σb_S of small openings, as defined in Ch 6, Sec 1, [2.1.8], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R\Delta}$ defined in [4.2.1] may be reduced by 3%.

4.2.3 Scantlings of members contributing to the longitudinal strength (see Ch 6, Sec 1, [2]) are to be maintained within 0,4 L amidships.

4.3 Section modulus outside 0,4L amidships

4.3.1 The net section moduli Z_{AB} and Z_{AD} outside 0,4 L amidships are to be not less than the value obtained, in m^3, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,ALL}} 10^{-3}$$

4.4 Midship section moment of inertia

4.4.1 The midship section moment of inertia about its horizontal neutral axis is to be not less than the value obtained, in m^4, from the following formula:

$I_{YR} = 2{,}77\ Z'_{R\Delta}\ L\ 10^{-2}$

where:

$Z'_{R\Delta}$: Required midship section modulus $Z_{R\Delta}$, in m^3, calculated as specified in [4.2.1], but assuming $\sigma_{\Delta,ALL} = 130$ N/mm^2 in all cases.

4.5 Extent of higher strength steel

4.5.1 When a material factor for higher strength steel is used in calculating the required section modulus at bottom or at the equivalent deck line according to [4.2] or [4.3], and when the distribution of vertical bending stress across the hull girder transverse section can be assumed to be linear, the vertical extent of higher strength steel, $z_{hts,i}$ used in the deck zone or bottom zone and measured respectively from the equivalent deck line or baseline is not to be taken less the value obtained from the following formula:

$$z_{hts,i} = z_1 \left(1 - \frac{\sigma_{perm,i}}{\sigma_L}\right)$$

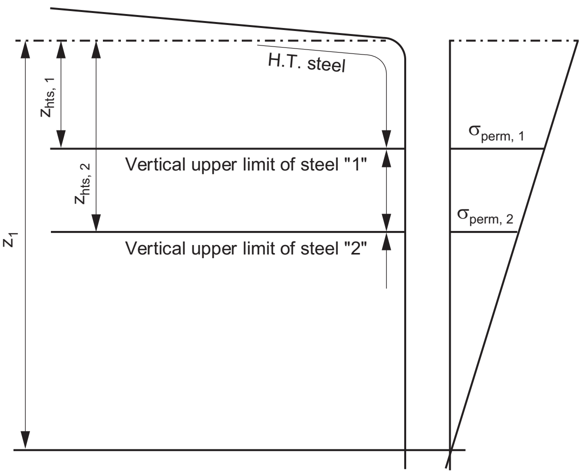
where:

σ_L : Normal stress, in N/mm^2, at the equivalent deck line or at bottom, calculated according to [2.1.1]

z_1 : Distance from horizontal neutral axis, to the equivalent deck line defined in Ch 6, Sec 1, [2.3.2], or to the baseline respectively, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [6]

$\sigma_{perm,i}$: Allowable normal stress defined in [3.1.1], in N/mm², for the adjacent zone of steel having lower strength (see Fig 3).

Figure 3 : Vertical extent of higher strength steel



4.5.2 The relevant higher strength steel is to be adopted for all members contributing to the longitudinal strength (see Ch 6, Sec 1, [2]) within the extent defined in [4.5.1].

4.5.3 The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes according to the provisions of Part B.

4.5.4 Longitudinal members not contributing to the hull girder longitudinal strength and welded to the strength deck or bottom plating and bilge strake, such as longitudinal hatch coamings, gutter bars, strengthening of deck openings, bilge keel, are to be made of steel with the same specified minimum yield stress as the strength deck or bottom structure steel.

4.5.5 The requirement in [4.5.4] is also applicable to non-continuous longitudinal stiffeners welded to the web of a primary structural member contributing to the hull girder longitudinal strength such as hatch coamings, stringers and girders or on the inner bottom when the hull girder stress in those members is higher than the permissible stress as defined in [3.1.1] for normal strength steel.

5 Permissible still water bending moment and shear force during navigation

5.1 Permissible still water bending moment

5.1.1 The permissible still water bending moment at any hull transverse section during navigation, in hogging or sagging conditions, is the value M_{SW} considered in the hull girder section modulus calculation according to Article [4].

In the case of structural discontinuities in the hull transverse sections, the distribution of permissible still water bending moments is considered on a case-by-case basis.

5.2 Permissible still water shear force

5.2.1 Direct calculations

Where the shear stresses are obtained through calculation analyses according to [2.3], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon|Q_T| - Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}\,(Q_{SW})$

Q_T : Shear force, in kN, which produces a shear stress $\tau = 122/k$ N/mm^2 in the most stressed point of the hull transverse section.

5.2.2 Single side ships without effective longitudinal bulkheads

Where the shear stresses are obtained through the simplified procedure in [2.4.1], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \varepsilon\left(\frac{122}{0,5k} \cdot \frac{I_Y t_S}{S}\right) - Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}\,(Q_{SW})$

t_S : Minimum net thickness, in mm, of side plating according to Tab 2.

5.2.3 Single side ships with two effective longitudinal bulkheads

Where the shear stresses are obtained through the simplified procedure in [2.4.2], the permissible positive or negative still water shear force at any hull transverse section is obtained, in kN, from the following formula:

$$Q_P = \frac{1}{\delta}\left(\varepsilon\frac{122}{k} \cdot \frac{I_Y t}{S}\right) - Q_{WV}$$

where:

δ : Shear distribution coefficient defined in Tab 2

$\varepsilon = \mathrm{sgn}\,(Q_{SW})$

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable, according to Tab 2.

6 Permissible still water bending moment and shear force in harbour conditions

6.1 Permissible still water bending moment

6.1.1 The permissible still water bending moment at any hull transverse section in harbour conditions, in hogging or sagging conditions, is obtained, in kN·m, from the following formula:

$$M_{P,H} = M_P + 0,6\ M_W$$

where M_P is the permissible still water bending moment during navigation in KN·m, to be calculated according to [5.1.1].

6.2 Permissible shear force

6.2.1 The permissible positive or negative still water shear force at any hull transverse section, in harbour conditions, is obtained, in kN, from the following formula:

$$Q_{P,H} = \varepsilon\ Q_P + 0,7\ Q_{WV}$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

Q_P : Permissible still water shear force during navigation, in kN, to be calculated according to [5.2].

Section 3 Ultimate Strength Check

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 Application

1.1

1.1.1 The requirements of this Section apply to ships equal to or greater than 90 m in length.

2 General

2.1 Net scantlings

2.1.1 As specified in Ch 4, Sec 2, [1], the ultimate strength of the hull girder is to be checked on the basis of the net strength characteristics of the transverse section which is to be calculated according to Ch 4, Sec 2, [2].

2.2 Partial safety factors

2.2.1 The partial safety factors to be considered for checking the ultimate strength of the hull girder are specified in Tab 1.

Table 1 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	Value
Still water hull girder loads	γ_{S1}	1,00
Wave induced hull girder loads	γ_{W1}	1,20
Material	γ_m	1,02
Resistance	γ_R	1,15

3 Hull girder ultimate strength check

3.1 Hull girder loads

3.1.1 Bending moments

The bending moment in sagging and hogging conditions, to be considered in the ultimate strength check of the hull girder, is to be obtained, in kN·m, from the following formula:

$M = \gamma_{S1} M_{SW} + \gamma_{W1} M_{WV}$

3.2 Hull girder ultimate bending moment capacities

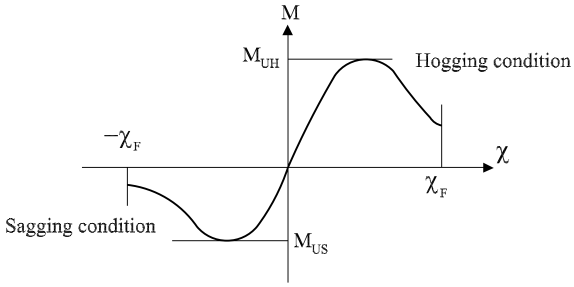
3.2.1 Curve M-χ

The ultimate bending moment capacities of a hull girder transverse section, in hogging and sagging conditions, are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

The curvature χ is positive for hogging condition and negative for sagging condition.

The curve M-χ is to be obtained through an incremental-iterative procedure according to the criteria specified in Ch 6, App 1.

Figure 1 : Curve bending moment capacity M versus curvature χ



3.2.2 Hull girder transverse sections

The hull girder transverse sections are constituted by the elements contributing to the hull girder longitudinal strength, considered with their net scantlings, according to Ch 6, Sec 1, [2].

3.3 Checking criteria

3.3.1 It is to be checked that the hull girder ultimate bending capacity at any hull transverse section is in compliance with the following formula:

$$\frac{M_U}{\gamma_R \gamma_m} \geq M$$

where:

M_U : Ultimate bending moment capacity of the hull transverse section considered, in kN·m:
- in hogging conditions: $M_U = M_{UH}$
- in sagging conditions: $M_U = M_{US}$

M_{UH} : Ultimate bending moment capacity in hogging conditions, defined in [3.2.1]

M_{US} : Ultimate bending moment capacity in sagging conditions, defined in [3.2.1]

M : Bending moment, in kN·m, defined in [3.1.1].

Appendix 1 Hull Girder Ultimate Strength

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

R_{eH} : Minimum upper yield stress, in N/mm², of the material

I_Y : Moment of inertia, in m⁴, of the hull transverse section around its horizontal neutral axis, to be calculated according to Ch 6, Sec 1, [2.4]

Z_{AB}, Z_{AD} : Section moduli, in cm³, at bottom and deck, respectively, defined in Ch 6, Sec 1, [2.3.2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, Fig 2 to Ch 4, Sec 3, Fig 5)

h_w : Web height, in mm, of an ordinary stiffener

t_w : Web net thickness, in mm, of an ordinary stiffener

b_f : Face plate width, in mm, of an ordinary stiffener

t_f : Face plate net thickness, in mm, of an ordinary stiffener

A_S : Net sectional area, in cm², of an ordinary stiffener

t_p : Net thickness, in mm, of the plating attached to an ordinary stiffener.

1 Hull girder ultimate strength check

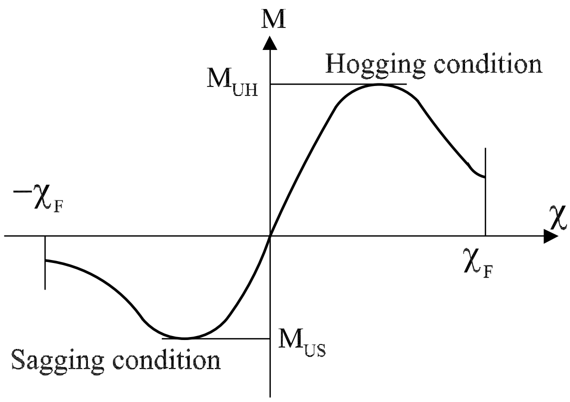
1.1 Introduction

1.1.1 Ch 6, Sec 3, [2] defines the criteria for calculating the ultimate bending moment capacities in hogging condition M_{UH} and sagging condition M_{US} of a hull girder transverse section.

As specified in Ch 6, Sec 3, [2], the ultimate bending moment capacities are defined as the maximum values of the curve of bending moment capacity M versus the curvature χ of the transverse section considered (see Fig 1).

1.1.2 This Appendix provides the criteria for obtaining the curve M-χ.

Figure 1 : Curve bending moment capacity M versus curvature χ



1.2 Criteria for the calculation of the curve M-χ

1.2.1 Procedure

The curve M-χ is to be obtained by means of an incremental-iterative approach, summarized in the flow chart in Fig 2.

Each step of the incremental procedure is represented by the calculation of the bending moment M_i which acts on the hull transverse section as the effect of an imposed curvature χ_i.

For each step, the value χ_i is to be obtained by summing an increment of curvature $\Delta\chi$ to the value relevant to the previous step χ_{i-1}. This increment of curvature corresponds to an increment of the rotation angle of the hull girder transverse section around its horizontal neutral axis.

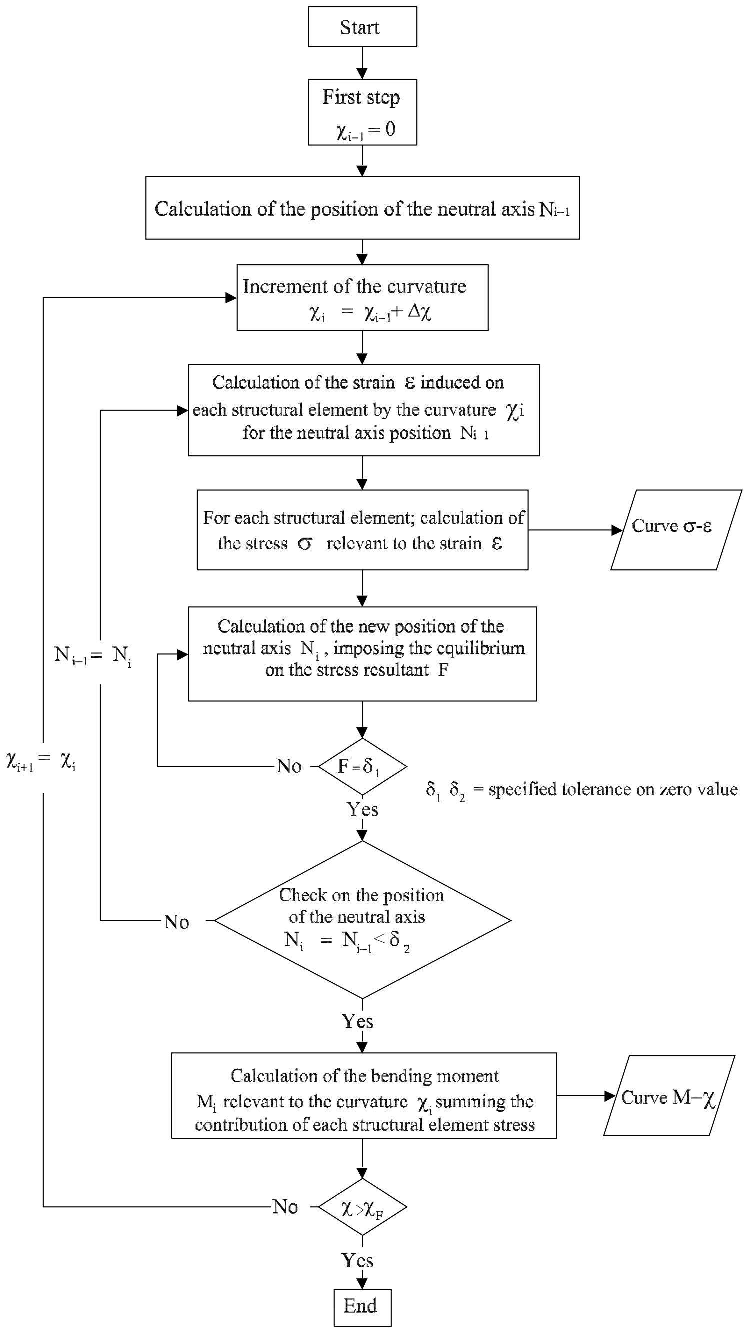
This rotation increment induces axial strains ε in each hull structural element, whose value depends on the position of the element. In hogging condition, the structural elements above the neutral axis are lengthened, while the elements below the neutral axis are shortened. Vice-versa in sagging condition.

The stress σ induced in each structural element by the strain ε is to be obtained from the load-end shortening curve σ-ε of the element, which takes into account the behaviour of the element in the non-linear elasto-plastic domain.

The distribution of the stresses induced in all the elements composing the hull transverse section determines, for each step, a variation of the neutral axis position, since the relationship σ-ε is non-linear. The new position of the neutral axis relevant to the step considered is to be obtained by means of an iterative process, imposing the equilibrium among the stresses acting in all the hull elements.

Once the position of the neutral axis is known and the relevant stress distribution in the section structural elements is obtained, the bending moment of the section M_i around the new position of the neutral axis, which corresponds to the curvature χ_i imposed in the step considered, is to be obtained by summing the contribution given by each element stress.

Figure 2 : Flow chart of the procedure for the evaluation of the curve M-χ



1.2.2 Assumption

In applying the procedure described in [1.2.1], the following assumptions are generally to be made:

- The ultimate strength is calculated at hull transverse sections between two adjacent reinforced rings.
- The hull girder transverse section remains plane during each curvature increment.
- The hull material has an elasto-plastic behaviour.
- The hull girder transverse section is divided into a set of elements, which are considered to act independently. These elements are:
  - transversely framed plating panels and/or ordinary stiffeners with attached plating, whose structural behaviour is described in [1.3.1]
  - hard corners, constituted by plating crossing, whose structural behaviour is described in [1.3.2].
- According to the iterative procedure, the bending moment M_i acting on the transverse section at each curvature value χ_i is obtained by summing the contribution given by the stress σ acting on each element. The stress σ, corresponding to the element strain ε, is to be obtained for each curvature increment from the non-linear load-end shortening curves σ-ε of the element.

  These curves are to be calculated, for the failure mechanisms of the element, from the formulae specified in [1.3]. The stress σ is selected as the lowest among the values obtained from each of the considered load-end shortening curves σ-ε.
- The procedure is to be repeated for each step, until the value of the imposed curvature reaches the value χ_F, in m^{-1}, in hogging and sagging condition, obtained from the following formula:

  $$\chi_F = \pm 0{,}003 \frac{M_Y}{EI_Y}$$

  where:

  M_Y : The lesser of the values M_{Y1} and M_{Y2}, in kN·m:

  $M_{Y1} = 10^{-3}\ R_{eH}\ Z_{AB}$

  $M_{Y2} = 10^{-3}\ R_{eH}\ Z_{AD}$

  If the value χ_F is not sufficient to evaluate the peaks of the curve M-χ, the procedure is to be repeated until the value of the imposed curvature permits the calculation of the maximum bending moments of the curve.

1.3 Load-end shortening curves σ-ε

1.3.1 Plating panels and ordinary stiffeners

Plating panels and ordinary stiffeners composing the hull girder transverse sections may collapse following one of the modes of failure specified in Tab 1.

1.3.2 Hard corners

Hard corners are sturdier elements composing the hull girder transverse section, which collapse mainly according to an elasto-plastic mode of failure. The relevant load-end shortening curve σ-ε is to be obtained for lengthened and shortened hard corners according to [1.3.3].

1.3.3 Elasto-plastic collapse

The equation describing the load-end shortening curve σ-ε for the elasto-plastic collapse of structural elements composing the hull girder transverse section is to be obtained from the following formula, valid for both positive (shortening) and negative (lengthening) strains (see Fig 3):

$\sigma = \Phi\ R_{eH}$

where:

Φ : Edge function:

$\Phi = -1$ for $\varepsilon < -1$

$\Phi = \varepsilon$ for $-1 < \varepsilon < 1$

$\Phi = 1$ for $\varepsilon > 1$

ε : Relative strain:

$$\varepsilon = \frac{\varepsilon_E}{\varepsilon_Y}$$

ε_E : Element strain

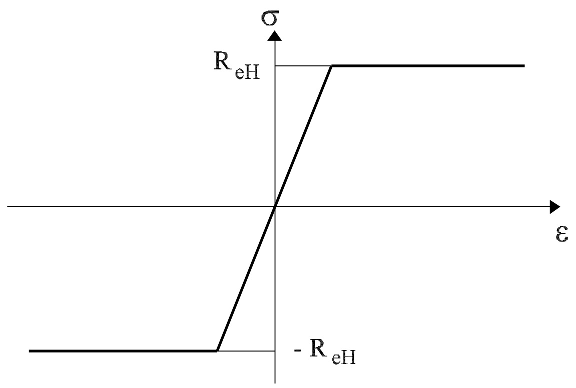
ε_Y : Strain inducing yield stress in the element:

$$\varepsilon_Y = \frac{R_{eH}}{E}$$

Table 1 : Modes of failure of plate panels and ordinary stiffeners

Element	Mode of failure	Curve σ-ε defined in
Lengthened plate panel or ordinary stiffeners	Elasto-plastic collapse	[1.3.3]
Shortened ordinary stiffeners	Beam columnbuckling	[1.3.4]
	Torsional buckling	[1.3.5]
	Web local buckling of flanged profiles	[1.3.6]
	Web local buckling of flat bars	[1.3.7]
Shortened transversely framed plate panel	Plate buckling	[1.3.8]
Shortened transversely framed curved plate panel	Curved plate buckling	[1.3.9]

Figure 3 : Load-end shortening curve σ-ε for elasto-plastic collapse



1.3.4 Beam column buckling

The equation describing the load-end shortening curve σ_{CR1}-ε for the beam column buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 4):

$$\sigma_{CR1} = \Phi\sigma_{C1}\frac{A_S + 10b_Et_P}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C1} : Critical stress, in N/mm²:

$$\sigma_{C1} = \frac{\sigma_{E1}}{\varepsilon} \quad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C1} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E1}}\right) \quad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}\varepsilon$$

ε : Relative strain defined in [1.3.3]

σ_{E1} : Euler column buckling stress, in N/mm²:

$$\sigma_{E1} = \pi^2E\frac{I_E}{A_E\ell^2}10^4$$

I_E : Net moment of inertia of ordinary stiffeners, in cm⁴, with attached shell plating of width b_{E1}

b_{E1} : Width, in m, of the attached shell plating:

$$b_{E1} = \frac{s}{\beta_E} \quad \text{for} \quad \beta_E > 1{,}0$$

$$b_{E1} = s \quad \text{for} \quad \beta_E \le 1{,}0$$

$$\beta_E = 10^3\frac{s}{t_p}\sqrt{\frac{\varepsilon R_{eH}}{E}}$$

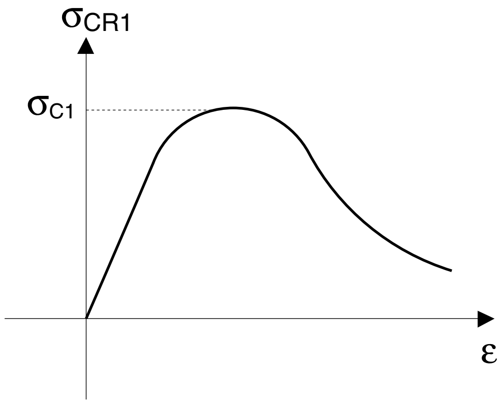
A_E : Net sectional area, in cm², of ordinary stiffeners with attached shell plating of width b_E

b_E : Width, in m, of the attached shell plating:

$$b_E = \left(\frac{2{,}25}{\beta_E} - \frac{1{,}25}{\beta_E^2}\right)s \quad \text{for} \quad \beta_E > 1{,}25$$

$$b_E = s \quad \text{for} \quad \beta_E \le 1{,}25$$

Figure 4 : Load-end shortening curve σ_{CR1}-ε for beam column buckling



1.3.5 Torsional buckling

The equation describing the load-end shortening curve σ_{CR2}-ε for the lateral-flexural buckling of ordinary stiffeners composing the hull girder transverse section is to be obtained according to the following formula (see Fig 5):

$$\sigma_{CR2} = \Phi\frac{A_S\sigma_{C2} + 10st_P\sigma_{CP}}{A_S + 10st_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{C2} : Critical stress, in N/mm²:

$$\sigma_{C2} = \frac{\sigma_{E2}}{\varepsilon} \quad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{C2} = R_{eH}\left(1 - \frac{\Phi R_{eH}\varepsilon}{4\sigma_{E2}}\right) \quad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E2} : Euler torsional buckling stress, in N/mm², defined in Ch 7, Sec 2, [4.3.3]

ε : Relative strain defined in [1.3.3]

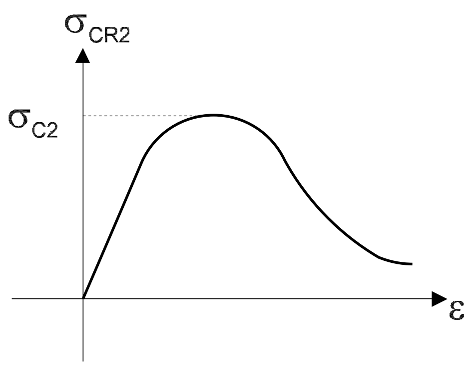
σ_{CP} : Buckling stress of the attached plating, in N/mm²:

$$\sigma_{CP} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right)R_{eH} \quad \text{for} \quad \beta_E > 1,25$$

$$\sigma_{CP} = R_{eH} \quad \text{for} \quad \beta_E \le 1,25$$

β_E : Coefficient defined in [1.3.4].

Figure 5 : Load-end shortening curve σ_{CR2}-ε for flexural-torsional buckling



1.3.6 Web local buckling of flanged ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR3}-ε for the web local buckling of flanged ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR3} = \Phi R_{eH}\frac{10^3 b_E t_P + h_{WE}t_W + b_F t_F}{10^3 s t_P + h_W t_W + b_F t_F}$$

where:

Φ : Edge function defined in [1.3.3]

b_E : Width, in m, of the attached shell plating, defined in [1.3.4]

h_{WE} : Effective height, in mm, of the web:

$$h_{WE} = \left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) h_W \quad \text{for} \quad \beta_W > 1,25$$

$$h_{WE} = h_W \quad \text{for} \quad \beta_W \le 1,25$$

β_E : Coefficient defined in [1.3.4]

$$\beta_W = 10^3 \frac{h_W}{t_W} \sqrt{\frac{\varepsilon R_{eH}}{E}}$$

ε : Relative strain defined in [1.3.3].

1.3.7 Web local buckling of flat bar ordinary stiffeners

The equation describing the load-end shortening curve σ_{CR4}-ε for the web local buckling of flat bar ordinary stiffeners composing the hull girder transverse section is to be obtained from the following formula (see Fig 6):

$$\sigma_{CR4} = \Phi \frac{10 s t_P \sigma_{CP} + A_S \sigma_{C4}}{A_S + 10 s t_P}$$

where:

Φ : Edge function defined in [1.3.3]

σ_{CP} : Buckling stress of the attached plating, in N/mm², defined in [1.3.5]

σ_{C4} : Critical stress, in N/mm²:

$$\sigma_{C4} = \frac{\sigma_{E4}}{\varepsilon} \quad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}\varepsilon$$

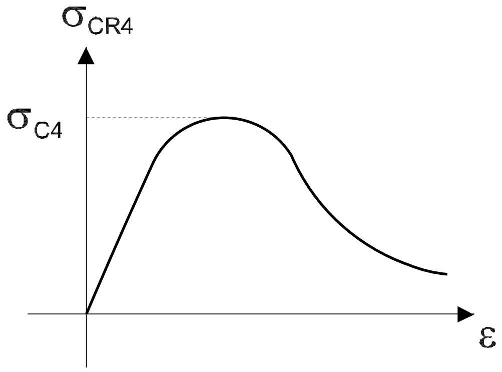
$$\sigma_{C4} = R_{eH}\left(1 - \frac{\Phi R_{eH} \varepsilon}{4 \sigma_{E4}}\right) \quad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}\varepsilon$$

σ_{E4} : Local Euler buckling stress, in N/mm²:

$$\sigma_{E4} = 160000 \left(\frac{t_W}{h_W}\right)^2$$

ε : Relative strain defined in [1.3.3].

Figure 6 : Load-end shortening curve σ_{CR4}-ε for web local buckling of flat bars



1.3.8 Plate buckling

The equation describing the load-end shortening curve σ_{CR5}-ε for the buckling of transversely stiffened panels composing the hull girder transverse section is to be obtained from the following formula:

$$\sigma_{CR5} = R_{eH}\left[\frac{s}{\ell}\left(\frac{2,25}{\beta_E} - \frac{1,25}{\beta_E^2}\right) + 0,1\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta_E^2}\right)^2\right]$$

where:

β_E : Coefficient defined in [1.3.4].

1.3.9 Transversely stiffened curved panels

The equation describing the load-end shortening curve σ_{CR6}-ε for the buckling of transversely stiffened curved panels is to be obtained from the following formulae:

$$\sigma_{CR6} = \frac{\Phi \sigma_{EC}}{\varepsilon} \quad \text{for} \quad \sigma_{EC} \le \frac{R_{eH}}{2}\varepsilon$$

$$\sigma_{CR6} = \Phi R_{eH}\left(1 - \frac{R_{eH}\varepsilon}{4\sigma_{EC}}\right) \quad \text{for} \quad \sigma_{EC} > \frac{R_{eH}}{2}\varepsilon$$

where:

σ_{EC} : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{EC} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t}{b}\right)^2 K_3 10^{-6}$$

b : Width of curved panel, in m, measured on arc between two adjacent supports

K_3 : Buckling factor to be taken equal to:

$$K_3 = 2\left\{1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4}\frac{b^4}{r^2 t^2}10^6}\right\}$$

r : Radius of curvature, in m.

CHAPTER 7
HULL SCANTLINGS

Section 1	Plating
Section 2	Ordinary Stiffeners
Section 3	Primary Supporting Members
Section 4	Fatigue Check of Structural Details
Appendix 1	Analyses Based on Three-Dimensional Models
Appendix 2	Analyses of Primary Supporting Members Subjected to Wheeled Loads
Appendix 3	Analyses Based on Complete Ship Models

Symbols used in this Chapter

L_1, L_2 : Lengths, in m, defined in Pt B, Ch 1, Sec 2, [2.1.1]

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general:
  $E = 2{,}06.10^5$ N/mm^2
- for stainless steels:
  $E = 1{,}95.10^5$ N/mm^2
- for aluminium alloys:
  $E = 7{,}0.10^4$ N/mm^2

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account

k : Material factor, defined in:

- Pt B, Ch 4, Sec 1, [2.3], for steel
- Pt B, Ch 4, Sec 1, [4.4], for aluminium alloys

R_y : Minimum yield stress, in N/mm^2, of the material to be taken equal to 235/k N/mm^2, unless otherwise specified

t_c : Corrosion addition, in mm, defined in Pt B, Ch 4, Sec 2, Tab 2

I_Y : Net moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

I_Z : Net moment of inertia, in m^4, of the hull transverse section around its vertical neutral axis, to be calculated according to Pt B, Ch 6, Sec 1, [2.4] considering the members contributing to the hull girder longitudinal strength as having their net scantlings

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Pt B, Ch 1, Sec 2, [6], of the centre of gravity of the hull transverse section constituted by members contributing to the hull girder longitudinal strength considered as having their net scantlings (see Pt B, Ch 6, Sec 1, [2])

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,Hmin}$: Minimum still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, without being taken greater than $0{,}3M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.1]

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.2]

M_{WT} : Wave torque, in kN.m, at the hull transverse section considered, defined in Pt B, Ch 5, Sec 2, [3.3].

Section 1 Plating

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m² (see [3.2.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m² (see [3.2.2])

p_{SF}, p_{WF} : Still water and wave pressure, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7] (see [3.2.3])

F_S : Still water wheeled force, in kN (see [4.2.2]

$F_{W,Z}$: Inertial wheeled force, in kN (see [4.2.2])

σ_{X1} : In-plane hull girder normal stress, in N/mm², defined in:

- [3.2.6] for the strength check of plating subjected to lateral pressure
- [5.2.2] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm², defined in [3.2.7]

R_{eH} : Minimum guaranteed yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side of the plate panel

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1{,}21\sqrt{1 + 0{,}33\left(\frac{s}{\ell}\right)^2} - 0{,}69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0{,}5\, s / r$

to be taken not less than 0,5

r : Radius of curvature, in m

t_{net} : Net thickness, in mm, of a plate panel.

1 General

1.1 Net thicknesses

1.1.1 As specified in Ch 4, Sec 2, [1], all thicknesses referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross thicknesses are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

1.3 Elementary plate panel

1.3.1 The elementary plate panel is the smallest unstiffened part of plating.

1.4 Load point

1.4.1 Unless otherwise specified, lateral pressure and hull girder stresses are to be calculated:

- for longitudinal framing, at the lower edge of the elementary plate panel or, in the case of horizontal plating, at the point of minimum y-value among those of the elementary plate panel considered
- for transverse framing, at the lower edge of the strake.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Strength check of plating subjected to lateral pressure			Buckling check
		General	Flooding pressure	Testing check	
		(see [3.2], [3.3.1], [3.4.1], [3.5.1] and [4])	(see [3.3.2], [3.4.2] and [3.5.2])	(see [3.3.2], [3.4.2] and [3.5.2])	(see [5])
Still water hull girder loads	γ_{S1}	1,00	1,00	Not applicable	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	Not applicable	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	Not applicable
Wave pressure	γ_{W2}	1,20	1,20	Not applicable	Not applicable
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20**(2)**	1,05 **(1)**	1,05**(2)**	1,10

(1) For plating of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damage stability considers at least two adjacent compartments flooded.
(2) For plating of decks and side walls of ammunition storage, for assessment under flooding by fire-extinguishing system, γ_R = 1,05. This requirement may be disregarded when the extinguishing system used for ammunition storage is not by flooding of the compartment

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to plating in addition of those in [3] to [5].

2.2 Minimum net thicknesses

2.2.1 As a rule, the net thickness of plating is to be not less than the values given in Tab 2.

The Society may consider lower thicknesses than those in Tab 2, on a case by case basis, when this is deemed appropriate on the basis of scantlings calculations for all types of loading cases.

Table 2 : Minimum net thickness of plating

Plating	Minimum net thickness, in mm
Deck Longitudinal bulkhead Shell	5
Transverse bulkhead	4

2.3 Bilge plating

2.3.1 The net thickness of the longitudinally framed bilge plating, in mm, is to be not less than the greater of the:

- value obtained from [3.3.1]
- value obtained from [5], to be checked as curved panel.

2.3.2 The net thickness of the transversely framed bilge plating, in mm, is to be not less than the greater of:

- $t = 0{,}7\ [\gamma_R\ \gamma_m\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s_b]^{0,4}\ R^{0,6}\ k^{1/2}$

  where:

  R : Bilge radius, in m
- value obtained from [5], to be checked as curved panel.

2.3.3 The net thickness bilge plating is to be not less than the actual thicknesses of the adjacent bottom or side plating, whichever is the greater.

2.4 Sheerstrake

2.4.1 Welded sheerstrake

The net thickness of a welded sheerstrake is to be not less than that of the adjacent side plating, taking into account higher strength steel corrections if needed.

In general, the required net thickness of the adjacent side plating is to be taken as a reference. In specific case, depending on its actual net thickness, this latter may be required to be considered when deemed necessary by the Society.

2.4.2 Rounded sheerstrake

The net thickness of a rounded sheerstrake is to be not less than the actual net thickness of the adjacent deck plating.

2.4.3 Net thickness of the sheerstrake in way of breaks of long superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship’s breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5 L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.4.4 Net thickness of the sheerstrake in way of breaks of short superstructures

The net thickness of the sheerstrake is to be increased in way of breaks of short superstructures occurring within 0,6 L amidships, over a length of about one sixth of the ship’s breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.5 Stringer plate

2.5.1 General

The net thickness of the stringer plate is to be not less than the actual net thickness of the adjacent deck plating.

2.5.2 Net thickness of the stringer plate in way of breaks of long superstructures

The net thickness of the stringer plate is to be increased in way of breaks of long superstructures occurring within 0,5L amidships, over a length of about one sixth of the ship’s breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 40%, but need not exceed 4,5 mm.

Where the breaks of superstructures occur outside 0,5L amidships, the increase in net thickness may be reduced to 30%, but need not exceed 2,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

2.5.3 Net thickness of the stringer plate in way of breaks of short superstructures

The net thickness of the stringer plate is to be increased in way of breaks of short superstructures occurring within 0,6L amidships, over a length of about one sixth of the ship breadth on each side of the superstructure end.

This increase in net thickness is to be equal to 15%, but need not exceed 4,5 mm.

Alternative arrangements justified by direct calculations or compliance with other regulations may be accepted, if deemed equivalent by the Society.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of plating subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for plating contributing to the longitudinal strength, to in-plane hull girder normal and shear stresses.

3.2 Load model

3.2.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the plating under consideration and the type of the compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The plating located below the deepest equilibrium waterline (excluding side shell plating) which constitute boundaries intended to stop vertical and horizontal flooding is to be subjected to lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.2.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure (p_S) includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case "a", "b", "c" and "d"
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.2.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.2.4 Lateral pressure in testing conditions

The lateral pressure (p_T) in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise,

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 10

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.2.5 Pressures induced by weapon firing dynamic loads

The following weapon firing dynamic loads are to be considered, depending on the location of the plating under consideration:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

The lateral pressure p_W induced by the above dynamic loads are to be calculated according to the requirements specified in Ch 5, Sec 6, [9].

3.2.6 In-plane hull girder normal stresses

The in-plane hull girder normal stresses to be considered for the strength check of plating are obtained, in N/mm², from the following formulae:

- for plating contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1})$

- for plating not contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = 0$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

Table 3 : Hull girder normal stresses

Condition	σ_{S1}, in N/mm² **(1)**	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
$\dfrac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} \geq 1$	$\left\lvert\dfrac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\dfrac{\lvert\gamma_{S1}M_{SW,S}+0,625\gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H}+0,625\gamma_{W1}C_{FV}M_{WV,H}} < 1$	$\left\lvert\dfrac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{0,625M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 4 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
Flooding	0,6	0	0

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \leq z \leq 0,25\ D$	$\tau_0\left(0,5 + 2\dfrac{z}{D}\right)$
• $0,25\ D < z \leq 0,75\ D$	τ_0
• $0,75\ D < z \leq D$	$\tau_0\left(2,5 - 2\dfrac{z}{D}\right)$
Note 1: $\tau_0 = \dfrac{47}{k}\left\{1 - \dfrac{6,3}{\sqrt{L_1}}\right\}$ N/mm²	

3.2.7 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the strength check of plating which contributes to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\tau_1 = \gamma_{S1}\ \tau_{S1} + 0,625\ C_{FV}\ \gamma_{W1}\ \tau_{W1}$$

where:

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum still water hull girder vertical shear force

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force

C_{FV} : Combination factor defined in Tab 4.

τ_{S1} and τ_{W1} may be calculated as indicated in Tab 5 where, at a preliminary design stage, the still water hull girder vertical shear force is not defined.

3.3 Longitudinally framed plating contributing to the hull girder longitudinal strength

3.3.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the shorter sides is to be not less than the value obtained, in mm, from the following formula:

$$t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_L R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

$$\lambda_L = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2 - 0,95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2} - 0,225\gamma_m \frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The plating of structural watertight elements which constitute boundaries intended to stop vertical and horizontal flooding as per Internal Watertight Plan is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_L R_y}}$$

where λ_L is defined in [3.3.1].

3.3.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.4 Transversely framed plating contributing to the hull girder longitudinal strength

3.4.1 General

The net thickness of laterally loaded plate panels subjected to in-plane normal stress acting on the longer sides is to be not less than the value obtained, in mm, from the following formula:

$$t = C_T c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

- for bottom, bilge, inner bottom and decks (excluding possible longitudinal sloping plates):

  C_T : Coefficient equal to 17,2

  $$\lambda_T = 1 - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

- for side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):

  C_T : Coefficient equal to:

  17,2 for side

  14,9 for inner side and longitudinal bulkheads (including possible longitudinal sloping plates)

  $$\lambda_T = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 17{,}2 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{\lambda_T R_y}}$$

where λ_T is defined in [3.4.1].

3.4.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{ST}}{R_y}}$$

3.5 Plating not contributing to the hull girder longitudinal strength

3.5.1 General

The net thickness of plate panels subjected to lateral pressure is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$$

3.5.2 Flooding conditions

The plating of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids is to be checked in flooding conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}}$$

3.5.3 Testing conditions

The plating of compartments or structures as defined in Ch 5, Sec 6, Tab 10 is to be checked in testing conditions. To this end, its net thickness is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_{ST}}{R_y}}$$

4 Strength check of plating subjected to wheeled loads

4.1 General

4.1.1 The requirements of this Article apply for the strength check of plating subjected to wheeled loads.

4.2 Load model

4.2.1 General

The still water and inertial forces induced by the sea and the various types of wheeled vehicles are to be considered, depending on the location of the plating.

The inertial forces induced by the sea are to be calculated in load case "b", as defined in Ch 5, Sec 4.

4.2.2 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force.

Still water force is the vertical force (F_S) defined in Ch 5, Sec 6, [4.1].

Inertial force is the vertical force ($F_{W,Z}$) defined in Ch 5, Sec 6, [4.1], for load case "b", with the acceleration a_{Z1} calculated at x = 0,5L.

4.3 Plating

4.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained, in mm, from the following formula:

$$t = 0{,}9\, C_{WL} \sqrt{\frac{n P_0 k}{\lambda}}$$

where:

C_{WL} : Coefficient to be taken equal to:

$$C_{WL} = 2,15 - 0,05\frac{\ell}{s} + 0{,}02\left(4 - \frac{\ell}{s}\right)\alpha^{0,5} - 1{,}75\alpha^{0,25}$$

where ℓ/s is to be taken not greater than 3

$$\alpha = \frac{A_T}{\ell s}$$

A_T : Tyre print area, in m². In the case of double or triple wheels, A_T is the print area of the group of wheels. A_T is not to be taken greater than the value given in [4.3.2]

ℓ, s : Lengths, in m, of, respectively, the longer and the shorter sides of the plate panel

n : Number of wheels on the plate panel, taken equal to:

- 1 in the case of a single wheel
- the number of wheels in a group of wheels in the case of double or triple wheels

P_0 : Wheeled force, in kN, taken equal to:

$$P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$$

λ : Coefficient taken equal to:

- for longitudinally framed plating:
  $\lambda = \lambda_L$ as defined in [3.3.1]
- for transversely framed plating:
  $\lambda = \lambda_T$ as defined in [3.4.1].

4.3.2 When the tyre print area is not known, it may be taken equal to:

$$A_T = 9,81\frac{nQ_A}{n_W p_T}$$

where:

n : Number of wheels on the plate panel, defined in [4.3.1]

Q_A : Axle load, in t

n_W : Number of wheels for the axle considered

p_T : Tyre pressure, in kN/m². When the tyre pressure is not indicated by the designer, it may be taken as defined in Tab 6.

Table 6 : Tyre pressures p_T for vehicles

Vehicle type	Tyre pressure p_T, in kN/m²	
	Pneumatic tyres	Solid rubber tyres
Private cars	250	not applicable
Trucks and trailers	800	not applicable
Handling machines	1100	1600

4.3.3 For vehicles with the four wheels of the axle located on a plate panel as shown in Fig 1, the net thickness of deck plating is to be not less than the greater of the values obtained, in mm, from the following formulae:

$t = t_1$

$t = t_2\,(1 + \beta_2 + \beta_3 + \beta_4)^{0,5}$

where:

t_1 : Net thickness obtained from [4.3.1] for n = 2, considering one group of two wheels located on the plate panel

t_2 : Net thickness obtained from [4.3.1] for n = 1, considering one wheel located on the plate panel

β_2, β_3, β_4 : Coefficients obtained from the following formula, by replacing i by 2, 3 and 4, respectively (see Fig 1):

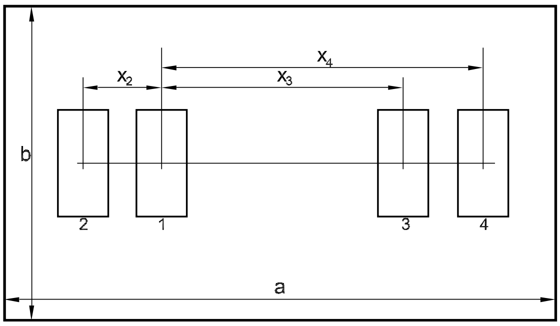
- for $x_i / b < 2$: $\beta_i = 0,8\,(1,2 - 2,02\,\alpha_i + 1,17\,\alpha_i^2 - 0,23\,\alpha_i^3)$
- for $x_i / b \geq 2$: $\beta_i = 0$

x_i : Distance, in m, from the wheel considered to the reference wheel (see Fig 1)

b : Dimension, in m, of the plate panel side perpendicular to the axle

$$\alpha_i = \frac{x_i}{b}$$

Figure 1 : Four wheel axle located on a plate panel



5 Buckling check

5.1 General

5.1.1 Application

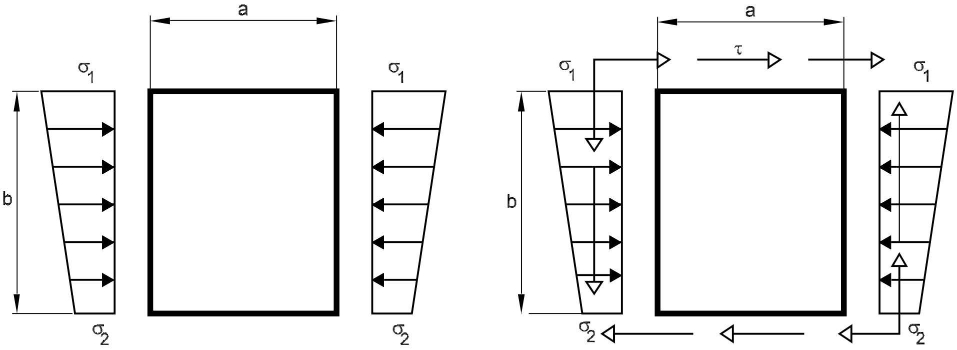
The requirements of this Article apply for the buckling check of plating subjected to in-plane compression stresses, acting on one or two sides, or to shear stress.

Rectangular plate panels are considered as being simply supported. For specific designs, other boundary conditions may be considered, at the Society's discretion, provided that the necessary information is submitted for review.

5.1.2 Compression and bending with or without shear

For plate panels subjected to compression and bending along one side, with or without shear, as shown in Fig 2, side "b" is to be taken as the loaded side. In such case, the compression stress varies linearly from σ_1 to $\sigma_2 = \psi\,\sigma_1$ (with $\psi \leq 1$) along edge "b".

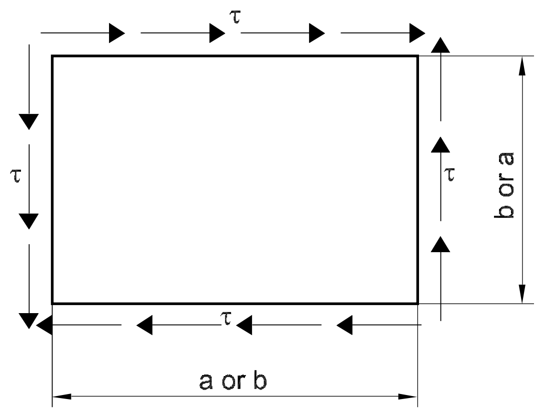
Figure 2 : Buckling of a simply supported rectangular plate panel subjected to compression and bending, with and without shear



5.1.3 Shear

For plate panels subjected to shear, as shown in Fig 3, side "b" may be taken as either the longer or the shorter side of the panel.

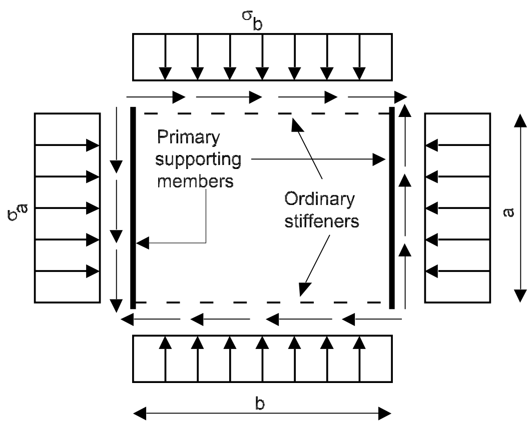
Figure 3 : Buckling of a simply supported rectangular plate panel subjected to shear



5.1.4 Bi-axial compression and shear

For plate panels subjected to bi-axial compression along sides "a" and "b", and to shear, as shown in Fig 4, side "a" is to be taken as the side in the direction of the primary supporting members.

Figure 4 : Buckling of a simply supported rectangular plate panel subjected to bi-axial compression and shear



5.2 Load model

5.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

5.2.2 In-plane hull girder compression normal stresses

The in-plane hull girder compression normal stresses to be considered for the buckling check of plating contributing to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 7

C_{FV}, C_{FH} : Combination factors defined in Tab 4.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship's characteristics and intended service. The calculations are to be submitted to the Society for approval.

5.2.3 In-plane hull girder shear stresses

The in-plane hull girder shear stresses to be considered for the buckling check of plating are obtained as specified in [3.2.7] for the strength check of plating subjected to lateral pressure, which contributes to the longitudinal strength.

5.2.4 Combined in-plane hull girder and local compression normal stresses

The combined in-plane compression normal stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5.

5.2.5 Combined in-plane hull girder and local shear stresses

The combined in-plane shear stresses to be considered for the buckling check of plating are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads given in Part B, Chapter 5.

The combined stresses are obtained, in N/mm², from the following formula:

$$\tau = \tau_1 + \gamma_{S2}\tau_{2,S} + \gamma_{W2}\tau_{2,W}$$

where:

τ_1 : Shear stress, in N/mm², induced by the hull girder still water and wave loads, defined in [5.2.3]

$\tau_{2,S}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads given in Part B, Chapter 5

$\tau_{2,W}$: Shear stress, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads given in Part B, Chapter 5.

Table 7 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
$z \geq N$	$\dfrac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\dfrac{0{,}625\,F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\dfrac{0{,}625\,M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\dfrac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\dfrac{0{,}625\,M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [5.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

Table 8 : Buckling factor K_1 for plate panels

Load pattern	Aspect ratio	Buckling factor K_1
$0 \le \psi \le 1$	$\alpha \ge 1$ $\alpha < 1$	$\dfrac{8{,}4}{\psi + 1{,}1}$ $\left(\alpha + \dfrac{1}{\alpha}\right)^2 \dfrac{2{,}1}{\psi + 1{,}1}$
$-1 < \psi < 0$		$(1+\psi)K_1' - \psi K_1'' + 10\psi(1+\psi)$
$\psi \le -1$	$\alpha \dfrac{1-\psi}{2} \ge \dfrac{2}{3}$	$23{,}9\left(\dfrac{1-\psi}{2}\right)^2$
	$\alpha \dfrac{1-\psi}{2} < \dfrac{2}{3}$	$\left(15{,}87 + \dfrac{1{,}87}{\left(\alpha\dfrac{1-\psi}{2}\right)^2} + 8{,}6\left(\alpha\dfrac{1-\psi}{2}\right)^2\right)\left(\dfrac{1-\psi}{2}\right)^2$

Note 1:

$\psi = \dfrac{\sigma_2}{\sigma_1}$

K_1' : Value of K_1 calculated for $\psi = 0$
K_1'' : Value of K_1 calculated for $\psi = -1$

5.3 Critical stresses

5.3.1 Compression and bending for plane panel

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_1 \varepsilon 10^{-6}$$

K_1 : Buckling factor defined in Tab 8

ε : Coefficient to be taken equal to:

- $\varepsilon = 1$ for $\alpha \ge 1$
- $\varepsilon = 1{,}05$ for $\alpha < 1$ and side “b” stiffened by flat bar
- $\varepsilon = 1{,}10$ for $\alpha < 1$ and side “b” stiffened by bulb section
- $\varepsilon = 1{,}21$ for $\alpha < 1$ and side “b” stiffened by angle or T-section
- $\varepsilon = 1{,}30$ for $\alpha < 1$ and side “b” stiffened by primary supporting members.

where $\alpha = a / b$

5.3.2 Shear for plane panel

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

$$\tau_c = \tau_E \quad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\,\tau_E}\right) \quad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_2 10^{-6}$$

K_2 : Buckling factor to be taken equal to:

$$K_2 = 5,34 + \frac{4}{\alpha^2} \quad \text{for } \alpha > 1$$

$$K_2 = \frac{5,34}{\alpha^2} + 4 \quad \text{for } \alpha \le 1$$

α : Coefficient defined in [5.3.1].

5.3.3 Bi-axial compression and shear for plane panel

The critical buckling stress $\sigma_{c,a}$ for compression on side "a" of the panel is to be obtained, in N/mm², from the following formula:

$$\sigma_{c,a} = \left(\frac{2,25}{\beta} - \frac{1,25}{\beta^2}\right) R_{eH}$$

where:

β : Slenderness of the panel, to be taken equal to:

$$\beta = 10^3 \frac{a}{t_{net}} \sqrt{\frac{R_{eH}}{E}}$$

without being taken less than 1,25.

The critical buckling stress $\sigma_{c,b}$ for compression on side "b" of the panel is to be obtained, in N/mm², from the formulae in [5.3.1].

The critical shear buckling stress is to be obtained, in N/mm², from the formulae in [5.3.2].

5.3.4 Compression and shear for curved panels

The critical buckling stress of curved panels subjected to compression on curved edges is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_3$$

b : Width of curved panel, in mm, measured on arc

K_3 : Buckling factor defined in Tab 9.

The critical shear buckling stress is to be obtained, in N/mm², from the following formulae:

$$\tau_c = \tau_E \quad \text{for } \tau_E \le \frac{R_{eH}}{2\sqrt{3}}$$

$$\tau_c = \frac{R_{eH}}{\sqrt{3}}\left(1 - \frac{R_{eH}}{4\sqrt{3}\tau_E}\right) \quad \text{for } \tau_E > \frac{R_{eH}}{2\sqrt{3}}$$

where:

τ_E : Euler shear buckling stress, to be obtained, in N/mm², from the following formula:

$$\tau_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_{net}}{b}\right)^2 K_4$$

K_4 : Buckling factor to be taken equal to:

$$K_4 = \frac{12(1-\nu^2)}{\pi^2}\left(5 + 0,1\frac{b^2}{rt_{net}}\right)$$

b, r : Defined above.

Table 9 : Buckling factor K_3 for curved panels

Load	Buckling factor K_3
Compression stress perpendicular to the curved edges	$2\left[1 + \sqrt{1 + \frac{12(1-\nu^2)}{\pi^4} \frac{b^4}{r^2 t_{net}^2}}\right]$
Note 1: r : Radius of curvature, in mm.	

5.3.5 Compression for corrugation flanges

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \qquad \text{for } \sigma_E \le \frac{R_{eH}}{2}$$

$$\sigma_c = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH}}{2}$$

where:

σ_E : Euler buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_f}{V}\right)^2 K_5$$

K_5 : Buckling factor to be taken equal to:

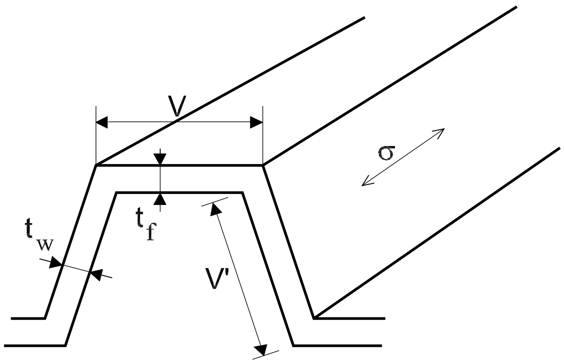
$$K_5 = \left(1 + \frac{t_w}{t_f}\right)\left\{3 + 0{,}5\frac{V'}{V} - 0{,}33\left(\frac{V'}{V}\right)^2\right\}$$

t_f : Net thickness, in mm, of the corrugation flange

t_w : Net thickness, in mm, of the corrugation web

V, V′ : Dimensions of a corrugation, in mm, shown in Fig 5.

Figure 5 : Dimensions of a corrugation



5.4 Checking criteria

5.4.1 Acceptance of results

The net thickness of plate panels is to be such as to satisfy the buckling check, as indicated in [5.4.2] to [5.4.5] depending on the type of stresses acting on the plate panel considered. When the buckling criteria is exceeded, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Ch 7, Sec 2, [4] and Ch 7, Sec 2, [5].

5.4.2 Compression and bending

For plate panels subjected to compression and bending on one side, the critical buckling stress is to comply with the following formula:

$$\frac{\sigma_c}{\gamma_R \gamma_m} \ge |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5], as the case may be

σ_b : Compression stress, in N/mm², acting on side "b" of the plate panel, to be calculated, as specified in [5.2.2] or [5.2.4], as the case may be.

5.4.3 Shear

For plate panels subjected to shear, the critical shear buckling stress is to comply with the following formula:

$$\frac{\tau_c}{\gamma_R \gamma_m} \ge |\tau_b|$$

where:

τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be

τ_b : Shear stress, in N/mm², acting on the plate panel, to be calculated as specified in [5.2.3] or [5.2.5], as the case may be.

5.4.4 Compression, bending and shear

For plate panels subjected to compression, bending and shear, the combined critical stress is to comply with the following formulae:

$$F \le 1 \qquad \text{for } \frac{\sigma_{comb}}{F} \le \frac{R_{eH}}{2\gamma_R\gamma_m}$$

$$F \le \frac{4\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\left(1 - \frac{\sigma_{comb}}{R_{eH}/\gamma_R\gamma_m}\right) \qquad \text{for } \frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R\gamma_m}$$

where:

$$\sigma_{comb} = \sqrt{\sigma_1^2 + 3\tau^2}$$

$$F = \gamma_R\gamma_m\left[\frac{1+\psi}{4}\frac{|\sigma_1|}{\sigma_E} + \sqrt{\left(\frac{3-\psi}{4}\right)^2\left(\frac{\sigma_1}{\sigma_E}\right)^2 + \left(\frac{\tau}{\tau_E}\right)^2}\right]$$

σ_E : Euler buckling stress, in N/mm², defined in [5.3.1], [5.3.4] or [5.3.5] as the case may be

τ_E : Euler shear buckling stress, in N/mm², defined in [5.3.2] or [5.3.4], as the case may be

$$\psi = \frac{\sigma_2}{\sigma_1}$$

σ_1, σ_2 and τ are defined in Fig 2 and are to be calculated, in N/mm², as specified in [5.2].

5.4.5 Bi-axial compression, taking account of shear stress

For plate panels subjected to bi-axial compression and shear, the critical buckling stresses are to comply with the following formula:

$$\left|\frac{\sigma_a}{\frac{\sigma_{c,a}}{\gamma_R\gamma_m}R_a}\right|^n + \left|\frac{\sigma_b}{\frac{\sigma_{c,b}}{\gamma_R\gamma_m}R_b}\right|^n \le 1$$

where:

$\sigma_{c,a}$: Critical buckling stress for compression on side “a”, in N/mm², defined in [5.3.3]

$\sigma_{c,b}$: Critical buckling stress for compression on side “b”, in N/mm², defined in [5.3.3]

σ_a : Compression stress acting on side “a”, in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

σ_b : Compression stress acting on side “b”, in N/mm², to be calculated as specified in [5.2.2] or [5.2.4], as the case may be

n : Coefficient to be taken equal to:

$n = 1$ for $\alpha \ge 1/\sqrt{2}$

$n = 2$ for $\alpha < 1/\sqrt{2}$

$\alpha = a / b$

$$R_a = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_a}$$

$$R_b = 1 - \left|\frac{\tau}{\tau_c}\right|^{n_b}$$

τ : Shear stress, in N/mm², to be calculated as specified in [5.2.3] or [5.2.5], as the case may be

τ_c : Critical shear buckling stress, in N/mm², defined in [5.3.2]

n_a : Coefficient to be taken equal to:

$n_a = 1 + 1/\alpha$ for $\alpha \ge 0,5$

$n_a = 3$ for $\alpha < 0,5$

n_b : Coefficient to be taken equal to:

$n_b = 1,9 + 0,1/\alpha$ for $\alpha \ge 0,5$

$n_b = 0,7(1 + 1/\alpha)$ for $\alpha < 0,5$

Section 2 Ordinary Stiffeners

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m² (see [3.3.2] and [5.3.2]

p_W : Wave pressure and, if necessary, dynamic pressures, according to the criteria in Ch 5, Sec 5, [2] and Ch 5, Sec 6, [2], in kN/m² (see [3.3.2] and [5.3.2])

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7]

F_S : Still water wheeled force, in kN (see [3.3.5])

$F_{W,Z}$: Inertial wheeled force, in kN (see [3.3.5]

σ_{X1} : Hull girder normal stress, in N/mm², defined in:

- [3.3.7] for the yielding check of ordinary stiffeners
- [4.2.2] for the buckling check of ordinary stiffeners
- [5.3.3] for the ultimate strength check of ordinary stiffeners

$R_{eH,P}$: Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2]

$R_{eH,S}$: Minimum yield stress, in N/mm², of the stiffener material, defined in Ch 4, Sec 1, [2]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members (see Ch 4, Sec 3, [3.2]

h_w : Web height, in mm

t_w : Net web thickness, in mm

b_f : Face plate width, in mm

t_f : Net face plate thickness, in mm

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 4, Sec 3, [3.3.1]

b_e : Width, in m, of the plating attached to the stiffener, for the buckling check, defined in [4.1]

b_U : Width, in m, of the plating attached to the stiffener, for the ultimate strength check, defined in [5.2]

t_p : Net thickness, in mm, of the attached plating

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

A_S : Net sectional area, in cm², of the stiffener with attached plating of width s

A_e : Net sectional area, in cm², of the stiffener with attached plating of width b_e

A_U : Net sectional area, in cm², of the stiffener with attached plating of width b_U

A_{Sh} : Net shear sectional area, in cm², of the stiffener, to be calculated as specified in Ch 4, Sec 3, [3.4]

I : Net moment of inertia, in cm⁴, of the stiffener without attached plating, about its neutral axis parallel to the plating (see Ch 4, Sec 3, Fig 4 and Ch 4, Sec 3, Fig 5)

I_S : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width s, about its neutral axis parallel to the plating

I_e : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_e, about its neutral axis parallel to the plating

I_U : Net moment of inertia, in cm⁴, of the stiffener with attached shell plating of width b_U, about its neutral axis parallel to the plating

ρ_S : Radius of gyration, in cm, of the stiffener with attached plating of width s

ρ_U : Radius of gyration, in cm, of the stiffener with attached plating of width b_U.

m : Boundary coefficient, to be taken equal to:

- m = 12 for stiffeners clamped at both ends, whose end connections comply with the requirements in [3.2.2]
- m = 8 for stiffeners clamped at one end and simply supported at the other end, with the clamped end connection complying with the requirements in [3.2.2]
- m = 8 for stiffeners simply supported at both ends.

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Partial safety factors

1.2.1 The partial safety factors to be considered for the checking of ordinary stiffeners are specified in Tab 1.

1.3 Load point

1.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.3.2 Hull girder stresses

For longitudinal ordinary stiffeners contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the neutral axis of the stiffener considered.

1.4 Net dimensions of ordinary stiffeners

1.4.1 Flat bar

The net dimensions of a flat bar ordinary stiffener (see Fig 1) are to comply with the following requirement:

$$\frac{h_w}{t_w} \leq 20\sqrt{k}$$

Figure 1 : Net dimensions of a flat bar

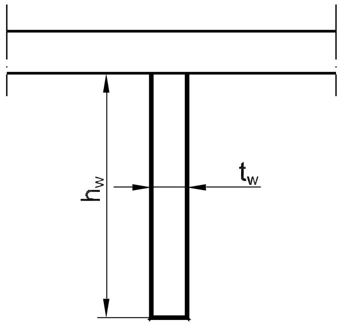


Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check			Buckling check	Ultimate strength check
		General	Flooding pressure	Testing check		
		(see [3.3] to [3.7])	(see [3.8])	(see [3.9])	(see [4])	(see [5])
Still water hull girder loads	γ_{S1}	1,00	1,00	N.A.	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	N.A.	1,15	1,30
Still water pressure	γ_{S2}	1,00	1,00	1,00	N.A.	1,00
Wave pressure	γ_{W2}	1,20	1,05	N.A.	N.A.	1,40
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,02**(2)**	1,02 **(1)**	1,20**(2)**	1,10	1,02

(1) For ordinary stiffeners of the collision bulkhead, γ_R =1,25. This requirement may be disregarded when damage stability considers at least two adjacent compartments flooded.

(2) For ordinary stiffeners of decks and side walls of ammunition storage, for assessment under flooding by fire-extinguishing system, γ_R = 1,02. This requirement may be disregarded when the extinguishing system used for ammunition storage is not by flooding of the compartment

Note 1: N.A. = Not applicable.

1.4.2 T-section

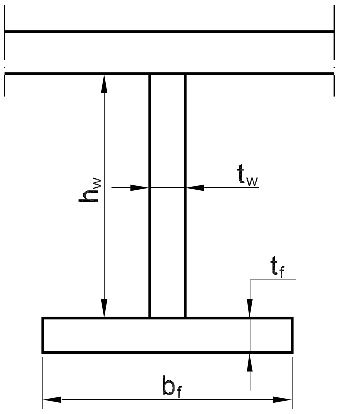
The net dimensions of a T-section ordinary stiffener (see Fig 2) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 33\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 2 : Net dimensions of a T-section



1.4.3 Angle

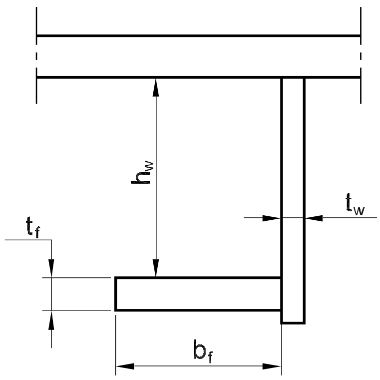
The net dimensions of an angle ordinary stiffener (see Fig 3) are to comply with the following two requirements:

$$\frac{h_w}{t_w} \le 55\sqrt{k}$$

$$\frac{b_f}{t_f} \le 16,5\sqrt{k}$$

$$b_f t_f \ge \frac{h_w t_w}{6}$$

Figure 3 : Net dimensions of an angle



2 General requirements

2.1 General

2.1.1 The requirements in [2.2] are to be applied to ordinary stiffeners in addition to the requirements from Articles [3] to [5].

2.2 Struts of open floors

2.2.1 The sectional area A_{ST}, in cm², and the moment of inertia I_{ST} about the main axes, in cm⁴, of struts of open floors are to be not less than the values obtained from the following formulae:

$$A_{ST} = \frac{p_{ST} s \ell}{20}$$

$$I_{ST} = \frac{0{,}75 s \ell (p_{STB} + p_{STU}) A_{AST} \ell_{ST}^2}{47{,}2 A_{AST} - s \ell (p_{STB} + p_{STU})}$$

where:

p_{ST} : Pressure to be taken equal to the greater of the values obtained, in kN/m², from the following formulae:

$p_{ST} = 0{,}5\ (p_{STB} + p_{STU})$

$p_{ST} = p_{STD}$

p_{STB} : Sea pressure, in kN/m², acting on the bottom in way of the strut, equal to:

$p_{STB} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{STU} : Pressure, in kN/m², acting on the inner bottom in way of the strut due to the load in the tank or hold above, equal to:

$p_{STU} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{STD} : Pressure, in kN/m², in double bottom at mid-span of the strut, equal to:

$p_{STD} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

ℓ : Span, in m, of the transverse ordinary stiffeners constituting the open floor (see Ch 4, Sec 3, [3.2.2])

ℓ_{ST} : Length, in m, of the strut

A_{AST} : Actual net sectional area, in cm², of the strut.

3 Yielding check

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of ordinary stiffeners subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 The yielding check is also to be carried out for ordinary stiffeners subjected to specific loads, such as concentrated loads.

3.2 Structural model

3.2.1 Boundary conditions

The requirements in [3.4], [3.7.3], [3.7.4], [3.8] and [3.9] apply to stiffeners considered either:

- clamped at both ends, whose end connections comply with the requirements in [3.2.2].
- clamped at one end and simply supported at the other end with the clamped end connection complying with the requirements in [3.2.2]
- simply supported at both ends

The requirements in [3.5] and [3.7.5] and [3.7.6] apply to stiffeners considered as simply supported at both ends. Other boundary conditions may be considered by the Society on a case-by-case basis, depending on the distribution of wheeled loads or weapon firing loads, as the case may be.

For other boundary conditions, the yielding check is to be considered on a case-by-case basis.

3.2.2 Bracket arrangement

The requirements of this Article apply to ordinary stiffeners without end brackets, with a bracket at one end or with two equal end brackets, where the bracket length is not greater than 0,2 ℓ.

In the case of ordinary stiffeners with two different end brackets of length not greater than 0,2 ℓ, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis. In general, an acceptable solution consists in applying the criteria for equal brackets, considering both brackets as having the length of the smaller one.

In the case of ordinary stiffeners with end brackets of length greater than 0,2 ℓ, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis.

3.3 Load model

3.3.1 General

The still water and wave lateral loads induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Ordinary stiffeners located on platings below the deepest equilibrium waterline (excluding those on side shell platings) which constitute boundaries intended to stop vertical and horizontal flooding are to be subjected to lateral pressure in flooding conditions.

The wave lateral loads and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

3.3.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”
- the dynamic pressures, according to the criteria in Ch 5, Sec 6, [2].

3.3.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

3.3.4 Lateral pressure in testing conditions

The lateral pressure p_T in testing conditions is taken equal to:

- $p_{ST} - p_S$ for bottom shell plating and side shell plating
- p_{ST} otherwise,

where:

p_{ST} : Still water pressure defined in Ch 5, Sec 6, Tab 10

p_S : Still water sea pressure defined in Ch 5, Sec 5, [1.1.1] for the draught T_1 at which the testing is carried out.

If the draught T_1 is not defined by the Designer, it may be taken equal to the light ballast draught T_B defined in Ch 5, Sec 1, [2.4.3].

3.3.5 Wheeled forces

The wheeled force applied by one wheel is constituted by still water force and inertial force:

- still water force is the vertical force F_S defined in Ch 5, Sec 6, [4.1]
- inertial force is the vertical force $F_{W,Z}$ defined in Ch 5, Sec 6, [4.1], for load case “b”.

3.3.6 Weapons firing dynamic loads

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

3.3.7 Hull girder normal stresses

The hull girder normal stresses to be considered for the yielding check of ordinary stiffeners are obtained, in N/mm², from the following formulae:

- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to lateral pressure:

  $\sigma_{X1} = \gamma_{S1}\, \sigma_{S1} + \gamma_{W1}\, (C_{FV}\, \sigma_{WV1} + C_{FH}\, \sigma_{WH1} + C_{F\Omega}\, \sigma_{\Omega})$
- for longitudinal stiffeners contributing to the hull girder longitudinal strength and subjected to wheeled loads:

  $\sigma_{X1,Wh} = \text{Max}\, (\sigma_{X1H}\, ;\, \sigma_{X1S})$
- for longitudinal stiffeners not contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = 0$
- for transverse stiffeners:

  $\sigma_{X1} = 0$

where:

σ_{S1} , σ_{WV1} , σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 2

σ_{Ω} : Absolute value of the warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

σ_{X1H} , σ_{X1S} : Hull girder normal stresses, in N/mm², respectively in hogging and in sagging, defined in Tab 3

C_{FV} , C_{FH} , $C_{F\Omega}$: Combination factors defined in Tab 4.

3.4 Normal and shear stresses due to lateral pressure in intact conditions

3.4.1 General

Normal and shear stresses, induced by lateral pressures, in ordinary stiffeners are to be obtained from the formulae in:

- [3.4.2] in the case of single span longitudinal and transverse stiffeners
- [3.4.3] in the case of single span vertical stiffeners
- [3.4.4] in the case of multispan vertical stiffeners.

Table 2 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1} , in N/mm² **(1)**	σ_{WV1} , in N/mm²	σ_{WH1} , in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			
• z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\|\dfrac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\|\dfrac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{0,625M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			$\left\|\dfrac{0,625M_{WH}}{I_Z}y\right\|10^{-3}$
• z ≥ N in general ; z < N for stiffeners simply supported at both ends	$\left\|\dfrac{M_{SW,H}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{0,625M_{WV,H}}{I_Y}(z-N)\right\|10^{-3}$	
• z < N in general ; z ≥ N for stiffeners simply supported at both ends	$\left\|\dfrac{M_{SW,S}}{I_Y}(z-N)\right\|10^{-3}$	$\left\|\dfrac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right\|10^{-3}$	

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4.2].

Table 3 : Hull girder normal stresses - Ordinary stiffeners subjected to wheeled loads

Condition	Hull girder normal stresses, in N/mm²
• Hogging	$\sigma_{X1H} = \left\|\gamma_{S1}\dfrac{M_{SW,H}}{I_Y}(z-N)10^{-3}+\gamma_{W1}\left(C_{FV}\dfrac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}+C_{FH}\dfrac{0,625M_{WH}}{I_Z}y10^{-3}+C_{F\Omega}\sigma_{\Omega}\right)\right\|$
• Sagging**(1)**	$\sigma_{X1S} = \left\|\gamma_{S1}\dfrac{M_{SW,S}}{I_Y}(z-N)10^{-3}+\gamma_{W1}\left(C_{FV}\dfrac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}+C_{FH}\dfrac{0,625M_{WH}}{I_Z}y10^{-3}+C_{F\Omega}\sigma_{\Omega}\right)\right\|$

(1) When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4.2].

Table 4 : Combination factors C_{FV} , C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0
Flooding	0,6	0	0

Table 5 : Coefficients β_b and β_s

Brackets at ends	Bracket lengths	β_b	β_s
0	–	1	1
1	ℓ_b	$\left(1-\frac{\ell_b}{2\ell}\right)^2$	$1-\frac{\ell_b}{2\ell}$
2	ℓ_{b1} ; ℓ_{b2}	$\left(1-\frac{\ell_{b1}}{2\ell}-\frac{\ell_{b2}}{2\ell}\right)^2$	$1-\frac{\ell_{b1}}{2\ell}-\frac{\ell_{b2}}{2\ell}$

3.4.2 Single span longitudinal and transverse ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w}\left(1-\frac{s}{2\ell}\right) s \ell^2 10^3 + \sigma_{X1}$$

$$\tau = 5\beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in Tab 5.

3.4.3 Single span vertical ordinary stiffeners

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w}\left(1-\frac{s}{2\ell}\right) s \ell^2 10^3$$

$$\tau = 5\lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}}\left(1-\frac{s}{2\ell}\right) s \ell$$

where:

β_b , β_s : Coefficients defined in Tab 5

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2\frac{\gamma_{S2}(p_{Sd}-p_{Su}) + \gamma_{W2}(p_{Wd}-p_{Wu})}{\gamma_{S2}(p_{Sd}+p_{Su}) + \gamma_{W2}(p_{Wd}+p_{Wu})}$$

$$\lambda_b = 1 - 0{,}2\frac{\gamma_{S2}(p_{Sd}-p_{Su}) + \gamma_{W2}(p_{Wd}-p_{Wu})}{\gamma_{S2}(p_{Sd}+p_{Su}) + \gamma_{W2}(p_{Wd}+p_{Wu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4\frac{\gamma_{S2}(p_{Sd}-p_{Su}) + \gamma_{W2}(p_{Wd}-p_{Wu})}{\gamma_{S2}(p_{Sd}+p_{Su}) + \gamma_{W2}(p_{Wd}+p_{Wu})}$$

$$\lambda_s = 1 - 0{,}4\frac{\gamma_{S2}(p_{Sd}-p_{Su}) + \gamma_{W2}(p_{Wd}-p_{Wu})}{\gamma_{S2}(p_{Sd}+p_{Su}) + \gamma_{W2}(p_{Wd}+p_{Wu})}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the ordinary stiffener considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the ordinary stiffener considered.

3.4.4 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces, to be determined on the basis of the criteria specified in Ch 5, Sec 5 and Ch 5, Sec 6
- the number and position of intermediate supports (decks, girders, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.5 Normal and shear stresses due to wheeled loads

3.5.1 General

Normal and shear stresses, induced by the wheeled loads, in ordinary stiffeners are to be obtained from the formulae in:

- [3.5.2] in the case of single span longitudinal and transverse stiffeners
- [3.5.3] in the case of multispan stiffeners.

3.5.2 Single span longitudinal and transverse ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \alpha_W K_S \frac{P_0 \ell}{6w} 10^3 + \sigma_{X1,Wh}$$

$$\tau = \alpha_W K_T \frac{10 P_0}{A_{Sh}}$$

where:

P_0 : Wheeled force, in kN, taken equal to: $P_0 = \gamma_{S2} F_S + \gamma_{W2} F_{W,Z}$

α_W : Coefficient taking account of the number of wheels per axle considered as acting on the stiffener, defined in Tab 6

K_S, K_T : Coefficients taking account of the number of axles considered as acting on the stiffener, defined in Tab 7.

Table 6 : Wheeled loads - Coefficients α_W

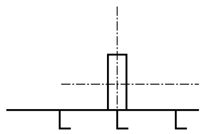
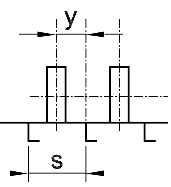
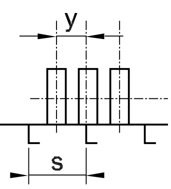
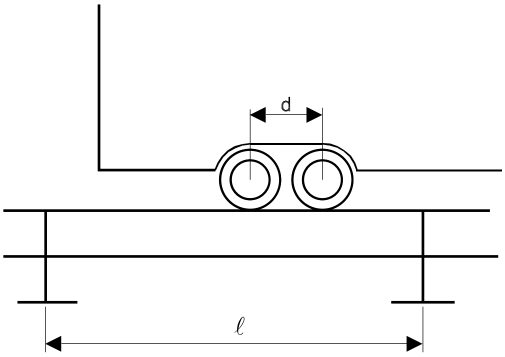
Configuration	α_W
Single wheel 	1
Double wheels 	$2\left(1-\frac{y}{s}\right)$
Triple wheels 	$3-2\frac{y}{s}$
Note 1: y : Distance, in m, from the external wheel of a group of wheels to the stiffener under consideration, to be taken equal to the distance from the external wheel to the centre of the group of wheels.	

Table 7 : Wheeled loads - Coefficients K_S and K_T

Coefficient	Configuration	
	Single axle	Double axles
K_S	1	• if $d \le \ell/\sqrt{3}$: $\frac{172}{81}-\frac{4d}{3\ell}-\frac{d^2}{\ell^2}+\frac{d^4}{\ell^4}$ • if $d > \ell/\sqrt{3}$: $\frac{4}{3}-\frac{4d}{3\ell}+\frac{3d^2}{\ell^2}-\frac{8d^3}{3\ell^3}$
K_T	1	$2-\frac{d}{2\ell}-\frac{3d^2}{2\ell^2}+\frac{d^3}{\ell^3}$
Note 1: d : Distance, in m, between two axles (see Fig 4).		

Figure 4 : Wheeled load on stiffeners - Double axles



3.5.3 Multispan ordinary stiffeners subjected to wheeled loads

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to be determined by a direct calculation taking into account:

- the distribution of still water forces and inertial forces applying on the stiffener, to be determined according to [3.3.5]
- the number and position of intermediate supports (girders, bulkheads, etc.)
- the condition of fixity at the ends of the stiffener and at intermediate supports
- the geometrical characteristics of the stiffener on the intermediate spans.

3.6 Checking criteria

3.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [3.4] and [3.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.7 Net section modulus and net shear sectional area of ordinary stiffeners, complying with the checking criteria

3.7.1 General

The requirements in [3.7.3] and [3.7.4] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.5] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to wheeled loads, complying with the checking criteria indicated in [3.6].

The requirements in [3.7.6] provide the minimum net section modulus and net shear sectional area of single span ordinary stiffeners subjected to weapon firing dynamic loads.

3.7.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.7.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.7.3 Single span longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5.

3.7.4 Single span vertical ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5

λ_b, λ_s : Coefficients defined in [3.4.3].

3.7.5 Single span ordinary stiffeners subjected to wheeled loads

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of ordinary stiffeners subjected to wheeled loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\alpha_W K_S P_0 \ell}{6(R_y - \gamma_R \gamma_m \sigma_{X1,Wh})} 10^3$$

$$A_{Sh} = 20 \gamma_R \gamma_m \frac{\alpha_W K_T P_0}{R_y}$$

where:

P_0 : Wheeled force, in kN, defined in [3.5.2]

α_W, K_S, K_T :Coefficients defined in [3.5.2].

3.7.6 Single span ordinary stiffeners subjected to weapon firing dynamic loads

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of ordinary stiffeners subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W}{R_y} s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5

p_w : Weapon firing dynamic pressure defined in Ch 5, Sec 6, [9].

3.7.7 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4] or [3.5.3], as applicable, taking account of the checking criteria indicated in [3.6].

3.8 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in flooding conditions

3.8.1 General

The requirements in [3.8.1] to [3.8.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners located on structural watertight elements which constitute boundaries intended to stop vertical and horizontal flooding.

These ordinary stiffeners are to be checked in flooding conditions as specified in [3.8.3] to [3.8.5], depending on the type of stiffener.

3.8.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.8.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.8.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5.

3.8.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0,2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_b = 1 - 0,2 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0,4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

$$\lambda_s = 1 - 0,4 \frac{\gamma_{S2}(p_{SFd} - p_{SFu}) + \gamma_{W2}(p_{WFd} - p_{WFu})}{\gamma_{S2}(p_{SFd} + p_{SFu}) + \gamma_{W2}(p_{WFd} + p_{WFu})}$$

p_{SFd} : Still water pressure, in kN/m², in flooding conditions, at the lower end of the ordinary stiffener considered

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the ordinary stiffener considered

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered.

3.8.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the still water pressure p_{SF} and wave pressure p_{WF} in flooding conditions, and taking account of the checking criteria indicated in [3.6].

3.9 Net section modulus and net shear sectional area of ordinary stiffeners subjected to lateral pressure in testing conditions

3.9.1 General

The requirements in [3.9.3] to [3.9.5] provide the minimum net section modulus and net shear sectional area of ordinary stiffeners of compartments subject to testing conditions.

3.9.2 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.9.1] is calculated as the average of the values required for all the stiffeners of the same group, but this average is to be taken not less than 90% of the maximum required value.

The same applies for the minimum net shear sectional area.

3.9.3 Single span longitudinal and transverse ordinary stiffeners

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{m R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5.

3.9.4 Single span vertical ordinary stiffeners

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of vertical ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 5

λ_b : Coefficient taken equal to the greater of the following values:

$$\lambda_b = 1 + 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0{,}2 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

λ_s : Coefficient taken equal to the greater of the following values:

$$\lambda_s = 1 + 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_s = 1 - 0{,}4 \frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m^2, in testing conditions, at the lower end of the ordinary stiffener considered

p_{Tu} : Still water pressure, in kN/m^2, in testing conditions, at the upper end of the ordinary stiffener considered.

3.9.5 Multispan ordinary stiffeners

The minimum net section modulus and the net shear sectional area of multispan ordinary stiffeners are to be obtained from [3.4.4], considering the pressure in testing conditions and taking account of the checking criteria indicated in [3.6].

4 Buckling check

4.1 Width of attached plating

4.1.1 The width of the attached plating to be considered for the buckling check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where no local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]):

  $b_e = s$

- where local buckling occurs on the attached plating (see Ch 7, Sec 1, [5.4.1]):

  $$b_e = \left(\frac{2{,}25}{\beta_e} - \frac{1{,}25}{\beta_e^2}\right) s$$

  to be taken not greater than s

where:

$$\beta_e = \frac{s}{t_p}\sqrt{\frac{\sigma_b}{E}} 10^3$$

σ_b : Compression stress σ_X or σ_Y, in N/mm^2, acting on the plate panel, defined in Ch 7, Sec 1, [5.2.4], according to the direction x or y considered.

4.2 Load model

4.2.1 Sign convention for normal stresses

The sign convention for normal stresses is as follows:

- tension: positive
- compression: negative.

4.2.2 Hull girder compression normal stresses

The hull girder compression normal stresses to be considered for the buckling check of ordinary stiffeners contributing to the hull girder longitudinal strength are obtained, in N/mm^2, from the following formula:

$\sigma_{X1} = \gamma_{S1} \sigma_{S1} + \gamma_{W1} (C_{FV} \sigma_{WV1} + C_{FH} \sigma_{WH1} + C_{F\Omega} \sigma_{\Omega})$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm^2, defined in Tab 8.

Table 8 : Hull girder normal compression stresses

Condition	σ_{S1} in N/mm² **(1)**	σ_{WV1} in N/mm²	σ_{WH1} in N/mm²
• $z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{0,625M_{WH}}{I_Z}y\right\rvert 10^{-3}$
• $z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{0,625M_{WV,H}}{I_Y}(z-N)10^{-3}$	

(1) When the ship in still water is always in hogging condition, σ_{S1} for $z \geq N$ is to be obtained, in N/mm², from the following formula, unless σ_{X1} is evaluated by means of direct calculations (see [4.2.2]):

$$\sigma_{S1} = \frac{M_{SW,Hmin}}{I_Y}(z-N)10^{-3}$$

Note 1:

F_D : Coefficient defined in Ch 5, Sec 2, [4].

σ_Ω : Compression warping stress, in N/mm², induced by the torque 0,625 M_{WT} and obtained through direct calculation analyses based on a structural model in accordance with Ch 6, Sec 1, [2.6]

C_{FV}, C_{FH}, $C_{F\Omega}$: Combination factors defined in Tab 4.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

When the ship in still water is always in hogging condition, σ_{X1} may be evaluated by means of direct calculations when justified on the basis of the ship characteristics and intended service. The calculations are to be submitted to the Society for approval.

4.2.3 Combined hull girder and local compression normal stresses

The combined compression normal stresses to be considered for the buckling check of ordinary stiffeners are to take into account the hull girder stresses and the local stresses resulting from the bending of the primary supporting members. These local stresses are to be obtained from a direct structural analysis using the design loads as given in Part B, Chapter 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10.1], the combined stresses in x and y direction are obtained, in N/mm², from the following formulae:

$$\sigma_X = \sigma_{X1} + \gamma_{S2}\sigma_{X2,S} + \gamma_{W2}\sigma_{X2,W}$$

$$\sigma_Y = \gamma_{S2}\sigma_{Y2,S} + \gamma_{W2}\sigma_{Y2,W}$$

where:

σ_{X1} : Compression normal stress, in N/mm², induced by the hull girder still water and wave loads, defined in [4.2.2]

$\sigma_{X2,S}$, $\sigma_{Y2,S}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the still water design loads as given in Part B, Chapter 5

$\sigma_{X2,W}$, $\sigma_{Y2,W}$: Compression normal stress in x and y direction, respectively, in N/mm², induced by the local bending of the primary supporting members and obtained from a direct structural analysis using the wave design loads as given in Part B, Chapter 5.

4.3 Critical stress

4.3.1 General

The critical buckling stress is to be obtained, in N/mm², from the following formulae:

$$\sigma_c = \sigma_E \quad \text{for } \sigma_E \leq \frac{R_{eH,S}}{2}$$

$$\sigma_c = R_{eH,S}\left(1 - \frac{R_{eH,S}}{4\sigma_E}\right) \quad \text{for } \sigma_E > \frac{R_{eH,S}}{2}$$

where:

σ_E = Min (σ_{E1} ; σ_{E2} ; σ_{E3})

σ_{E1} : Euler column buckling stress, in N/mm², given in [4.3.2]

σ_{E2} : Euler torsional buckling stress, in N/mm², given in [4.3.3]

σ_{E3} : Euler web buckling stress, in N/mm², given in [4.3.4].

4.3.2 Column buckling of axially loaded stiffeners

The Euler column buckling stress is obtained, in N/mm², from the following formula:

$$\sigma_E = \pi^2 E \frac{I_e}{A_e \ell^2} 10^{-4}$$

4.3.3 Torsional buckling of axially loaded stiffeners

The Euler torsional buckling stresses is obtained, in N/mm², from the following formula:

$$\sigma_E = \frac{\pi^2 E I_w}{10^4 I_p \ell^2}\left(\frac{K_C}{m^2} + m^2\right) + 0{,}385 E \frac{I_t}{I_p}$$

where:

I_w : Net sectorial moment of inertia, in cm⁶, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_w = \frac{h_w^3 t_w^3}{36} 10^{-6}$$

- for T-sections:

$$I_w = \frac{t_f b_f^3 h_w^2}{12} 10^{-6}$$

- for angles and bulb sections:

$$I_w = \frac{b_f^3 h_w^2}{12(b_f + h_w)^2}[t_f(b_f^2 + 2b_f h_w + 4h_w^2) + 3t_w b_f h_w]\, 10^{-6}$$

I_p : Net polar moment of inertia, in cm⁴, of the stiffener about its connection to the attached plating:

- for flat bars:

$$I_p = \frac{h_w^3 t_w}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_p = \left(\frac{h_w^3 t_w}{3} + h_w^2 b_f t_f\right) 10^{-4}$$

I_t : St. Venant's net moment of inertia, in cm⁴, of the stiffener without attached plating:

- for flat bars:

$$I_t = \frac{h_w t_w^3}{3} 10^{-4}$$

- for stiffeners with face plate:

$$I_t = \frac{1}{3}\left[h_w t_w^3 + b_f t_f^3\left(1 - 0{,}63\frac{t_f}{b_f}\right)\right] 10^{-4}$$

m : Number of half waves, to be taken equal to the integer number such that (see also Tab 9):

$$m^2(m-1)^2 \le K_C < m^2(m+1)^2$$

$$K_C = \frac{C_0 \ell^4}{\pi^4 E I_w} 10^6$$

C_0 : Spring stiffness of the attached plating:

$$C_0 = \frac{E t_p^3}{2{,}73 s} 10^{-3}$$

Table 9 : Torsional buckling of axially loaded stiffeners Number m of half waves

K_C	$0 \le K_C < 4$	$4 \le K_C < 36$	$36 \le K_C < 144$
m	1	2	3

4.3.4 Web buckling of axially loaded stiffeners

The Euler buckling stress of the stiffener web is obtained, in N/mm², from the following formulae:

- for flat bars:

$$\sigma_E = 16\left(\frac{t_W}{h_W}\right)^2 10^4$$

- for stiffeners with face plate:

$$\sigma_E = 78\left(\frac{t_W}{h_W}\right)^2 10^4$$

4.4 Checking criteria

4.4.1 Stiffeners parallel to the direction of compression

The critical buckling stress of the ordinary stiffener is to comply with the following formula:

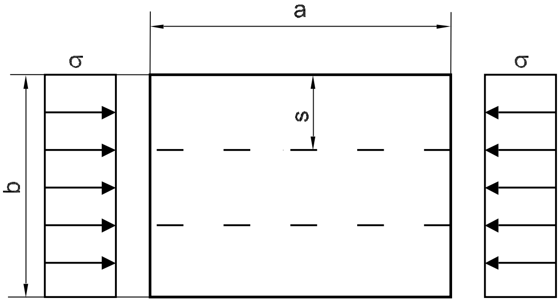
$$\frac{\sigma_c}{\gamma_R \gamma_m} \geq |\sigma_b|$$

where:

σ_c : Critical buckling stress, in N/mm², as calculated in [4.3.1]

σ_b : Compression stress σ_{xb} or σ_{yb}, in N/mm², in the stiffener, as calculated in [4.2.2] or [4.2.3].

Figure 5 : Buckling of stiffeners parallel to the direction of compression



4.4.2 Stiffeners perpendicular to the direction of compression

The net moment of inertia of stiffeners, in cm⁴, is to be not less than the greatest value obtained from the following formulae:

- $I = 360\,\ell^2$
- for $\sigma \leq R_{eH,P} / 2$:

$$I = \frac{s t_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right](\sigma - \sigma_{E,0})$$

- for $\sigma > R_{eH,P} / 2$:

$$I = \frac{s t_p^3}{485}\left[\frac{\left(\frac{\ell}{s}\right)^4 - 4}{\sigma_{E,1} - \sigma_{E,0}}\right]\left[\frac{R_{eH,P}}{4\left(1 - \frac{\sigma}{R_{eH,P}}\right)} - \sigma_{E,0}\right]$$

where:

ℓ/s : Ratio to be taken not less than 1,41

$\sigma_{E,0}$: Euler buckling stress, in N/mm², of the unstiffened plate taken equal to:

$$\sigma_{E,0} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,0} 10^{-6}$$

$K_{1,0}$: Coefficient defined in Ch 7, Sec 1, Tab 8 for:
$0 \leq \Psi \leq 1$ and $\alpha = a / \ell$

ε : Coefficient defined in Ch 7, Sec 1, [5.3.1]

$\sigma_{E,1}$: Euler buckling stress, in N/mm², of the plate panel taken equal to:

$$\sigma_{E,1} = \frac{\pi^2 E}{12(1-\nu^2)}\left(\frac{t_p}{\ell}\right)^2 \varepsilon K_{1,1} 10^{-6}$$

$K_{1,1}$: Coefficient defined in Ch 7, Sec 1, Tab 8 for:
$0 \leq \Psi \leq 1$ and $\alpha = s/ \ell$

Where intercostal stiffeners are fitted, as shown in Fig 7, the check of the moment of inertia of stiffeners perpendicular to the direction of compression is to be carried out with the equivalent net thickness $t_{eq,net}$, in mm, obtained from the following formula:

$$t_{eq,net} = \frac{1 + \left(\frac{s}{\ell_1}\right)^2}{1 + \left(\frac{s}{\ell}\right)^2} t_{net}$$

where ℓ_1 is to be taken not less than s.

Figure 6 : Buckling of stiffeners perpendicular to the direction of compression

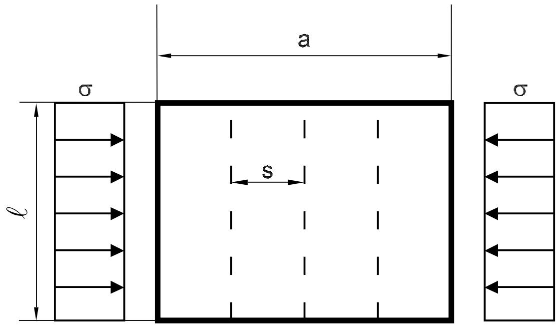
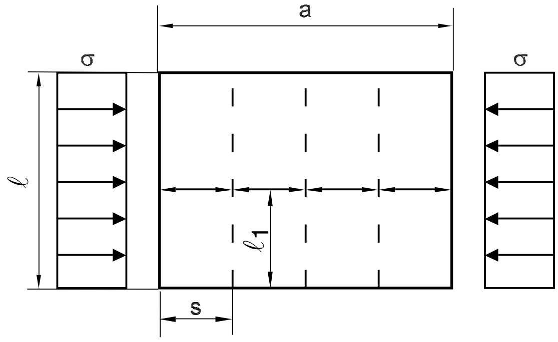


Figure 7 : Buckling of stiffeners perpendicular to the direction of compression (intercostal stiffeners)



5 Ultimate strength check of ordinary stiffeners contributing to the hull girder longitudinal strength

5.1 Application

5.1.1 The requirements of this Article apply to ships equal to or greater than 90 m in length. For such ships, the ultimate strength of stiffeners subjected to lateral pressure and to hull girder normal stresses is to be checked.

5.2 Width of attached plating

5.2.1 The width of the attached plating to be considered for the ultimate strength check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta_U \leq 1{,}25$:

  $b_U = s$

- if $\beta_U > 1{,}25$:

$$b_U = \left(\frac{2{,}25}{\beta_U} - \frac{1{,}25}{\beta_U^2}\right)s$$

where:

$$\beta_U = \frac{s}{t_p}\sqrt{\frac{\sigma_{X1E}}{E}}10^3$$

σ_{X1E} : Stress defined in Tab 10.

5.3 Load model

5.3.1 General

The still water and wave lateral pressures induced by the sea and the various types of weights and ballast in intact conditions are to be considered, depending on the location of the ordinary stiffener under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases "a", "b", "c" and "d" in Ch 5, Sec 4.

Table 10 : Ultimate strength stress

Symbol	Resultant load pressure acting on the side opposite to the ordinary stiffener, with respect to the plating, in N/mm²	Resultant load pressure acting on the same side as the ordinary stiffener, in N/mm²
σ_U	$f\frac{A_U}{A_S}\left(1-\frac{s}{10b_U}\right)R_{eH,P}$	$R_{eH,S}\, f$
f	$\frac{\zeta}{2}-\sqrt{\frac{\zeta^2}{4}-\frac{1-\mu}{(1+\eta_P)\lambda_U^2}}$	
ζ	$\frac{1-\mu}{1+\eta_P}+\frac{1+\eta_P+\eta}{(1+\eta_P)\lambda_U^2}$	
μ	$\frac{125ps\ell^2 d_{P,U}}{R_{eH,P}I_U\left(1-\frac{s}{10b_U}\right)}$	$\frac{41,7ps\ell^2 d_{F,S}}{R_{eH,S}I_S}$
η	$\left(\delta_0+\frac{13ps\ell^4}{E_T I_S}10^4\right)\frac{d_{P,U}}{\rho_U^2}$	$\left(0,577\delta_0+\frac{1,5ps\ell^4}{E_T I_S}10^4\right)\frac{d_{F,S}}{\rho_S^2}$
η_P	$d_P A\left(\frac{1}{A_U}-\frac{1}{A_S}\right)\frac{d_{P,U}}{\rho_U^2}$	0
λ_U	$\frac{31,8\ell}{\rho_U}\sqrt{\frac{R_{eH,P}}{E_T}\left(1-\frac{s}{10b_U}\right)}$	$\frac{18,4\ell}{\rho_S}\sqrt{\frac{R_{eH,S}}{E_T}}$

Note 1:

$d_{P,U}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width b_U and the fibre at half-thickness of the plating

$d_{F,S}$: Distance, in cm, between the neutral axis of the cross-section of the stiffener with attached plating of width s and the fibre at half-thickness of the face plate of the stiffener

d_P : Distance, in cm, between the neutral axis of the ordinary stiffener without attached plating and the fibre at half-thickness of the attached plating

A : Net sectional area, in cm², of the stiffener without attached plating

p : Lateral pressure acting on the stiffener, equal to: $p = \gamma_{S2}\, p_S + \gamma_{W2U}\, p_W$

δ_0 : Pre-deformation, in cm, of the ordinary stiffener, to be assumed, in the absence of more accurate evaluation: $\delta_0 = 0,2\ \ell$

E_T : Structural tangent modulus, equal to:

$$E_T = 4E\frac{\sigma_{X1E}}{R_{eH,P}}\left(1-\frac{\sigma_{X1E}}{R_{eH,P}}\right) \quad \text{for } \sigma_{X1E} > 0,5R_{eH,P}$$

$$E_T = E \quad \text{for } \sigma_{X1E} \le 0,5R_{eH,P}$$

σ_{X1E} : Stress to be obtained, in N/mm², from the following formulae:

$$\text{if } \alpha > \frac{1,25}{\sqrt{|\sigma_{X1}|}}: \quad \sigma_{X1E} = \left\{\frac{-\frac{22,5st_P}{\alpha}+\sqrt{\left(\frac{22,5st_P}{\alpha}\right)^2+4A\left[(A_S+10st_P)\sigma_{X1}+\frac{12,5st_P}{\alpha^2}\right]}}{2A}\right\}^2$$

$$\text{if } \alpha \le \frac{1,25}{\sqrt{|\sigma_{X1}|}}: \quad \sigma_{X1E} = \sigma_{X1}$$

$$\alpha = 1000\frac{s}{t_P\sqrt{E}}$$

σ_{X1} : Compression stress, in N/mm², acting on the stiffener, as defined in [5.3.3].

5.3.2 Lateral pressure

Lateral pressure is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for minimum operational condition.

Wave induced pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for minimum operational condition, and for each load case "a", "b", "c" and "d".

5.3.3 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} to be considered for the ultimate strength check of stiffeners contributing to the longitudinal strength are those given in [4.2.2], where the partial safety factors are those specified in Tab 1 for the ultimate strength check.

5.4 Ultimate strength stress

5.4.1 The ultimate strength stress σ_U is to be obtained, in N/mm², from the formulae in Tab 10, for resultant lateral pressure acting either on the side opposite to the ordinary stiffener, with respect to the plating, or on the same side as the ordinary stiffener.

5.5 Checking criteria

5.5.1 The ultimate strength stress of the ordinary stiffener is to comply with the following formula:

$$\frac{\sigma_U}{\gamma_R \gamma_m} \geq |\sigma_{X1}|$$

where:

σ_U : Ultimate strength stress, in N/mm², as calculated in [5.4.1]

σ_{X1} : Compression stress, in N/mm², as calculated in [5.3.3].

Section 3 Primary Supporting Members

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_S : Still water pressure, in kN/m², see [2.4.2] and [2.4.4]

p_W : Wave pressure, in kN/m², see [2.4.2] and [2.4.4]

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 5, Sec 6, [7]

σ_{X1} : Hull girder normal stress, in N/mm², defined in [2.4.6]

σ_N : Normal stress, in N/mm², defined in [2.4.6]

s : Spacing, in m, of primary supporting members

ℓ : Span, in m, of primary supporting members, measured between the supporting elements, see Ch 4, Sec 3, [4.1]

ℓ_b : Length, in m, of one bracket, see [2.2] and Ch 4, Sec 3, [4.4]

b_p : Width, in m, of the plating attached to the primary supporting member, for the yielding check, defined in Ch 4, Sec 3, [4.2]

w : Net section modulus, in cm³, of the primary supporting member, with an attached plating of width b_p , to be calculated as specified in Ch 4, Sec 3, [4.3]

A_{Sh} : Net shear sectional area, in cm², of the primary supporting member, to be calculated as specified in Ch 4, Sec 3, [4.3]

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side girders

1 General

1.1 Application

1.1.1 Analysis criteria

The requirements of this Section apply for the yielding and buckling checks of primary supporting members.

Depending on their arrangement, primary supporting members are to be analysed through one of the following models:

- an isolated beam structural model
- a three-dimensional structural model
- a complete ship structural model.

1.1.2 Structural models

Depending on the length, primary structural models are to be adopted as specified in Tab 1.

Table 1 : Selection of structural models

Ship length, in m	Calculation model
L < 90	Isolated beam model, or three-dimensional beam model for grillage or complex arrangements
L ≥ 90	Three-dimensional beam model **(1)**
(1) A three-dimensional finite element model or a complete ship model may also be used.	

1.1.3 Yielding check

The yielding check is to be carried out according to:

- [2] for primary supporting members analysed through isolated beam models
- [3] for primary supporting members analysed through three-dimensional models
- [4] for primary supporting members analysed through complete ship models.

1.1.4 Buckling check

The buckling check is to be carried out according to [5], on the basis of the stresses in primary supporting members calculated according to Articles [2], [3] or [4], depending on the structural model adopted.

1.1.5 Normal mode analysis

A normal mode analysis of primary supporting members may be required by the Society to be carried out, when deemed necessary on the basis of the expected frequency of cyclic loads.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for checking primary supporting members are specified in:

- Tab 2 for analyses based on isolated beam models
- Tab 3 for analyses based on three-dimensional models
- Tab 4 for analyses based on complete ship models.

Table 2 : Primary supporting members analysed through isolated beam models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check	
		General (see [2.4] to [2.7])	Flooding **(1)** (see [2.8])	Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,15	1,15	1,15	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,05	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	• 1,02 in general • 1,15 for bottom and side girders	1,02 **(2)**	1,10	for [5.2]: see Tab 12 for [5.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions.
(2) For primary supporting members of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damaged stability considers at least two adjacent compartments flooded.

Table 3 : Primary supporting members analysed through three-dimensional models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [3])		Buckling check	
		General	Flooding **(1)**	Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,05	1,05	1,05
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	Defined in Tab 5 and Tab 6 **(2)**	1,02	for [5.2]: see Tab 12 for [5.3]: 1,15

(1) Applies only to primary supporting members to be checked in flooding conditions.
(2) For primary supporting members of the collision bulkhead, γ_R = 1,25. This requirement may be disregarded when damaged stability considers at least two adjacent compartments flooded.

Table 4 : Primary supporting members analysed through complete ship models - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check (see [4])	Buckling check	
			Plate panels (see [5.1])	Pillars (see [5.2] and [5.3])
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,10	1,10	1,10
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10	1,10
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	Defined in Tab 5 and Tab 6	1,02	for [5.2]: see Tab 12 for [5.3]: 1,15

Table 5 : Primary supporting members analysed through three-dimensional or complete ship models Resistance partial safety factor

Type of three-dimensional model (see Ch 7, App 1)	Resistance partial safety factor γ_R (see [3.3.1] and [4.3.1])	
	General	Watertight bulkhead primary supporting members
Beam model	1,20	1,02
Coarse mesh finite element model	1,20	1,02
Fine mesh finite element model	1,10	1,02

Table 6 : Additional criteria for analyses based on fine mesh finite element models Resistance partial safety factor

Symbol	Resistance partial safety factor (see [3.3.2] and [4.3.2])	
	General	Watertight bulkhead primary supporting members
γ_R	1,10	1,02

2 Yielding check of primary supporting members analysed through an isolated beam structural model

2.1 General

2.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for primary supporting members contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through an isolated beam model, according to [1.1.2].

2.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

2.2 Bracket arrangement

2.2.1 The requirements of this Article apply to primary supporting members with brackets at both ends of length not greater than 0,2 ℓ.

In the case of a significantly different bracket arrangement, the determination of normal and shear stresses due to design loads and the required section modulus and shear sectional area are considered by the Society on a case-by-case basis.

2.3 Load point

2.3.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the primary supporting member considered.

2.3.2 Hull girder normal stresses

For longitudinal primary supporting members contributing to the hull girder longitudinal strength, the hull girder normal stresses are to be calculated in way of the face plate of the primary supporting member considered.

2.4 Load model

2.4.1 General

The still water and wave lateral pressures induced by the sea and the various types of cargoes and ballast in intact conditions are to be considered, depending on the location of the primary supporting member under consideration and the type of compartments adjacent to it, in accordance with Ch 5, Sec 1, [2.4].

Primary supporting members of bulkheads or inner side which constitute the boundary of compartments not intended to carry liquids are to be subjected to the lateral pressure in flooding conditions.

The wave lateral pressures and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

2.4.2 Lateral pressure in intact conditions

The lateral pressure in intact conditions is constituted by still water pressure and wave pressure.

Still water pressure p_S includes:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave pressure p_W includes:

- the wave pressure, defined in Ch 5, Sec 5, [2] for each load case “a”, “b”, “c” and “d”
- the inertial pressure, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

2.4.3 Lateral pressure in flooding conditions

The lateral pressure in flooding conditions is constituted by the still water pressure p_{SF} and the wave pressure p_{WF} defined in Ch 5, Sec 6, [7].

2.4.4 Wheeled loads

For primary supporting members subjected to wheeled loads, the yielding check may be carried out according to [2.5] to [2.7] considering uniform pressures equivalent to the distribution of vertical concentrated forces, when such forces are closely located.

For the determination of the equivalent uniform pressures, the most unfavourable case, i.e. where the maximum number of axles are located on the same primary supporting member, according to Fig 1 to Fig 3, is to be considered.

The equivalent still water pressure and inertial pressure are indicated in Tab 7.

For arrangements different from those shown in Fig 1 to Fig 3, the yielding check of primary supporting members is to be carried out by a direct calculation, taking into account the distribution of concentrated loads induced by vehicle wheels.

Table 7 : Wheeled loads - Equivalent uniform still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = 10\ p_{eq}$
Upright condition	“a”	No inertial pressure
	“b”	$p_W = p_{eq}\ a_{Z1}$
Inclined condition	“c”	The inertial pressure may be disregarded
	“d”	$p_W = p_{eq}\ a_{Z2}$
Note 1: $p_{eq} = \frac{n_V Q_A}{\ell s}\left(3 - \frac{X_1 + X_2}{s}\right)$ n_V : Maximum number of vehicles possible located on the primary supporting member Q_A : Maximum axle load, in t, defined in Ch 5, Sec 6, Tab 5 X_1 : Minimum distance, in m, between two consecutive axles (see Fig 2 and Fig 3) X_2 : Minimum distance, in m, between axles of two consecutive vehicles (see Fig 3).		

Figure 1 : Wheeled loads - Distribution of vehicles on a primary supporting member

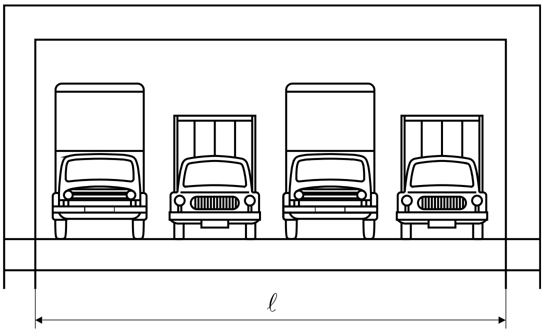


Figure 2 : Wheeled loads - Distance between two consecutive axles

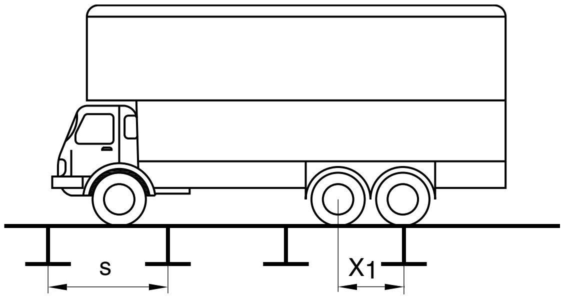
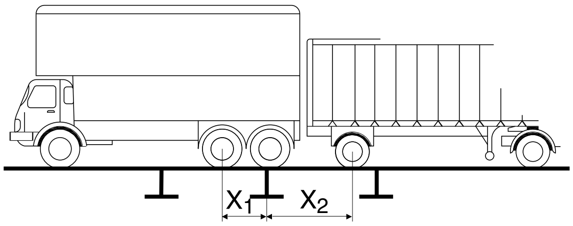


Figure 3 : Wheeled loads - Distance between axles of two consecutive vehicles



2.4.5 Weapon firing dynamic loads

For primary supporting members subjected to weapon firing dynamic loads, the yielding check may be carried out according to [2.7.4] considering uniform pressure distribution.

The pressure p_W is to be calculated according to the requirements specified in Ch 5, Sec 6, [9] for the following weapon firing dynamic loads:

- missile blast dynamic pressure
- accidental missile ignition dynamic pressure
- gun blast dynamic pressure.

For primary supporting members subjected to the gun recoil dynamic force and, in general, when the weapon firing dynamic loads cannot be considered as uniformly distributed, the yielding check is to be carried out taking into account the actual load distribution.

2.4.6 Normal stresses

The normal stresses to be considered for the yielding check of primary supporting members are obtained, in N/mm², from the following formulae:

- for longitudinal primary supporting members contributing to the hull girder longitudinal strength:

  $\sigma_N = \sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$

- for longitudinal primary supporting members not contributing to the hull girder longitudinal strength and for transverse primary supporting members:

  $\sigma_N = 45/k$ N/mm²

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in:

- Tab 8 for primary supporting members subjected to lateral pressure,
- Tab 9 for primary supporting members subjected to wheeled loads

C_{FV}, C_{FH} : Combination factors defined in Tab 10.

Table 8 : Hull girder normal stresses - Primary supporting members subjected to lateral pressure

<table>
<tr><th colspan="2">Condition</th><th>σ_{S1} , in N/mm² **(1)**</th><th>σ_{WV1} , in N/mm²</th><th>σ_{WH1} , in N/mm²</th></tr>
<tr><td rowspan="2">Lateral pressure applied on the side opposite to the primary supporting member, with respect to the plating:</td><td>• z ≥ N</td><td>$\left|\frac{M_{SW,S}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right|10^{-3}$</td><td rowspan="4">$\left|\frac{0,625M_{WH}}{I_Z}y\right|10^{-3}$</td></tr>
<tr><td>• z < N</td><td>$\left|\frac{M_{SW,H}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625M_{WV,H}}{I_Y}(z-N)\right|10^{-3}$</td></tr>
<tr><td rowspan="2">Lateral pressure applied on the same side as the primary supporting member:</td><td>• z ≥ N</td><td>$\left|\frac{M_{SW,H}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625M_{WV,H}}{I_Y}(z-N)\right|10^{-3}$</td></tr>
<tr><td>• z < N</td><td>$\left|\frac{M_{SW,S}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right|10^{-3}$</td></tr>
<tr><td colspan="5">**(1)** When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].</td></tr>
</table>

Table 9 : Hull girder normal stresses - Primary supporting members subjected to wheeled loads

<table>
<tr><th>Condition</th><th>σ_{S1} in N/mm² **(1)**</th><th>σ_{WV1} in N/mm²</th><th>σ_{WH1} in N/mm²</th></tr>
<tr><td>z ≥ N</td><td>$\left|\frac{M_{SW,H}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625M_{WV,H}}{I_Y}(z-N)\right|10^{-3}$</td><td rowspan="2">$\left|\frac{0,625M_{WH}}{I_Z}y\right|10^{-3}$</td></tr>
<tr><td>z < N</td><td>$\left|\frac{M_{SW,S}}{I_Y}(z-N)\right|10^{-3}$</td><td>$\left|\frac{0,625F_D M_{WV,S}}{I_Y}(z-N)\right|10^{-3}$</td></tr>
<tr><td colspan="4">**(1)** When the ship in still water is always in hogging condition, $M_{SW,S}$ is to be taken equal to 0.
Note 1:
F_D : Coefficient defined in Ch 5, Sec 2, [4].</td></tr>
</table>

Table 10 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	1,0	0
"c"	0,4	1,0
"d"	0,4	1,0
Flooding	0,6	0

2.5 Normal and shear stresses due to lateral pressure in intact conditions

2.5.1 General

Normal and shear stresses, induced by lateral pressures, in primary supporting members are to be determined from the formulae given in:

- [2.5.2] in the case of longitudinal and transverse primary supporting members
- [2.5.3] in the case of vertical primary supporting members.

2.5.2 Longitudinal and transverse primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m w} s \ell^2 10^3 + \sigma_N$$

$$\tau = 5\beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{A_{Sh}} s \ell$$

where:

$$\beta_b = \left(1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}\right)^2$$

$$\beta_s = 1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}$$

ℓ_{b1} , ℓ_{b2} : Lengths of the brackets at ends, in m.

2.5.3 Vertical primary supporting members

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \beta_b \frac{\gamma_{S2}\lambda_{bS}p_S + \gamma_{W2}\lambda_{bW}p_W}{mw} s\ell^2 10^3 + \sigma_A$$

$$\tau = 5\beta_s \frac{\gamma_{S2}\lambda_{sS}p_S + \gamma_{W2}\lambda_{sW}p_W}{A_{Sh}} s\ell$$

where:

β_b, β_s : Coefficients defined in [2.5.2]

$$\lambda_{bS} = 1 + 0{,}2\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{bW} = 1 + 0{,}2\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

$$\lambda_{sS} = 1 + 0{,}4\frac{p_{Sd} - p_{Su}}{p_{Sd} + p_{Su}}$$

$$\lambda_{sW} = 1 + 0{,}4\frac{p_{Wd} - p_{Wu}}{p_{Wd} + p_{Wu}}$$

p_{Sd} : Still water pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Su} : Still water pressure, in kN/m², at the upper end of the primary supporting member considered

p_{Wd} : Wave pressure, in kN/m², at the lower end of the primary supporting member considered

p_{Wu} : Wave pressure, in kN/m², at the upper end of the primary supporting member considered

σ_A : Axial stress, to be obtained, in N/mm², from the following formula:

$$\sigma_A = 10\frac{F_A}{A}$$

F_A : Axial load (still water and wave) transmitted to the vertical primary supporting members by the structures above. For multideck ships, the criteria in [5.2.1] for pillars are to be adopted

A : Net sectional area, in cm², of the vertical primary supporting members with attached plating of width b_P.

2.6 Checking criteria

2.6.1 General

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [2.5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R\gamma_m} \geq \sigma$$

$$0{,}5\frac{R_y}{\gamma_R\gamma_m} \geq \tau$$

2.7 Net section modulus and net sectional shear area complying with the checking criteria

2.7.1 General

The requirements in [2.7.2] and [2.7.3] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in intact conditions, complying with the checking criteria indicated in [2.6].

The requirements in [2.7.4] provide the minimum net section modulus and net shear sectional area of primary supporting members subjected to weapon firing dynamic loads.

2.7.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R\gamma_m\beta_b \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{m(R_y - \gamma_R\gamma_m\sigma_N)} s\ell^2 10^3$$

$$A_{Sh} = 10\gamma_R\gamma_m\beta_s \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{R_y} s\ell$$

where β_b and β_s are the coefficients defined in [2.5.2].

2.7.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh} , in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{m(R_y - \gamma_R \gamma_m \sigma_A)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{R_y} s \ell$$

where:

β_b , β_s : Coefficients defined in [2.5.2]

λ_{bs} , λ_{bW} , λ_{sS} , λ_{sW} : Coefficients defined in [2.5.3]

σ_A : Defined in [2.5.3].

2.7.4 Primary supporting members subjected to weapon firing dynamic loads

The net section modulus w, in cm³, and the net shear sectional area A_{Sh} , in cm², of primary supporting members subjected to weapon firing dynamic loads are to be not less than the values obtained from the following formulae:

$$w = c_C \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_W s \ell^2}{8 R_y} 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_W s \ell^2}{R_y}$$

where:

β_b , β_s : Coefficients defined in [2.5.2]

p_w : Weapon firing dynamic pressure defined in Ch 5, Sec 6, [9].

2.8 Net section modulus and net shear sectional area of primary supporting members subjected to lateral pressure in flooding conditions

2.8.1 General

The requirements in [2.8.1] to [2.8.3] apply to primary supporting members located on structural watertight elements as per Internal Watertight Plan which constitute boundaries intended to stop vertical and horizontal flooding.

These primary supporting members are to be checked in flooding conditions as specified in [2.8.2] and [2.8.3], depending on the type of member.

2.8.2 Longitudinal and transverse primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh} , in cm², of longitudinal or transverse primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \sigma_N)} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y} s \ell$$

where:

β_b , β_s : Coefficients defined in [2.5.2].

2.8.3 Vertical primary supporting members

The net section modulus w, in cm³, and the net shear sectional area A_{Sh} , in cm², of vertical primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_{SF} + \gamma_{W2}\lambda_{bW} p_{WF}}{m R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_{SF} + \gamma_{W2}\lambda_{sW} p_{WF}}{R_y} s \ell$$

where:

β_b , β_s : Coefficients defined in [2.5.2]

$$\lambda_{bS} = 1 + 0{,}2\frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{bW} = 1 + 0{,}2\frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

$$\lambda_{sS} = 1 + 0{,}4\frac{p_{SFd} - p_{SFu}}{p_{SFd} + p_{SFu}}$$

$$\lambda_{sW} = 1 + 0{,}4\frac{p_{WFd} - p_{WFu}}{p_{WFd} + p_{WFu}}$$

p_{SFd} : Still water pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the primary supporting member considered

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the primary supporting member considered.

3 Yielding check of primary supporting members analysed through a three-dimensional structural model

3.1 General

3.1.1 The requirements of this Article apply for the yielding check of primary supporting members subjected to lateral pressure, wheeled loads or weapon firing dynamic loads and, for those contributing to the hull girder longitudinal strength, to hull girder normal stresses, which are to be analysed through a three-dimensional structural model, according to [1.1.2].

3.1.2 The yielding check is also to be carried out for primary supporting members subjected to specific loads, such as concentrated loads.

3.2 Analysis criteria

3.2.1 The analysis of primary supporting members based on three-dimensional models is to be carried out according to:

- the requirements in Ch 7, App 1 for primary supporting members subjected to lateral pressure or weapon firing dynamic loads
- the requirements in Ch 7, App 2 for primary supporting members subjected to wheeled loads.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

3.3 Checking criteria

3.3.1 General

For all types of analysis (see Ch 7, App 1, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 1, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

3.3.2 Additional criteria for analyses based on fine mesh finite element models

Fine mesh finite element models are defined with reference to Ch 7, App 1, [3.4].

For all the elements of the fine mesh models, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to Ch 7, App 1, [5], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \mathrm{Max}\,(\sigma_1;\sigma_2)$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

3.3.3 Specific case of primary supporting members subjected to wheeled loads

For all types of analysis (see Ch 7, App 2, [2]), it is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 2, [5] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4 Yielding check of primary supporting members analysed through a complete ship structural model

4.1 General

4.1.1 The requirements of this Article apply for the yielding check of primary supporting members which are to be analysed through a complete ship structural model.

4.1.2 A complete ship structural model is to be carried out, when deemed necessary by the Society, to analyse primary supporting members of ships with one or more of the following characteristics:

- ships having large deck openings
- ships having large space arrangements
- multideck ships having series of openings in side or longitudinal bulkheads, when the stresses due to the different contribution of each deck to the hull girder strength are to be taken into account.

4.2 Analysis criteria

4.2.1 The analysis of primary supporting members based on complete ship models is to be carried out according to Ch 7, App 3.

These requirements apply for:

- the structural modelling
- the load modelling
- the stress calculation.

4.3 Checking criteria

4.3.1 General

It is to be checked that the equivalent stress σ_{VM}, calculated according to Ch 7, App 3, [4] is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

4.3.2 Additional criteria for elements modelled with fine meshes

Fine meshes are defined with reference to Ch 7, App 3, [2.4].

For all the elements modelled with fine meshes, it is to be checked that the normal stresses σ_1 and σ_2 and the shear stress τ_{12}, calculated according to Ch 7, App 3, [4], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \mathrm{Max}\,(\sigma_1;\sigma_2)$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau_{12}$$

5 Buckling check

5.1 Local buckling of plate panels

5.1.1 A local buckling check is to be carried out, according to Ch 7, Sec 1, [5], for plate panels which constitute primary supporting members.

In carrying out this check, the stresses in the plate panels are to be calculated according to [2], [3] or [4], depending on the structural model adopted for the analysis of primary supporting members.

5.2 Buckling of pillars subjected to compression axial load

5.2.1 Compression axial load

The compression axial load in the pillar is to be obtained, in kN, from the following formula:

$$F_A = A_D(\gamma_{S2} p_S + \gamma_{W2} p_W) + \sum_i r(\gamma_{S2} Q_{i,S} + \gamma_{W2} Q_{i,W})$$

where:

A_D : Area, in m², of the portion of the deck or the platform supported by the pillar considered

r : Coefficient which depends on the relative position of each pillar above the one considered, to be taken equal to:
- $r = 1,0$ for the pillar considered
- $r = 0,9$ for the pillar immediately above that considered
- $r = 0,9^{i}$ for the i^{th} pillar of the line above the pillar considered, to be taken not less than 0,478

$Q_{i,S}$, $Q_{i,W}$: Still water and wave load, respectively, in kN, from the i^{th} pillar of the line above the pillar considered, if any.

5.2.2 Critical column buckling stress of pillars

The critical column buckling stress of pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cB} = \sigma_{E1} \qquad \text{for} \quad \sigma_{E1} \le \frac{R_{eH}}{2}$$

$$\sigma_{cB} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E1}}\right) \qquad \text{for} \quad \sigma_{E1} > \frac{R_{eH}}{2}$$

where:

σ_{E1} : Euler column buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E1} = \pi^2 E \frac{I}{A(f\ell)^2} 10^{-4}$$

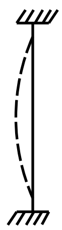
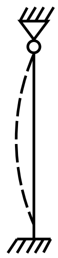
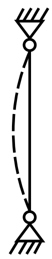
I : Minimum net moment of inertia, in cm⁴, of the pillar

A : Net cross-sectional area, in cm², of the pillar

ℓ : Span, in m, of the pillar

f : Coefficient, to be obtained from Tab 11.

Table 11 : Coefficient f

	Both ends fixed	One end fixed, one end pinned	Both ends pinned
Boundary conditions of the pillar			
Coefficient f	$f = 0,5$	$f = \frac{\sqrt{2}}{2}$	$f = 1,0$

5.2.3 Critical torsional buckling stress of built-up pillars

The critical torsional buckling stress of built-up pillars is to be obtained, in N/mm², from the following formulae:

$$\sigma_{cT} = \sigma_{E2} \qquad \text{for} \quad \sigma_{E2} \le \frac{R_{eH}}{2}$$

$$\sigma_{cT} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E2}}\right) \qquad \text{for} \quad \sigma_{E2} > \frac{R_{eH}}{2}$$

where:

σ_{E2} : Euler torsional buckling stress, to be obtained, in N/mm², from the following formula:

$$\sigma_{E2} = \frac{\pi^2 E I_w}{10^4 I_p \ell^2} + 0,41 E \frac{I_t}{I_p}$$

I_w : Net sectorial moment of inertia of the pillar, to be obtained, in cm⁶, from the following formula:

$$I_w = \frac{t_f b_f^3 h_w^2}{24} 10^{-6}$$

h_W : Web height of built-up section, in mm

t_W : Net web thickness of built-up section, in mm

b_F : Face plate width of built-up section, in mm

t_F : Net face plate thickness of built-up section, in mm

I_p : Net polar moment of inertia of the pillar, to be obtained, in cm⁴, from the following formula:

$I_P = I_{XX} + I_{YY}$

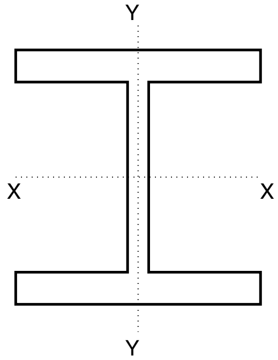
I_{XX} : Net moment of inertia about the XX axis of the pillar section (see Fig 4)

I_{YY} : Net moment of inertia about the YY axis of the pillar section (see Fig 4)

I_t : St. Venant's net moment of inertia of the pillar, to be obtained, in cm^4, from the following formula:

$$I_t = \frac{1}{3}[h_w t_w^3 + 2 b_f t_f^3] 10^{-4}$$

Figure 4 : Reference axes for the calculationof the moments of inertia of a built-up section



5.2.4 Critical local buckling stress of built-up pillars

The critical local buckling stress of built-up pillars is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E3} \qquad \text{for} \quad \sigma_{E3} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E3}}\right) \qquad \text{for} \quad \sigma_{E3} > \frac{R_{eH}}{2}$$

where:

σ_{E3} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

$$\sigma_{E3} = 78\left(\frac{E}{206000}\right)\left(\frac{t_W}{h_W}\right)^2 10^4$$

$$\sigma_{E3} = 32\left(\frac{E}{206000}\right)\left(\frac{t_F}{b_F}\right)^2 10^4$$

t_W, h_W, t_F, b_F : Dimensions, in mm, of the built-up section, defined in [5.2.3].

5.2.5 Critical local buckling stress of pillars having hollow rectangular section

The critical local buckling stress of pillars having hollow rectangular section is to be obtained, in N/mm^2, from the following formulae:

$$\sigma_{cL} = \sigma_{E4} \qquad \text{for} \quad \sigma_{E4} \le \frac{R_{eH}}{2}$$

$$\sigma_{cL} = R_{eH}\left(1 - \frac{R_{eH}}{4\sigma_{E4}}\right) \qquad \text{for} \quad \sigma_{E4} > \frac{R_{eH}}{2}$$

where:

σ_{E4} : Euler local buckling stress, to be taken equal to the lesser of the values obtained, in N/mm^2, from the following formulae:

$$\sigma_{E4} = 78\left(\frac{E}{206000}\right)\left(\frac{t_2}{b}\right)^2 10^4$$

$$\sigma_{E4} = 78\left(\frac{E}{206000}\right)\left(\frac{t_1}{h}\right)^2 10^4$$

b : Length, in mm, of the shorter side of the section

t_2 : Net web thickness, in mm, of the shorter side of the section

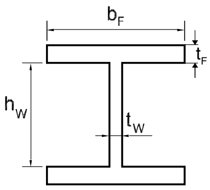
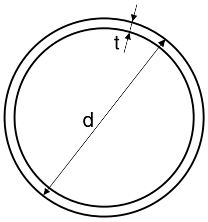
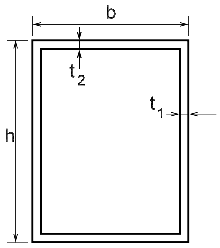
h : Length, in mm, of the longer side of the section

t_1 : Net web thickness, in mm, of the longer side of the section.

5.2.6 Checking criteria

The net scantlings of the pillar loaded by the compression axial stress F_A defined in [5.2.1] are to comply with the formulae in Tab 12.

Table 12 : Buckling check of pillars subject to compression axial load

Pillar cross-section	Column buckling check	Torsional buckling check	Local buckling check	Geometric condition
Built-up 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cT}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b_F}{t_F} \leq 40$
Hollow tubular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	Not required	Not required	$\frac{d}{t} \leq 55$ $t \geq 5{,}5$ mm
Hollow rectangular 	$\frac{\sigma_{cB}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	Not required	$\frac{\sigma_{cL}}{\gamma_R\gamma_m} \geq 10\frac{F_A}{A}$	$\frac{b}{t_2} \leq 55$ $\frac{h}{t_1} \leq 55$ $t_1 \geq 5{,}5$ mm $t_2 \geq 5{,}5$ mm

Note 1:

σ_{cB} : Critical column buckling stress, in N/mm², defined in [5.2.2]
σ_{cT} : Critical torsional buckling stress, in N/mm², defined in [5.2.3]
σ_{cL} : Critical local buckling stress, in N/mm², defined in [5.2.4] for built-up section or in [5.2.5] for hollow rectangular section
γ_R : Resistance partial safety factor, to be taken equal to:
- 1,15 for column buckling
- 1,05 for torsional and local buckling

F_A : compression axial load in the pillar, in kN, defined in [5.2.1]
A : Net sectional area, in cm², of the pillar.

5.2.7 Contact pressure

At connections between pillars and decks, it is to be checked that the contact pressure σ_C, in N/mm2, complies with the following criteria:

$\sigma_c \leq 0{,}8\ R_{eH}$

where:

$\sigma_c = 10F_A/A_C$

with:

F_A : Compression axial load in the pillar, in kN
A_C : Contact area between the pillar and the deck structural members, in cm²
R_{eH} : Smallest of the assembled elements yield stress, in N/mm².

5.3 Buckling of pillars subjected to compression axial load and bending moments

5.3.1 Checking criteria

In addition to the requirements in [5.2], the net scantlings of the pillar loaded by the compression axial load and bending moments are to comply with the following formula:

$$10F\left(\frac{1}{A} + \frac{\Phi e}{w_P}\right) + \left(10^3\frac{M_{max}}{w_P}\right) \leq \frac{R_{eH}}{\gamma_R\gamma_m}$$

where:

F : Compression load, in kN, acting on the pillar

A : Net cross-sectional area, in cm², of the pillar

e : Eccentricity, in cm, of the compression load with respect to the centre of gravity of the cross-section

$$\Phi = \frac{1}{1 - \frac{F}{\sigma_{E1} A}}$$

σ_{E1} : Euler column buckling stress, in N/mm², defined in [5.2.2]

w_P : Minimum net section modulus, in cm³, of the cross-section of the pillar

$M_{max} = Max\ (M_1\ ;\ M_2\ ;\ M_0)$

M_1 : Bending moment, in kN.m, at the upper end of the pillar

M_2 : Bending moment, in kN.m, at the lower end of the pillar

$$M_0 = \frac{0{,}5(\sqrt{1 + t^2})(M_1 + M_2)}{\cos(u)}$$

$$u = 0{,}5\pi\sqrt{\frac{F}{\sigma_{E1} A}}$$

$$t = \frac{1}{\tan(u)}\left(\frac{M_2 - M_1}{M_2 + M_1}\right)$$

6 Dynamic analysis of main weapon mount supporting structure

6.1 Application

6.1.1 The requirements of this Article apply for the dynamic analysis of main weapon mount supporting structure subjected to dynamic loads.

6.2 Dynamic analysis

6.2.1 Analysis criteria

The dynamic analysis of main weapon mount supporting structure is to be based on direct calculations performed through three-dimensional models.

The criteria adopted for structural modelling are to comply with the requirements specified in Ch 7, App 1.

In any case, the mesh accuracy is to be such that the stiffness and the mass distribution of the model elements of the mount supporting structure and of the surrounding hull structure properly represent those of the actual structure.

Dynamic analysis of special weapons, such as vertical missile launching system (VLS) and rocket or missile launching system with elevation and slewing capabilities, are to be considered by the Society on a case-by-case basis. When deemed necessary, the Society may also require that finite element model transient analyses be performed.

6.2.2 Normal mode analysis

It is to be checked that each normal mode frequency f_{Ni}, in Hz, of the weapon mount supporting structure is in compliance with one of the following formulae:

$f_{Ni} < 0{,}8\ f_{E,MIN}$

$f_{Ni} > 1{,}2\ f_{E,MAX}$

where:

$F_{E,MIN}$, $F_{E,MAX}$: The lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the weapon (e.g. hail) or the propulsion system.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case-by-case basis.

When at least one of the normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [6.2.3].

6.2.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the weapon mounting supporting structure by the weapon or the propulsion system are within allowable limits, when this is required according to [6.2.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating:

- the response of the weapon system in the time domain to possible excitations due to the weapon (e.g. hail)
- the response amplitude operators (RAOs) of the weapon system versus possible excitations due to the propulsion system.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the mass of the system constituted by the weapon and its mounting supporting structure.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^{th} modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case-by-case basis.

Section 4 Fatigue Check of Structural Details

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

p_W : Wave pressure, in kN/m² (see [2.2])

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

K_h, $K\ell$: Stress concentration factors, defined in Ch 11, Sec 2 for the special structural details there specified

K_F : Fatigue notch factor, defined in [4.3.1]

K_m : Stress concentration factor, taking account of misalignment, defined in [4.3.1]

$\Delta\sigma_{P0}$: Allowable stress range, defined in Article [4].

T_1 : Draught, in m, corresponding to the loading condition considered.

1 General

1.1 Net scantlings

1.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2 Application

1.2.1 Structural details to be checked

The requirements of this Section apply for the fatigue check of special structural details, according to Ch 11, Sec 2.

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry, tolerances and stress level, in agreement with the Designer.

1.2.2 Categorisation of details

With respect to the method to be adopted to calculate the stresses acting on structural members, the details for which the fatigue check is to be carried out may be grouped as follows:

- details where the stresses are to be calculated through a three-dimensional structural model (e.g. connections between primary supporting members)
- details located at ends of ordinary stiffeners, for which an isolated structural model can be adopted.

1.2.3 Details where the stresses are to be calculated through a three-dimensional structural model

The requirements of Ch 7, App 1, [6] apply, in addition to those from Articles [1] to [5] of this Section.

1.2.4 Details located at ends of ordinary stiffeners

The requirements from Articles [1] to [6] of this Section apply.

1.2.5 Other details

In general, for details other than those in [1.2.2], the stresses are to be calculated through a method agreed by the Society on a case-by-case basis, using the load model defined in Article [2].

The checking criterion in Article [5] is generally to be applied.

1.3 Definitions

1.3.1 Hot spots

Hot spots are the locations where fatigue cracking may occur. They are indicated in the relevant figures of special structural details in Ch 11, Sec 2.

1.3.2 Nominal stress

Nominal stress is the stress in a structural component taking into account macro-geometric effects but disregarding the stress concentration due to structural discontinuities and to the presence of welds (see Fig 1).

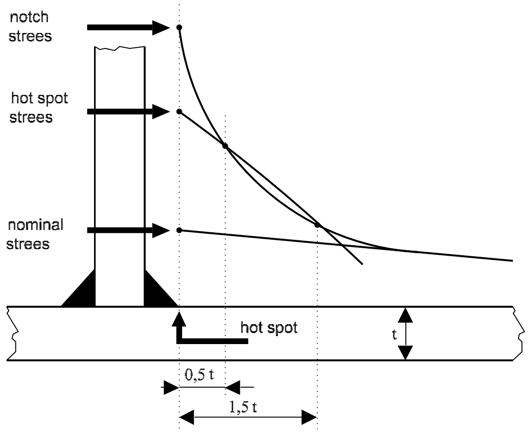
1.3.3 Hot spot stress

Hot spot stress is a local stress at the hot spot taking into account the influence of structural discontinuities due to the geometry of the detail, but excluding the effects of welds (see Fig 1).

1.3.4 Notch stress

Notch stress is a peak stress in a notch such as the root of a weld or the edge of a cut-out. This peak stress takes into account the stress concentrations due to the presence of notches (see Fig 1).

Figure 1 : Nominal, hot spot and notch stresses



1.3.5 Elementary stress range

Elementary stress range is the stress range determined for one of the load cases "a", "b", "c" or "d" (see Ch 5, Sec 4, [2]) and for either of the loading conditions (see Ch 5, Sec 1, [2.4] and Ch 5, Sec 1, [2.5]).

1.3.6 Equivalent stress range

Equivalent stress range is a stress range obtained from a combination of elementary stress ranges, as indicated in [4.3.1] for notch stress and [2.3.1] for hull girder nominal stress.

1.4 Partial safety factors

1.4.1 The partial safety factors to be considered for the fatigue check of structural details are specified in Tab 1.

Table 1 : Fatigue check - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Value	
		General	Details at ends of ordinary stiffeners
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave hull girder loads	γ_{W1}	1,05	1,15
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,20
Resistance	γ_R	1,02	1,02

2 Load model

2.1 General

2.1.1 Load point

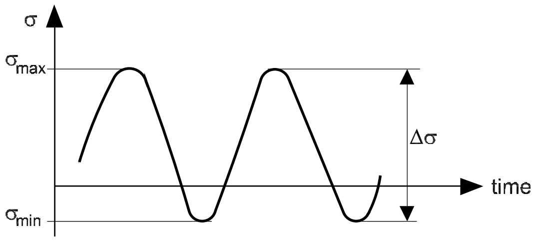
Unless otherwise specified, design loads are to be determined at points defined in:

- Ch 7, Sec 2, [1.3] for ordinary stiffeners
- Ch 7, Sec 3, [1] for primary supporting members.

2.1.2 Local and hull girder loads

The fatigue check is based on the stress range induced at the hot spot by the time variation of local and hull girder loads in each load case "a", "b", "c" and "d" defined in [2.2] for the loading conditions defined in [2.1.4] and [2.1.3] (see Fig 2).

Figure 2 : Stress range



2.1.3 Loading conditions for details where the stresses are to be calculated through a three-dimensional structural model

The most severe full load and operational load conditions for the detail concerned are to be considered in accordance with Ch 5, Sec 1, [2.5].

2.1.4 Loading conditions for details located at ends of ordinary stiffeners

The load distribution is to be considered in accordance with Ch 5, Sec 1, [2.4].

2.1.5 Spectral fatigue analysis

For ships with non-conventional shapes or with restricted navigation, the Society may require a spectral fatigue analysis to be carried out.

In this analysis, the loads and stresses are to be evaluated through long-term stochastic analysis taking into account the characteristics of the ship and the navigation notation.

The load calculations and fatigue analysis are to be submitted to the Society for approval.

2.2 Local lateral pressures

2.2.1 General

The still water and wave lateral pressures induced by the sea, various types of loads and ballast are to be considered.

Lateral pressure is constituted by still water pressure and wave pressure.

2.2.2 Load cases “a-max” and “a-min”, in upright ship condition

The still water sea pressure (p_S) is defined in Ch 5, Sec 5, [1.1.1].

The wave pressure p_W is defined in Tab 2.

No internal inertial pressures are considered.

2.2.3 Load cases “b-max” and “b-min”, in upright ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Dynamic pressure p_W is constituted by internal inertial pressures defined in Tab 4.

No sea wave dynamic pressures are considered.

2.2.4 Load cases “c-max” and “c-min”, in inclined ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Wave pressure p_W includes:

- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of loads and ballast.

2.2.5 Load cases “d-max” and “d-min”, in inclined ship condition

Still water pressures p_S includes:

- the still water sea pressure defined in Ch 5, Sec 5, [1]
- the still water internal pressure, defined in Ch 5, Sec 6 for the various types of loads and for ballast.

Wave pressure p_W includes:

- the wave pressure obtained from Tab 3
- the inertial pressure obtained from Tab 4 for the various types of loads and ballast.

Table 2 : Wave pressure in load case "a"

Location	Wave pressure p_W, in kN/m²	
	a-max	a-min
Bottom and sides below the waterline ($z \le T_1$)	$\alpha^{1/4}\rho g\frac{h_1}{2}\left[\frac{T_1+z}{T_1}\right]$	$-\alpha^{1/4}\rho g\frac{h_1}{2}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$
Sides above the waterline ($z > T_1$)	$\rho g(T_1+\alpha^{1/4}h_1-z)$	0,0

Note 1:
α : Coefficient equal to T_1/T, but not to be taken greater than 1

Table 3 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location		Wave pressure p_W, in kN/m² **(1)**	
		c-max / d-max	c-min / d-min
Bottom and sides below the waterline ($z \le T_1$)	$y \ge 0$	$C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$	$-C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$
	$y < 0$	$-C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$ without being taken less than $\frac{\gamma_S}{\gamma_W}\rho g(z-T_1)$	$C_{F2}\alpha^{1/4}\rho g h_2\frac{\lvert y\rvert}{B_W}\left[\frac{T_1+z}{T_1}\right]$
Sides above the waterline ($z > T_1$)	$y \ge 0$	$\rho g\left[T_1+2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2-z\right]$	0,0
	$y < 0$	0,0	$\rho g\left[T_1+2C_{F2}\alpha^{1/4}\frac{\lvert y\rvert}{B_W}h_2-z\right]$

(1) In the formulae giving the wave pressure p_W, the ratio $|y| / B_W$ is not to be taken greater than 0,5.
Note 1:
α : Coefficient equal to T_1/T, but not to be taken greater than 1
C_{F2} : Combination factor, to be taken equal to:
- C_{F2} = 1,0 for load case "c"
- C_{F2} = 0,5 for load case "d"

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered
h_2 : Reference value, in m, of the relative motion in the inclined ship condition, defined in Ch 5, Sec 3, [3.3.2] and not to be taken greater than the minimum of T_1 and (D – 0,9 T_1).

Table 4 : Inertial pressures

Loads	Load case	Inertial pressures, in kN/m² **(1)**
Liquids	b-max	$p_W = \rho_L[-0,5a_{X1}\ell_B - a_{Z1}(z_{TOP}-z)]$
	b-min	$p_W = \rho_L[0,5a_{X1}\ell_B + a_{Z1}(z_{TOP}-z)]$
	c-max d-max	$p_W = \rho_L[0,7C_{FA}a_{Y2}(y-y_H)+(-0,7C_{FA}a_{Z2}-g)(z-z_H)+g(z-z_{TOP})]$
	c-min d-min	$p_W = \rho_L[-0,7C_{FA}a_{Y2}(y-y_H)+(0,7C_{FA}a_{Z2}-g)+g(z-z_{TOP})]$

(1) The symbols used in the formulae of inertial pressures are defined in Ch 5, Sec 6.
Note 1:
C_{FA} : Combination factor, to be taken equal to:
C_{FA} = 0,7 for load case "c"
C_{FA} = 1,0 for load case "d"

2.3 Nominal hull girder normal stresses

2.3.1 The nominal hull girder normal stresses are obtained, in N/mm², from the following formulae:

- for members contributing to the hull girder longitudinal strength:

$$\sigma_h = \gamma_{S1}\sigma_{SW} + \gamma_{W1}(C_{FV}\sigma_{WV} + C_{FH}\sigma_{WH})$$

- for members not contributing to the hull girder longitudinal strength:

$\sigma_h = 0$

where:

σ_{SW} : Still water hull girder normal stresses, in N/mm², taken equal to:

$$\sigma_{SW} = \frac{M_{SW}}{I_Y}(z-N)10^{-3}$$

M_{SW} : Still water bending moment for the loading condition considered

σ_{WV}, σ_{WH}: Hull girder normal stresses, in N/mm², defined in Tab 5

C_{FV}, C_{FH} : Combination factors defined in Tab 6.

Table 5 : Nominal hull girder normal stresses

Load case	σ_{WV}, in N/mm²	σ_{WH}, in N/mm²
a-max	$\frac{0,625 M_{WV,H}}{I_Y}(z-N)10^{-3}$	0
a-min	$\frac{0,625 M_{WV,S}}{I_Y}(z-N)10^{-3}$	0
b-max b-min	0	0
c-max d-max	0	$-\frac{0,625 M_{WH}}{I_Z}y10^{-3}$
c-min d-min	0	$\frac{0,625 M_{WH}}{I_Z}y10^{-3}$

Table 6 : Combination factors C_{FV}, C_{FH} and $C_{F\Omega}$

Load case	C_{FV}	C_{FH}	$C_{F\Omega}$
"a"	1,0	0	0
"b"	1,0	0	0
"c"	0,4	1,0	1,0
"d"	0,4	1,0	0

3 Fatigue damage ratio

3.1 General

3.1.1 Elementary fatigue damage ratio

The elementary fatigue damage ratio is to be obtained from the following formula:

$$D_{ij} = \frac{N_t}{K_p}\frac{(\Delta\sigma_{N,ij})^3}{(-\ln p_R)^{3/\xi}}\mu_{ij}\,\Gamma_C\left[\frac{3}{\xi}+1\right]$$

where:

$\Delta\sigma_{N,ij}$: Elementary notch stress range, in N/mm², defined in [4.3.1]

$$\mu_{ij} = 1 - \frac{\Gamma_N\frac{3}{\xi}+1, \nu_{ij} - \Gamma_N\frac{5}{\xi}+1, \nu_{ij}\nu_{ij}^{-2/\xi}}{\Gamma_C\frac{3}{\xi}+1}$$

$\xi = \xi_0 K_2$

$\xi_0 = \frac{73 - 0,07L}{60}$ without being less than 0,85

K_2 : For fatigue calculation in way of connection of longitudinals on transverses, K_2 is given below, without being taken less than 0,9:

$$K_2 = 1,04 - 0,14\frac{|z - T_1|}{D - T_1}$$

K_2 is to be taken equal to 1 for all other fatigue calculations

T_1 : Draught, in m, corresponding to the loading condition "Full load" or "Operational load"

$$\nu_{ij} = -\left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi}\ln p_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5,802\left(\frac{22}{t}\right)^{0,9}10^{12}$$

t : Net thickness, in mm, of the element under consideration not being taken less than 22 mm

N_t : Number of cycles corresponding to the design fatigue life T_{FL}, to be taken equal to:

$$N_t = \frac{31,55 \cdot \alpha_0 \cdot T_{FL}}{T_A}10^6$$

α_0 : Sailing factor, taken equal to 0,80, except if otherwise specified

T_A : Average period, in seconds, to be taken equal to: $T_A = 4 \log L$

T_{FL} : Increased design fatigue life, in years, having a value between 30 and 40

$p_R = 10^{-5}$

$\Gamma_N[X+1,\nu_{ij}]$: Incomplete Gamma function, calculated for $X = 3 / \xi$ or $X = 5 / \xi$ and equal to:

$$\Gamma_N[X+1,\nu_{ij}] = \int_0^{\nu_{ij}} t^X e^{-t} dt$$

Values of $\Gamma_N[X+1,\nu_{ij}]$ are also indicated in Tab 7. For intermediate values of X and ν_{ij}, Γ_N may be obtained by linear interpolation

$\Gamma_C[X+1]$: Complete Gamma function, calculated for $X = 3/\xi$, equal to:

$$\Gamma_C[X+1] = \int_0^{\infty} t^X e^{-t} dt$$

Values of $\Gamma_C[X+1]$ are also indicated in Tab 8. For intermediate values of X, Γ_C may be obtained by linear interpolation.

3.1.2 Cumulative damage ratio

The cumulative damage ratio is to be obtained from the following formula:

$D = K_{cor} [\alpha D_F + (1 - \alpha) D_B]$

where:

K_{cor} : Corrosion factor, taken equal to:

- $K_{cor} = 1,0$ for dry compartments
- $K_{cor} = 1,1$ for ballast tanks having an effective coating protection
- $K_{cor} = 1,5$ for cargo oil tanks

α : coefficient to be taken equal to 0,75

D_F : Cumulative damage ratio for ship in "Full load" condition, taken equal to:

$$D_F = \frac{1}{6}D_{aF} + \frac{1}{6}D_{bF} + \frac{1}{3}D_{cF} + \frac{1}{3}D_{dF}$$

D_B : Cumulative damage ratio for ship in "Operational load" condition, taken equal to:

$$D_B = \frac{1}{3}D_{aB} + \frac{1}{3}D_{bB} + \frac{1}{3}D_{cB}$$

D_{aF}, D_{bF}, D_{cF}, D_{dF} : Elementary damage ratios for load cases "a", "b", "c" and "d", respectively, in "Full load" condition, defined in [3.1.1]

D_{aB}, D_{bB}, D_{cB} : Elementary damage ratios for load cases "a", "b", and "c", respectively, in "Operational load" condition, defined in [3.1.1].

Table 7 : Function Γ_N [X+1, ν_{ij}]

X	ν_{ij} = 1,5	ν_{ij} = 2,0	ν_{ij} = 2,5	ν_{ij} = 3,0	ν_{ij} = 3,5	ν_{ij} = 4,0	ν_{ij} = 4,5
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,32
6,0	0,67	3,26	10,21	24,13	47,00	79,69	121,64
6,1	0,68	3,44	10,98	26,39	52,14	89,45	137,95
6,2	0,70	3,62	11,82	28,87	57,86	100,45	156,51
6,3	0,72	3,81	12,71	31,60	64,24	112,86	177,65
6,4	0,73	4,02	13,68	34,60	71,34	126,85	201,74
6,5	0,75	4,23	14,73	37,90	79,25	142,62	229,20
6,6	0,77	4,46	15,87	41,52	88,07	160,42	260,50

Table 8 : Function Γ_C [X+1]

X	Γ_C [X+1]	X	Γ_C [X+1]
2,6	3,717	3,4	10,136
2,7	4,171	3,5	11,632
2,8	4,694	3,6	13,381
2,9	5,299	3,7	15,431
3,0	6,000	3,8	17,838
3,1	6,813	3,9	20,667
3,2	7,757	4,0	24,000
3,3	8,855		

4 Stress range

4.1 General

4.1.1 Calculation point

Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

4.1.2 Stress components

For the details in [1.2.2], the stresses to be used in the fatigue check are the normal stresses in the directions indicated, for each detail, in the relevant figures in Ch 11, Sec 2.

Where the fatigue check is required for details other than those in [1.2.2], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

4.2 Hot spot stress range

4.2.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm^2, in accordance with:

- Ch 7, App 1, [6] for details where the stresses are to be calculated through a three-dimensional structural models
- [6.2] for details located at ends of ordinary stiffeners.

4.3 Notch stress range

4.3.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm^2, from the following formula:

$\Delta\sigma_{N,ij} = K_{C,ij}\ \Delta\sigma_{N0,ij}$

with:

$\Delta\sigma_{N0,ij} = 0{,}7\ K_F\ K_m\ \Delta\sigma_{G,ij}$

Table 9 : Weld coefficient λ

Weld configuration	Coefficient λ	
	Grind welds	Other cases
Butt joints:		
• Stresses parallel to weld axis		
- full penetration	1,85	2,10
- partial penetration	1,85	2,10
• Stresses perpendicular to weld axis		
- full penetration	2,10	2,40
- partial penetration	3,95	4,50
T joints:		
• Stresses parallel to weld axis; fillet weld and partial penetration	1,60	1,80
• Stresses perpendicular to weld axis and in plane of continuous element **(1)**; fillet weld and partial penetration	1,90	2,15
• Stresses perpendicular to weld axis and in plane of welded element; fillet weld and partial penetration	3,95	4,50
Cruciform joints:		
• Full penetration	1,85	2,10
• Partial penetration	2,05	2,35
(1) This case includes the hot spots indicated in the sheets of special structural details in Ch 11, Sec 2 relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members.		

where:

K_F : Fatigue notch factor, equal to:

$$K_F = \lambda \sqrt{\frac{\theta}{30}}$$

for flame-cut edges, K_F may be taken equal to 2,0

λ : Coefficient depending on the weld configuration, and given in Tab 9

θ : Mean weld toe angle, in degrees, without being taken less than 30°. Unless otherwise specified, θ may be taken equal to:

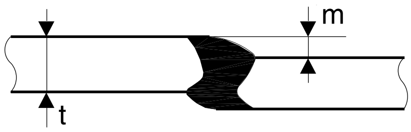
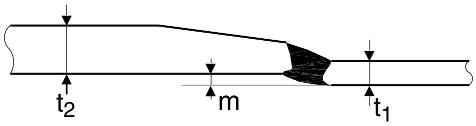
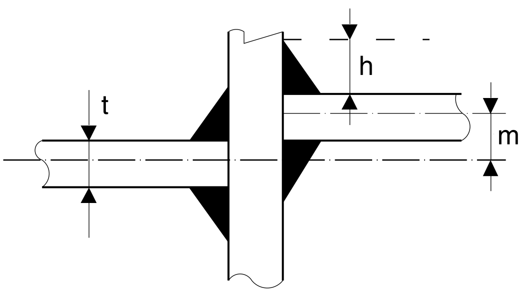
- 30° for butt joints
- 45° for T joints or cruciform joints

K_m : Stress concentration factor, taking account of misalignment, defined in Tab 10, and to be taken not less than 1

$\Delta\sigma_{G,ij}$: Elementary hot spot stress range, defined in [4.2.1]

$$K_{C,ij} = \frac{0,4R_{eH}}{\Delta\sigma_{N0,ij}} + 0,6 \quad \text{with} \quad 0,8 \le K_{C,ij} \le 1$$

Table 10 : Stress concentration factor K_m for misalignment

Geometry	K_m **(1)**
Axial misalignment between flat plates 	$1 + \frac{3(m - m_0)}{t}$
Axial misalignment between flat plates of different thicknesses 	$1 + \frac{6(m - m_0)}{t_1} \frac{t_1^{3/2}}{t_1^{3/2} + t_2^{3/2}}$
Axial misalignment in fillet welded cruciform joints 	$1 + \frac{m - m_0}{t + h}$

(1) When the actual misalignment m is lower than the permissible misalignment m_0, K_m is to be taken equal to 1.

Note 1:

m : Actual misalignment between two abutting members

m_0 : Permissible misalignment for the detail considered, given in Ch 11, Sec 2, or any other agreed document according to [1.2.1].

5 Checking criterion

5.1 Damage ratio

5.1.1 The cumulative damage ratio D, calculated according to [3.1.2], is to comply with the following criterion:

$$D \le \frac{1}{\gamma_R}$$

6 Structural details located at ends of ordinary stiffeners

6.1 General

6.1.1 For the fatigue check of connections located at ends of ordinary stiffeners, the elementary hot spot stress range $\Delta\sigma_{G,ij}$ may be calculated as indicated in [6.2].

6.2 Determination of elementary hot spot stress range

6.2.1 Nominal local stress

For each load case "a", "b", "c" and "d", "-max" and "-min", the nominal local stress $\sigma\ell$ applied to the ordinary stiffener, is to be obtained, in N/mm², from the following formula:

$$\sigma_\ell = \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

w : Net section modulus, in cm³, of the stiffener, with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4]

s : Spacing, in m, of ordinary stiffeners

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 4, Sec 3, [3.2]

β_b : Coefficient to be taken as follows:

- $\beta_b = 1,0$ in the case of an ordinary stiffener without brackets at ends
- $\beta_b = \beta_{b1}$ defined in Ch 7, Sec 2, [3.4.3], in the case of an ordinary stiffener with a bracket of length not greater than 0,2 ℓ at one end
- $\beta_b = \beta_{b2}$ defined in Ch 7, Sec 2, [3.4.4], in the case of an ordinary stiffener with equal brackets of length not greater than 0,2 ℓ at ends.

6.2.2 Elementary hot spot stress range

For each load case "a", "b", "c" and "d", the elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{G,\,ij} = |\sigma_{G\,(i\text{-}max)} - \sigma_{G\,(i\text{-}min)}| + K\ell\ \Delta\sigma_{DEF,\,ij}$$

where:

$$\sigma_{G\,(i\text{-}max)} = K_N\,(K_h\,\sigma_h + K\ell\,K_S\,\sigma\ell)_{(i\text{-}max)}$$

$$\sigma_{G\,(i\text{-}min)} = K_N\,(K_h\,\sigma_h + K\ell\,K_S\,\sigma\ell)_{(i\text{-}min)}$$

$\Delta\sigma_{DEF,\,ij}$: Nominal stress range due to the local deflection of the ordinary stiffener to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{DEF,ij} = \frac{4(\Delta\delta)EI}{w\ell^2}10^{-5}$$

σ_h : Nominal hull girder stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [2.3.1]

$\sigma\ell$: Nominal local stress for the load case "i-max" or "i-min" considered, to be determined as indicated in [6.2.1]

K_N : Coefficient taking account of North Atlantic navigation, taken equal to 1

K_h , $K\ell$: Geometrical stress concentration factors for overall hull girder stress and local stress, as given in Pt B, Ch 11, App 2

K_S : Coefficient taking account of the stiffener section geometry, equal to:

$$K_S = 1 + \left[\frac{t_f(a^2 - b^2)}{2 w_B}\right]\left[1 - \frac{b}{a+b}\left(1 + \frac{w_B}{w_A}\right)\right]10^{-3}$$

a, b : Eccentricities of the stiffener, in mm, defined in Fig 3

Bulb sections may be taken as equivalent to an angle profile, as defined in Ch 4, Sec 3, [3.1.2] with:

$a = 0,75\ b_f$

$b = 0,25\ b_f$

t_f : Face plate net thickness, in mm

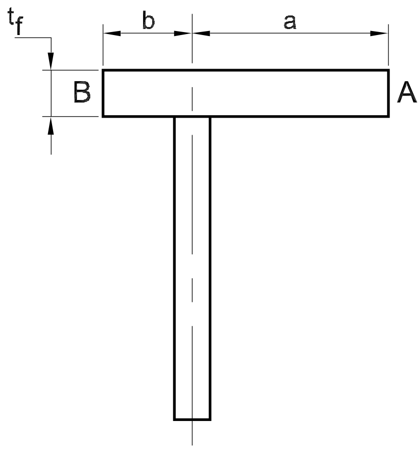
b_f : Face plate width, in mm

w_A, w_B : Net section moduli of the stiffener, in cm^3, in A and B, respectively, about its vertical axis and without attached plating

$\Delta\delta$: Local range of deflection, in mm, of the ordinary stiffener (total amplitude of vertical deflection between the two adjacent primary members supporting the ordinary stiffener under consideration)

I : Net moment of inertia, in cm^4, of the ordinary stiffener with an attached plating of width b_p, to be calculated as specified in Ch 4, Sec 3, [3.4].

Figure 3 : Geometry of a stiffener section



Appendix 1 Analyses Based on Three-Dimensional Models

Symbols

For symbols not defined in this Appendix, refer to the list at the beginning of this Chapter.

ρ : Sea water density, taken equal to 1,025 t/m^3

g : Gravity acceleration, in m/s^2: g = 9,81 m/s^2

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3]

h_2 : Reference values of the ship relative motions in the inclined ship conditions, defined in Ch 5, Sec 3, [3.3]

$\alpha = \frac{T_1}{T}$

T_1 : draught, in m, corresponding to the loading condition considered

M_{SW} : Still water bending moment, in kN.m, at the hull transverse section considered

M_{WV} : Vertical wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.1], having the same sign as M_{SW}

Q_{SW} : Still water shear force, in kN, at the hull transverse section considered

Q_{WV} : Vertical wave shear force, in kN, at the hull transverse section considered, defined in Ch 5, Sec 2, [3.4], having:

- where M_{WV} is positive (hogging condition):
  - a positive sign for $x < 0,5L$
  - a negative sign for $x \geq 0,5L$
- where M_{WV} is negative (sagging condition):
  - a negative sign for $x < 0,5L$
  - a positive sign for $x \geq 0,5L$

γ_{S1} , γ_{W1} : Partial safety factors, defined in Ch 7, Sec 3.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through three-dimensional structural models, according to Ch 7, Sec 3.

The analysis application procedure is shown graphically in Fig 1.

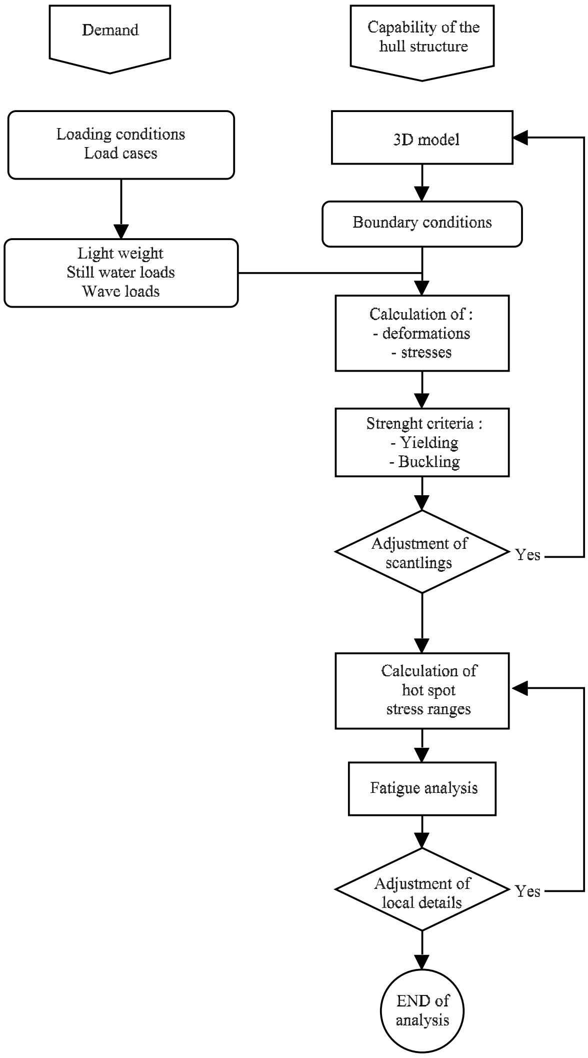
1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating:

- the stresses in the primary supporting members in the midship area and, when necessary, in other areas, which are to be used in the yielding and buckling checks
- the hot spot stress ranges in the structural details which are to be used in the fatigue check.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

The fatigue check of structural details is to be carried out according to Ch 7, Sec 4.

Figure 1 : Application procedure of the analyses based on three-dimensional models



1.2 Information required

1.2.1 The following information is necessary to perform these structural analyses:

- general arrangement
- capacity plan
- structural plans of the areas involved in the analysis
- longitudinal sections and decks.

2 Analysis criteria

2.1 General

2.1.1 All primary supporting members in the midship regions are normally to be included in the three-dimensional model, with the purpose of calculating their stress level and verifying their scantlings.

When the primary supporting member arrangement is such that the Society can accept that the results obtained for the midship region are extrapolated to other regions, no additional analyses are required. Otherwise, analyses of the other regions are to be carried out.

2.2 Finite element model analysis

2.2.1 For ships more than 150 m in length, finite element models, built according to [3.2] and [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in [3.4.3].

2.3 Beam model analysis

2.3.1 Beam models may be adopted in lieu of the finite element models for cases specified in Ch 7, Sec 3, [1.1.2] provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship structural arrangement.

2.4 Structural detail analysis

2.4.1 Structural details in Ch 7, Sec 4, [1.2.3], for which a fatigue analysis is to be carried out, are to be modelled as specified in [6].

3 Structural modelling of primary supporting members

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and inertia of the actual hull girder structure. The way ordinary stiffeners are represented in the model depends on the type of model (beam or finite element), as specified in [3.4] and [3.5].

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1]. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

3.2 Model extension

3.2.1 The longitudinal extension of the structural model is to be such that:

- the hull girder stresses in the area to be analysed are properly taken into account in the structural analysis
- the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 In the case of structural symmetry with respect to the ship centreline longitudinal plane, the hull structures may be modelled over half the ship breadth.

3.3 Finite element modelling criteria

3.3.1 Modelling of primary supporting members

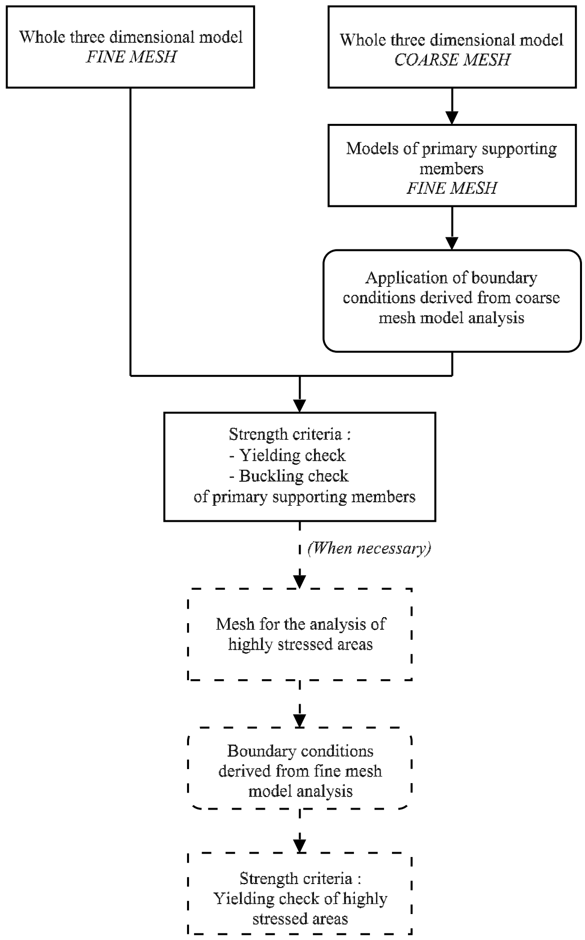
The analysis of primary supporting members based on fine mesh models, as defined in [3.4.3], is to be carried out by applying one of the following procedures (see Fig 2), depending on the computer resources:

- an analysis of the whole three-dimensional model based on a fine mesh
- an analysis of the whole three-dimensional model based on a coarse mesh, as defined in [3.4.2], from which the nodal displacements or forces are obtained to be used as boundary conditions for analyses based on fine mesh models of primary supporting members, e.g.:
  - transverse rings
  - double bottom girders
  - side girders
  - deck girders
  - primary supporting members of transverse bulkheads
  - primary supporting members which appear from the analysis of the whole model to be highly stressed.

3.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in [3.4.4].

Figure 2 : Finite element modelling criteria



3.4 Finite element models

3.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified in [3.4.2] to [3.4.4].

3.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and inertia of the model properly represent those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.3 Fine mesh

The ship structure may be considered as finely meshed when each longitudinal ordinary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- the holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

3.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

3.5 Beam models

3.5.1 Beams representing primary supporting members

Primary supporting members are to be modelled by beam elements with shear strain, positioned on their neutral axes, whose inertia characteristics are to be calculated as specified in Ch 4, Sec 3, [4].

3.5.2 Torsional moments of inertia

Whenever the torsional effects of the modelling beams are to be taken into account (e.g. for modelling the double bottom, hopper tanks and lower stools), their net torsional moments of inertia are obtained, in cm^4, from the following formulae:

- for open section beams (see Fig 3):

$$I_T = \frac{1}{3}\sum_i (t_i^3 \ell_i) 10^{-4}$$

- for beams of double skin structures (see Fig 4):

$$I_T = \frac{t_1 t_2 (b_1 + b_2) H_D^2}{2(t_1 + t_2)} 10^{-4}$$

where:

Σi	:	Sum of all the profile segments that constitute the beam section
t_i, ℓ_i	:	Net thickness and length, respectively, in mm, of the i-th profile segment of the beam section
t_1, t_2	:	Net thickness, in mm, of the inner and outer plating, respectively
b_1, b_2	:	Distances, in mm, from the beam considered to the two adjacent beams
H_D	:	Height, in mm, of the double skin.

Figure 3 : Open section beams

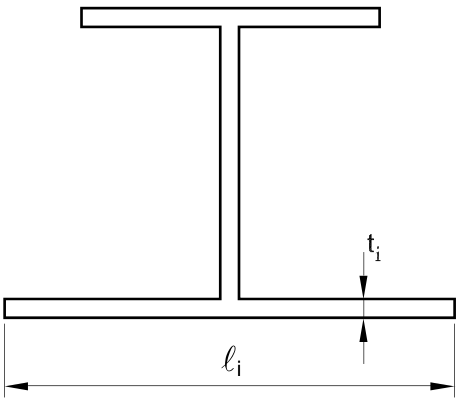
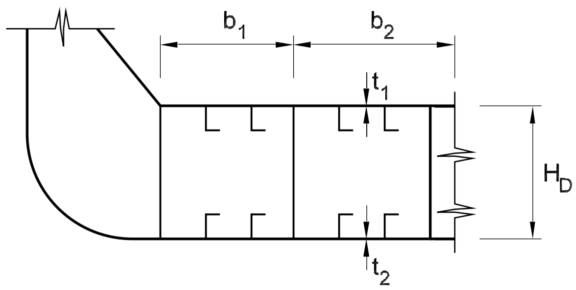


Figure 4 : Beams of double skin structures



3.5.3 Primary supporting members with variable cross-section

In the case of primary supporting members with variable cross-section, the inertia characteristics of the modelling beams may be assumed as a constant and equal to their average value along the length of the elements themselves.

3.5.4 Modelling of primary supporting member ends

The presence of end brackets may be disregarded; in such case their presence is also to be neglected for the evaluation of the beam inertia characteristics.

Rigid end beams are generally to be used to connect ends of the various primary supporting members, such as:

- floors and side vertical primary supporting members
- bottom girders and vertical primary supporting members of transverse bulkheads
- cross ties and side/longitudinal bulkhead primary supporting members.

3.5.5 Beams representing hull girder characteristics

The stiffness and inertia of the hull girder are to be taken into account by longitudinal beams positioned as follows:

- on deck and bottom in way of side shell and longitudinal bulkheads, if any, for modelling the hull girder bending strength
- on deck, side shell, longitudinal bulkheads, if any, and bottom for modelling the hull girder shear strength.

3.6 Boundary conditions of the whole three-dimensional model

3.6.1 Structural model extended over at least three cargo tank/hold lengths

The whole three-dimensional model is assumed to be fixed at its aft end, while shear forces and bending moments are applied at its fore end to ensure equilibrium (see Article [4]).

At the fore end section, rigid constraint conditions are to be applied to all nodes located on longitudinal members, in such a way that the transverse section remains plane after deformation.

When the hull structure is modelled over half the ship's breadth (see [3.2.2]), in way of the ship centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 1 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 1 : Symmetry and anti-symmetry conditions in way of the ship centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions **(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

4 Load models of primary supporting members

4.1 General

4.1.1 Loading conditions and load cases in intact conditions

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximizing the stresses in the longitudinal structure and primary supporting members.

The following loading conditions are generally to be considered:

- homogeneous loading conditions at draught T
- non-homogeneous loading conditions at draught T, when applicable
- partial loading conditions at the relevant draught
- ballast conditions at the relevant draught.

The wave local and hull girder loads are to be calculated in the mutually exclusive load cases “a”, “b”, “c” and “d” in Ch 5, Sec 4.

4.1.2 Loading conditions and load cases in flooding conditions

When applicable, the pressures in flooding conditions are to be calculated according to Ch 5, Sec 6, [7].

4.1.3 Lightweight

The lightweight of the modelled portion of the hull is to be uniformly distributed over the length of the model in order to obtain the actual longitudinal distribution of the still water bending moment.

4.1.4 Models extended over half breadth of ship

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship centreline longitudinal plane (see [3.6]).

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads include:

- the wave pressure, defined in [4.2.2] for each load case “a”, “b”, “c” and “d”
- the inertial loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast, and for each load case “a”, “b”, “c” and “d”.

4.2.2 Wave loads

The wave pressure at any point of the model is obtained from the formulae in Tab 2 for upright ship conditions (load cases “a” and “b”) and in Tab 3 for inclined ship conditions (load cases “c” and “d”).

4.2.3 Distributed loads

Distributed loads are to be applied to the plating panels.

In the analyses carried out on the basis of membrane finite element models or beam models, the loads distributed perpendicularly to the plating panels are to be applied on the ordinary stiffeners proportionally to their areas of influence. When ordinary stiffeners are not modelled or are modelled with rod elements (see [3.4]), the distributed loads are to be applied to the primary supporting members actually supporting the ordinary stiffeners.

4.2.4 Concentrated loads

When the elements directly supporting the concentrated loads are not represented in the structural model, the loads are to be distributed on the adjacent structures according to the actual stiffness of the structures which transmit them.

In the analyses carried out on the basis of coarse mesh finite element models or beam models, concentrated loads applied in five or more points almost equally spaced inside the same span may be applied as equivalent linearly distributed loads.

Table 2 : Wave pressure in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	C_1	
		crest	trough **(1)**
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	– 1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_1 \rho g h e^{\frac{-2\pi(T_1 - z)}{\alpha L}}$	1,0	$\frac{z - T_1}{h}$
Sides above the waterline: $z > T_1$	$C_1 \rho g (T_1 + h - z)$	1,0	0,0

(1) The wave pressure for load case "b, trough" is to be used only for the fatigue check of structural details.

Note 1:

$h = \alpha^{1/4} C_{F1} h_1$

C_{F1} : Combination factor, to be taken equal to:
- $C_{F1} = 1,0$ for load case "a"
- $C_{F1} = 0,5$ for load case "b".

Table 3 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m²	C_2 (negative roll angle)	
		$y \ge 0$	$y < 0$
Bottom and sides below the waterline with: $z \le T_1 - h$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	1,0
Sides below the waterline with: $T_1 - h < z \le T_1$	$C_2 C_{F2} \alpha^{1/4} \rho g \left[\frac{y}{B_W} h_1 e^{\frac{-2\pi(T_1 - z)}{\alpha L}} + A_R y e^{\frac{-\pi(T_1 - z)}{\alpha L}}\right]$	1,0	$\frac{T_1 - z}{h}$
Sides above the waterline: $z > T_1$	$C_2 \rho g \left[T_1 + C_{F2} \alpha^{1/4}\left(\frac{y}{B_W} h_1 + A_R y\right) - z\right]$	1,0	0,0

Note 1:

$h = \alpha^{1/4} C_{F2} h_2$

C_{F2} : Combination factor, to be taken equal to:
- $C_{F2} = 1,0$ for load case "c"
- $C_{F2} = 0,5$ for load case "d"

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

A_R : Roll amplitude, defined in Ch 5, Sec 3, [2.4.1].

4.2.5 Cargo in sacks, bales and similar packages

The vertical loads are comparable to distributed loads. The loads on vertical walls may be disregarded.

4.2.6 Other cargoes

The modelling of cargoes other than those mentioned under [4.2.3] to [4.2.5] will be considered by the Society on a case-by-case basis.

4.3 Hull girder loads

4.3.1 The hull girder loads are constituted by:

- the still water and wave vertical bending moments
- the horizontal wave bending moment
- the still water and wave vertical shear forces,

and are to be applied at the model fore end section. The shear forces are to be distributed on the plating according to the theory of bidimensional flow of shear stresses.

These loads are to be applied separately for the following two conditions:

- maximal bending moments at the middle of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 4 are obtained
- maximal shear forces in way of the aft transverse bulkhead of the central tank/hold: the hull girder loads applied at the fore end section are to be such that the values of the hull girder loads in Tab 5 are obtained.

Table 4 : Hull girder loads - Maximal bending moments at the middle of the model

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model	Vertical shear forces at the middle of the model	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1}\, M_{SW}$	$0,625\, \gamma_{W1}\, M_{WV,H}$	0	0	0
	"a" trough	$\gamma_{S1}\, M_{SW}$	$0,625\, \gamma_{W1}\, M_{WV,S}$	0	0	0
	"b"	$\gamma_{S1}\, M_{SW}$	$0,625\, \gamma_{W1}\, M_{WV,S}$	0	0	0
Inclined	"c"	$\gamma_{S1}\, M_{SW}$	$0,25\, \gamma_{W1}\, M_{WV}$	$0,625\, \gamma_{W1}\, M_{WH}$	$\gamma_{S1}\, Q_{SW}$	$0,25\, \gamma_{W1}\, Q_{WV}$
	"d"	$\gamma_{S1}\, M_{SW}$	$0,25\, \gamma_{W1}\, M_{WV}$	$0,625\, \gamma_{W1}\, M_{WH}$	$\gamma_{S1}\, Q_{SW}$	$0,25\, \gamma_{W1}\, Q_{WV}$
Note 1: Hull girder loads are to be calculated at the middle of the model.						

Table 5 : Hull girder loads - Maximal shear forces in way of the aft bulkhead of the model

Ship condition	Load case	Vertical bending moments in way of the aft bulkhead of the model		Vertical shear forces in way of the aft bulkhead of the model	
		Still water	Wave	Still water	Wave
Upright	"a" crest	$\gamma_{S1}\, M_{SW}$	$0,4\, \gamma_{W1}\, M_{WV}$	$\gamma_{S1}\, Q_{SW}$	$0,625\, \gamma_{W1}\, Q_{WV}$
	"a" trough	$\gamma_{S1}\, M_{SW}$	$0,4\, \gamma_{W1}\, M_{WV}$	$\gamma_{S1}\, Q_{SW}$	$0,625\, \gamma_{W1}\, Q_{WV}$
	"b"	$\gamma_{S1}\, M_{SW}$	$0,4\, \gamma_{W1}\, M_{WV}$	$\gamma_{S1}\, Q_{SW}$	$0,625\, \gamma_{W1}\, Q_{WV}$
Inclined	"c"	$\gamma_{S1}\, M_{SW}$	$0,4\, \gamma_{W1}\, M_{WV}$	$\gamma_{S1}\, Q_{SW}$	$0,25\, \gamma_{W1}\, Q_{WV}$
	"d"	$\gamma_{S1}\, M_{SW}$	$0,4\, \gamma_{W1}\, M_{WV}$	$\gamma_{S1}\, Q_{SW}$	$0,25\, \gamma_{W1}\, Q_{WV}$
Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the model.					

5 Stress calculation

5.1 Analysis based on finite element models

5.1.1 Stresses induced by local and hull girder loads

Both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1] so that the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

5.1.2 Stress components

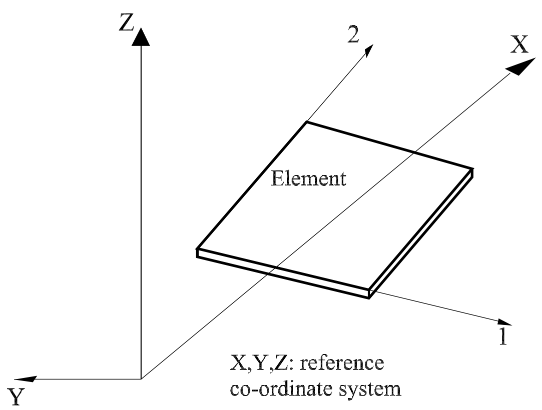
Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 5. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of the element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 + 3\tau_{12}^2}$$

Figure 5 : Reference and element co-ordinate systems



5.1.3 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

5.2 Analysis based on beam models

5.2.1 Stresses induced by local and hull girder loads

Since beam models generally have limited extension compared with the ship length, only local loads are directly applied to the structural model, as specified in [4.2]. Therefore, the stresses calculated by the beam program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2.2 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^{\ 2} + 3\tau_{12}^{\ 2}}$$

5.2.3 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses are to be used for carrying out the checks required.

6 Fatigue analysis

6.1 Elementary hot spot stress range calculation

6.1.1 General

The requirements of this Article apply for calculating the elementary hot spot stress range for the fatigue check of structural details at the connections of primary supporting members analysed through a three-dimensional structural model. The fatigue check of these details is to be carried out in accordance with the general requirements of Ch 7, Sec 4, [1] to Ch 7, Sec 4, [5].

The definitions in Ch 7, Sec 4, [1.3] apply.

6.1.2 Net scantlings

The three-dimensional structural model is to be built considering all the structures with their net scantlings according to Ch 4, Sec 2, [1].

6.1.3 Hot spot stresses directly obtained through finite element analysis

Where the structural detail is analysed through a finite element analysis based on a very fine mesh, the elementary hot spot stress range may be obtained as the difference between the maximum and minimum stresses induced by the wave loads in the hot spot considered.

The requirements for:

- the finite element modelling, and
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.2].

6.1.4 Hot spot stresses directly obtained through the calculation of nominal stresses

Where the structural detail is analysed through a finite element analysis based on a mesh less fine than that in [6.1.3], the elementary hot spot stress range may be obtained by multiplying the nominal stress range, obtained as the difference between the maximum and minimum nominal stresses induced by the wave loads in the vicinity of the hot spot considered, by the appropriate stress concentration factors.

The requirements for:

- the finite element modelling
- the calculation of the nominal stresses and the nominal stress range
- the stress concentration factors
- the calculation of the hot spot stresses and the hot spot stress range

are specified in [6.3].

6.2 Hot spot stresses directly obtained through finite element analysis

6.2.1 Finite element model

In general, the determination of hot spot stresses necessitates carrying out a very fine mesh finite element analysis, further to a coarser mesh finite element analysis. The boundary nodal displacements or forces obtained from the coarser mesh model are applied to the very fine mesh model as boundary conditions.

The model extension is to be such as to enable a faithful representation of the stress gradient in the vicinity of the hot spot and to avoid it being incorrectly affected by the application of the boundary conditions.

6.2.2 Finite element modelling criteria

The finite element model is to be built according to the following requirements:

- the detail may be considered as being realised with no misalignment
- the size of finite elements located in the vicinity of the hot spot is to be about twice to three times the thickness of the structural member. Where the details is the connection between two or more members of different thickness, the thickness to be considered is that of the thinnest member
- the centre of the first element adjacent to a weld toe is to be located between the weld toe and 0,4 times the thickness of the thinnest structural member connected by the weld
- plating, webs and face plates of primary and secondary members are to be modelled by 4-node thin shell or 8-node solid elements. In the case of a steep stress gradient, 8-node thin shell elements or 20-node solid elements are recommended
- when thin shell elements are used, the structure is to be modelled at mid-face of the plates
- the aspect ratio of elements is to be not greater than 3.

6.2.3 Calculation of hot spot stresses

The hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot.

The stress components to be considered are those specified in Ch 7, Sec 4, [3.1.2]. They are to be calculated at the surface of the plate in order to take into account the plate bending moment, where relevant.

Where the detail is the free edge of an opening (e.g. a cutout for the passage of an ordinary stiffener through a primary supporting member), fictitious truss elements with minimal stiffness may needed to be fitted along the edge to calculate the hot spot stresses.

6.2.4 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{S,ij} = |\sigma_{S,ij,max} - \sigma_{S,ij,min}|$$

where:

$\sigma_{S,ij,max}$, $\sigma_{S,ij,min}$: Maximum and minimum values of the hot spot stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3 Hot spot stresses directly obtained through calculation of nominal stresses

6.3.1 Finite element model

A finite element is to be adopted, to be built according to the requirements in [3.3] and [3.4]. The areas in the vicinity of the structural details are to be modelled with fine mesh models, as defined in [3.4.3].

6.3.2 Calculation of the elementary nominal stress range

The elementary nominal stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{n,ij} = |\sigma_{n,ij,max} - \sigma_{n,ij,min}|$$

where:

$\sigma_{n,ij,max}$, $\sigma_{n,ij,min}$: Maximum and minimum values of the nominal stress, induced by the maximum and minimum loads, defined in Ch 7, Sec 4, [2.2] and Ch 7, Sec 4, [2.3]

i : Denotes the load case

j : Denotes the loading condition.

6.3.3 Calculation of the elementary hot spot stress range

The elementary hot spot stress range is to be obtained, in N/mm², from the following formula:

$\Delta\sigma_{S,ij} = K_S \, \Delta\sigma_{n,ij}$

where:

K_S : Stress concentration factor, defined in Ch 11, Sec 2, [2] for the relevant detail configuration

$\Delta\sigma_{n,ij}$: Elementary nominal stress range, defined in [6.3.2].

Appendix 2 Analyses of Primary Supporting Members Subjected to Wheeled Loads

1 General

1.1 Scope

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members subjected to wheeled loads which are to be analysed through three-dimensional structural models, according to Ch 7, Sec 3.

1.1.2 The purpose of these structural analyses is to determine:

- the distribution of the forces induced by the vertical acceleration acting on wheeled cargoes, among the various primary supporting members of decks, sides and possible bulkheads
- the behaviour of the above primary supporting members under the racking effects due to the transverse forces induced by the transverse acceleration acting on wheeled cargoes, when the number or location of transverse bulkheads are not sufficient to avoid such effects,

and to calculate the stresses in primary supporting members.

The above calculated stresses are to be used in the yielding and buckling checks.

In addition, the results of these analyses may be used, where deemed necessary by the Society, to determine the boundary conditions for finer mesh analyses of the most highly stressed areas.

1.1.3 When the behaviour of primary supporting members under the racking effects, due to the transverse forces induced by the transverse acceleration, is not to be determined, the stresses in deck primary supporting members may be calculated according to the simplified analysis in [6], provided that the conditions for its application are fulfilled (see [6.1]).

1.1.4 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

1.2 Application

1.2.1 The requirements of this Appendix apply to ships whose structural arrangement is such that the following assumptions may be considered as being applicable:

- primary supporting members of side and possible bulkheads may be considered fixed in way of the double bottom (this is generally the case when the stiffness of floors is at least three times that of the side primary supporting members)
- under transverse inertial forces, decks behave as beams loaded in their plane and supported at the ship ends; their effect on the ship transverse rings (side primary supporting members and deck beams) may therefore be simulated by means of elastic supports in the transverse direction or transverse displacements assigned at the central point of each deck beam.

1.2.2 When the assumptions in [1.2.1] are considered by the Society as not being applicable, the analysis criteria are defined on a case-by-case basis, taking into account the ship structural arrangement and loading conditions. In such cases, the analysis is generally to be carried out on the basis of a finite element model of the whole ship, built according to the requirements in Ch 7, App 1, as far as applicable.

1.3 Information required

1.3.1 The following information is necessary to perform these structural analyses:

- general arrangement
- structural plans of the areas involved in the analysis
- longitudinal sections and decks
- characteristics of vehicles loaded: load per axles, arrangement of wheels on axles, tyre dimensions.

1.4 Lashing of vehicles

1.4.1 The presence of lashing for vehicles is generally to be disregarded, but may be given consideration by the Society, on a case-by-case basis, at the request of the interested parties.

2 Analysis criteria

2.1 Finite element model analysis

2.1.1 For ships greater than 200 m in length, finite element models, built according to Ch 7, App 1, [3.4], are generally to be adopted.

The analysis of primary supporting members is to be carried out on fine mesh models, as defined in Ch 7, App 1, [3.4.3].

2.1.2 Areas which appear, from the primary supporting member analysis, to be highly stressed may be required to be further analysed through appropriately meshed structural models, as defined in Ch 7, App 1, [3.4.4].

2.2 Beam model analysis

2.2.1 For ships less than 200 m in length, beam models, built according to Ch 7, App 1, [3.5], may be adopted in lieu of the finite element models in [2.1], provided that:

- primary supporting members are not so stout that the beam theory is deemed inapplicable by the Society
- their behaviour is not substantially influenced by the transmission of shear stresses through the shell plating.

2.2.2 In any case, finite element models may need to be adopted when deemed necessary by the Society on the basis of the ship structural arrangement.

3 Structural modelling of primary supporting members

3.1 Model construction

3.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected. In particular, the following primary supporting members are to be included in the model:

- deck beams
- side primary supporting members
- primary supporting members of longitudinal and transverse bulkheads, if any
- pillars
- deck beams, deck girders and pillars supporting ramps and deck openings, if any.

3.1.2 Net scantlings

All the elements in [3.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2, [1].

3.2 Model extension

3.2.1 The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

In addition, the longitudinal extension of the structural model is to be such that the results in the areas to be analysed are not influenced by the unavoidable inaccuracy in the modelling of the boundary conditions.

3.2.2 Double bottom structures are not required to be included in the model, based on the assumptions in [1.2.1].

3.3 Boundary conditions of the three-dimensional model

3.3.1 Boundary conditions at the lower ends of the model

The lower ends of the model (i.e. the lower ends of primary supporting members of side and possible bulkheads) are to be considered as being clamped in way of the inner bottom.

3.3.2 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

Table 1 : Symmetry conditions at the model fore and aft ends

DISPLACEMENTS in directions **(1)**			ROTATION around axes **(1)**		
X	Y	Z	X	Y	Z
fixed	free	free	free	fixed	fixed
(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].					

3.3.3 Additional boundary conditions at the fore and aft ends of models subjected to transverse loads

When the model is subjected to transverse loads, i.e. when the loads in inclined ship conditions (as defined in Ch 5, Sec 4) are applied to the model, the transverse displacements of the deck beams are to be obtained by means of a racking analysis and applied at the fore and aft ends of the model, in way of each deck beam.

For ships with a traditional arrangement of fore and aft parts, a simplified approximation may be adopted, when deemed acceptable by the Society, defining the boundary conditions without taking into account the racking calculation and introducing springs, acting in the transverse direction, at the fore and aft ends of the model, in way of each deck beam (see Fig 1). Each spring, which simulates the effects of the deck in way of which it is modelled, has a stiffness obtained, in kN/m, from the following formula:

$$R_D = \frac{24EJ_Ds_a10^3}{2x^4 - 4L_Dx^3 + L_D^2\left(x^2 + 15{,}6\frac{J_D}{A_D}\right) + L_D^3x}$$

where:

J_D : Net moment of inertia, in m^4, of the average cross-section of the deck, with the attached side shell plating

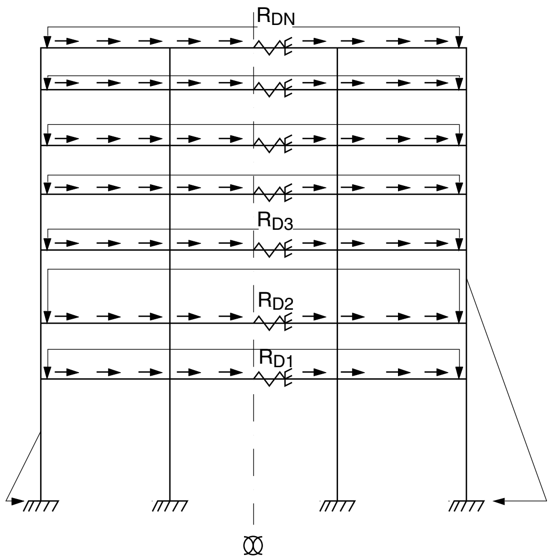
A_D : Net area, in m^2, of the average cross-section of deck plating

s_a : Spacing of side vertical primary supporting members, in m

x : Longitudinal distance, in m, measured from the transverse section at mid-length of the model to any deck end

L_D : Length of the deck, in m, to be taken equal to the ship length. Special cases in which such value may be reduced will be considered by the Society on a case-by-case basis.

Figure 1 : Springs at the fore and aft ends of models subjected to transverse loads



4 Load model

4.1 General

4.1.1 Hull girder and local loads

Only local loads are to be directly applied to the structural model.

The stresses induced by hull girder loads are to be calculated separately and added to the stresses induced by local loads.

4.1.2 Loading conditions and load cases: wheeled cargoes

The still water and wave loads are to be calculated for the most severe loading conditions as given in the loading manual, with a view to maximizing the stresses in primary supporting members.

The loads transmitted by vehicles are to be applied taking into account the most severe axle positions for the ship structures.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases “b” and “d” in Ch 5, Sec 4. Load cases “a” and “c” may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.1.3 Loading conditions and load cases: dry uniform cargoes

When the ship decks are also designed to carry dry uniform cargoes, the loading conditions which envisage the transportation of such cargoes are also to be considered. The still water and wave loads induced by these cargoes are to be calculated for the most severe loading conditions, with a view to maximizing the stresses in primary supporting members.

The wave local loads and hull girder loads are to be calculated in the mutually exclusive load cases “b” and “d” in Ch 5, Sec 4. Load cases “a” and “c” may be disregarded for the purposes of the structural analyses dealt with in this Appendix.

4.2 Local loads

4.2.1 General

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water forces induced by wheeled cargoes, defined in Ch 5, Sec 6, Tab 5.

Wave induced loads include:

- the wave pressure, defined in Ch 5, Sec 5, [2] for load cases “b” and “d”
- the inertial forces defined in Ch 5, Sec 6, Tab 5 for load cases “b” and “d”.

When the ship decks are also designed to carry dry uniform cargoes, local loads also include the still water and inertial pressures defined in Ch 5, Sec 6, [4]. Inertial pressures are to be calculated for load cases “b” and “d”.

4.2.2 Tyred vehicles

For the purpose of primary supporting members analyses, the forces transmitted through the tyres may be considered as concentrated loads in the tyre print centre.

The forces acting on primary supporting members are to be determined taking into account the area of influence of each member and the way ordinary stiffeners transfer the forces transmitted through the tyres.

4.2.3 Non-tyred vehicles

The requirements in [4.2.2] also apply to tracked vehicles. In this case, the print to be considered is that below each wheel or wheelwork.

For vehicles on rails, the loads transmitted are to be applied as concentrated loads.

4.2.4 Distributed loads

In the analyses carried out on the basis of beam models or membrane finite element models, the loads distributed perpendicularly to the plating panels are to be applied on the primary supporting members proportionally to their areas of influence.

4.3 Hull girder loads

4.3.1 The normal stresses induced by the hull girder loads in Tab 2 are to be added to the stresses induced in the primary supporting members by local loads.

Table 2 : Hull girder loads

Ship condition	Load case	Vertical bending moments at the middle of the model		Horizontal wave bending moment at the middle of the model
		Still water	Wave	
Upright	“b”	M_{SW}	0,625 $M_{WV,S}$	0
Inclined	“d”	M_{SW}	0,25 M_{WV}	0,625 M_{WH}

Note 1:
M_{SW} : Still water bending moment at the middle of the model, for the loading condition considered
$M_{WV,S}$: Sagging wave bending moments at the middle of the model, defined in Ch 5, Sec 2
M_{WV} : Wave bending moment at the middle of the model, defined in Ch 5, Sec 2, having the same sign as M_{SW}
M_{WH} : Horizontal wave bending moment at the middle of the model, defined in Ch 5, Sec 2.
Note 2: Lower values of wave bending moments may be considered on case-by-case basis, for wheeled loads applied only in specified limited sea states.

5 Stress calculation

5.1 Stresses induced by local and hull girder loads

5.1.1 Only local loads are directly applied to the structural model, as specified in [4.1.1]. Therefore, the stresses calculated by the program include the contribution of local loads only. Hull girder stresses are to be calculated separately and added to the stresses induced by local loads.

5.2 Analysis based on finite element models

5.2.1 Stress components

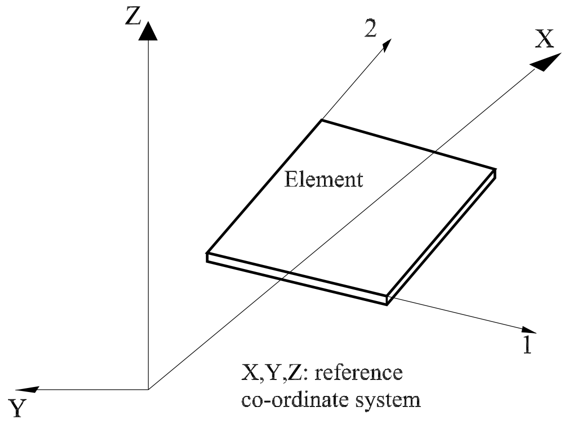
Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 2. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Figure 2 : Reference and element co-ordinate systems



5.2.2 Stress calculation points

Stresses are generally calculated by the computer programs for each element. The values of these stresses are to be used for carrying out the checks required.

5.3 Analysis based on beam models

5.3.1 Stress components

The following stress components are to be calculated:

- the normal stress σ_1 in the direction of the beam axis
- the shear stress τ_{12} in the direction of the local loads applied to the beam
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + 3\tau_{12}^2}$$

5.3.2 Stress calculation points

Stresses are to be calculated at least in the following points of each primary supporting member:

- in the primary supporting member span where the maximum bending moment occurs
- at the connection of the primary supporting member with other structures, assuming as resistant section that formed by the member, the bracket (if any and if represented in the model) and the attached plating
- at the toe of the bracket (if any and if represented in the model) assuming as resistant section that formed by the member and the attached plating.

The values of the stresses calculated in the above points are to be used for carrying out the checks required.

6 Grillage analysis of deck primary supporting members

6.1 Application

6.1.1 For the sole purpose of calculating the stresses in deck primary supporting members, due to the forces induced by the vertical accelerations acting on wheeled cargoes, these members may be subjected to the simplified two-dimensional analysis described in [6.2].

This analysis is generally considered as being acceptable for usual structural typology, where there are neither pillar lines, nor longitudinal bulkheads.

6.2 Analysis criteria

6.2.1 Structural model

The structural model used to represent the deck primary supporting members is a beam grillage model.

6.2.2 Model extension

The structural model is to represent a hull portion which includes the zone under examination and which is repeated along the hull. The non-modelled hull parts are to be considered through boundary conditions as specified in [3.3].

6.3 Boundary conditions

6.3.1 Boundary conditions at the fore and aft ends of the model

Symmetry conditions are to be applied at the fore and aft ends of the model, as specified in Tab 1.

6.3.2 Boundary conditions at the connections of deck beams with side vertical primary supporting members

Vertical supports are to be fitted at the nodes positioned in way of the connection of deck beams with side primary supporting members.

The contribution of flexural stiffness supplied by the side primary supporting members to the deck beams is to be simulated by springs, applied at their connections, having rotational stiffness, in the plane of the deck beam webs, obtained, in kN.m/rad, from the following formulae:

- for intermediate decks:

$$R_F = \frac{3E(J_1 + J_2)(\ell_1 + \ell_2)}{\ell_1^2 + \ell_2^2 - \ell_1 \ell_2} 10^{-5}$$

- for the uppermost deck:

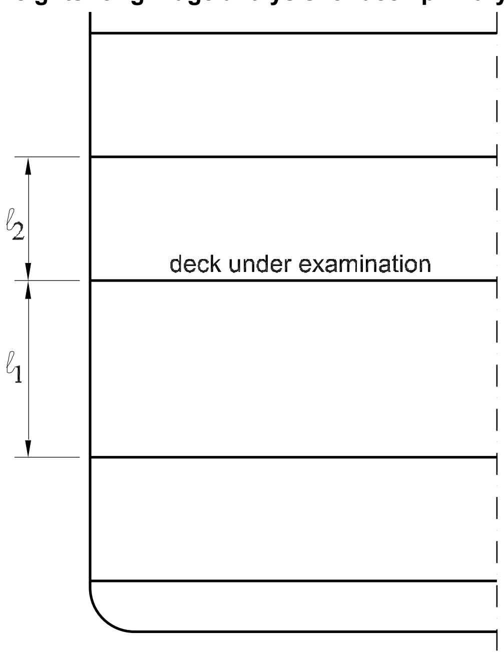
$$R_F = \frac{6EJ_1}{\ell_1} 10^{-5}$$

where:

ℓ_1 , ℓ_2 : Heights of the 'tweendecks, in m, respectively below and above the deck under examination (see Fig 3)

J_1 , J_2 : Net moments of inertia, in cm^4, of side primary supporting members with attached shell plating, relevant to the 'tweendecks, respectively below and above the deck under examination.

Figure 3 : 'Tweendeck heights for grillage analysis of deck primary supporting members



6.4 Load model

6.4.1 Hull girder and local loads are to be calculated and applied to the model according to Article [4].

Wave loads are to be calculated considering load case "b" only.

6.5 Stress calculation

6.5.1 Stress components are to be calculated according to [5.1] and [5.3].

Appendix 3 Analyses Based on Complete Ship Models

Symbols

g : Gravity acceleration, equal to 9,81 m/s^2

Δ : Moulded displacement in seawater, in t

B_{WS} : Breadth at full load waterline, in m, defined in Ch 1, Sec 2, [4.4]

L : Rule length, in m

T_R : Roll period, in s, defined in Ch 5, Sec 3, [2.4.1]

F : Froude's number, defined in Part B, Chapter 5, calculated at the maximum service speed

γ_{S1} , γ_{W1} , γ_{S2} , γ_{W2} : Partial safety factors defined in Ch 7, Sec 3

λ : Wave length, in m.

1 General

1.1 Application

1.1.1 The requirements of this Appendix apply for the analysis criteria, structural modelling, load modelling and stress calculation of primary supporting members which are to be analysed through a complete ship model, according to Ch 7, Sec 3.

1.1.2 This Appendix deals with that part of the structural analysis which aims at calculating the stresses in the primary supporting members and more generally in the hull plating, to be used for yielding and buckling checks.

1.1.3 The yielding and buckling checks of primary supporting members are to be carried out according to Ch 7, Sec 3.

2 Structural modelling

2.1 Model construction

2.1.1 Elements

The structural model is to represent the primary supporting members with the plating to which they are connected.

Ordinary stiffeners are also to be represented in the model in order to reproduce the stiffness and the inertia of the actual hull girder structure.

2.1.2 Net scantlings

All the elements in [2.1.1] are to be modelled with their net scantlings according to Ch 4, Sec 2. Therefore, also the hull girder stiffness and inertia to be reproduced by the model are those obtained by considering the net scantlings of the hull structures.

2.2 Model extension

2.2.1 Superstructures are to be modelled in order to reproduce the correct lightweight distribution.

Long superstructures are to be modelled in order to also reproduce the correct hull global strength, in particular the contribution of each superstructure deck to the hull girder longitudinal strength.

2.2.2 In the case of structural symmetry with respect to the ship centreline longitudinal plane, the hull structures may be modelled over half the ship breadth.

2.3 Finite element modelling criteria

2.3.1 Modelling of primary supporting members

The analyses of primary supporting members are to be based on fine mesh models, as defined in [2.4.2].

Such analyses may be carried out deriving the nodal displacements or forces, to be used as boundary conditions, from analyses of the complete ships based on coarse meshes, as defined in Ch 7, App 1, [3.4.2].

The areas for which analyses based on fine mesh models are to be carried out are the following:

- typical reinforced transverse rings
- typical deck girders
- areas of structural discontinuity (e.g. ramp areas)
- areas in way of typical side and deck openings
- areas of significant discontinuity in primary supporting, member arrangements (e.g. in way of large spaces).

Other areas may be required to be analysed through fine mesh models, where deemed necessary by the Society, depending on the ship structural arrangement and loading conditions as well as the results of the coarse mesh analysis.

2.3.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on fine mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in Ch 7, App 1, [3.4.4].

2.4 Finite element models

2.4.1 General

Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

In general, for some of the most common elements, the quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 4 and, in any case, is less than 2 for most elements. Their angles are to be greater than 60° and less than 120°. The triangular element angles are to be greater than 30° and less than 120°.

Further modelling criteria depend on the accuracy level of the mesh, as specified from [2.4.2] to [2.4.4].

2.4.2 Coarse mesh

The number of nodes and elements is to be such that the stiffness and the inertia of the model represent properly those of the actual hull girder structure, and the distribution of loads among the various load carrying members is correctly taken into account.

To this end, the structural model is to be built on the basis of the following criteria:

- ordinary stiffeners contributing to the hull girder longitudinal strength and which are not individually represented in the model are to be modelled by rod elements and grouped at regular intervals
- webs of primary supporting members may be modelled with only one element on their height
- face plates may be simulated with bars having the same cross-section
- the plating between two primary supporting members may be modelled with one element stripe
- holes for the passage of ordinary stiffeners or small pipes may be disregarded
- manholes (and similar discontinuities) in the webs of primary supporting members may be disregarded, but the element thickness is to be reduced in proportion to the hole height and the web height ratio.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.3 Fine mesh

The ship structure may be considered as finely meshed when each longitudinal secondary stiffener is modelled; as a consequence, the standard size of finite elements used is based on the spacing of ordinary stiffeners.

The structural model is to be built on the basis of the following criteria:

- webs of primary members are to be modelled with at least three elements on their height
- the plating between two primary supporting members is to be modelled with at least two element stripes
- the ratio between the longer side and the shorter side of elements is to be less than 3 in the areas expected to be highly stressed
- holes for the passage of ordinary stiffeners may be disregarded.

In some specific cases, some of the above simplifications may not be deemed acceptable by the Society in relation to the type of structural model and the analysis performed.

2.4.4 Mesh for the analysis of structural details

The structural modelling is to be accurate; the mesh dimensions are to be such as to enable a faithful representation of the stress gradients. The use of membrane elements is only allowed when significant bending effects are not present; in other cases, elements with general behaviour are to be used.

2.5 Boundary conditions of the model

2.5.1 In order to prevent rigid body motions of the overall model, the constraints specified in Tab 1 are to be applied.

Table 1 : Boundary conditions to prevent rigid body motion of the model

Boundary conditions	DISPLACEMENTS in directions**(1)**		
	X	Y	Z
One node on the fore end of the ship	free	fixed	fixed
One node on the port side shell at aft end of the ship**(2)**	fixed	free	fixed
One node on the starboard side shell at aft end of the ship**(2)**	free	fixed	fixed

Boundary conditions	ROTATION around axes **(1)**		
	X	Y	Z
One node on the fore end of the ship	free	free	free
One node on the port side shell at aft end of the ship**(2)**	free	free	free
One node on the starboard side shell at aft end of the ship**(2)**	free	free	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].
(2) The nodes on the port side shell and that on the starboard side shell are to be symmetrical with respect to the ship longitudinal plane of symmetry.

Table 2 : Symmetry and anti-symmetry conditions in way of the ship centreline longitudinal plane

Boundary conditions	DISPLACEMENTS in directions**(1)**		
	X	Y	Z
Symmetry	free	fixed	free
Anti-symmetry	fixed	free	fixed

Boundary conditions	ROTATION around axes**(1)**		
	X	Y	Z
Symmetry	fixed	free	fixed
Anti-symmetry	free	fixed	free

(1) X, Y and Z directions and axes are defined with respect to the reference co-ordinate system in Ch 1, Sec 2, [10].

2.5.2 When the hull structure is modelled over half the ship's breadth (see [2.2.2]), in way of the ship centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 2 are to be applied, depending on the loads applied to the model (respectively symmetrical or anti-symmetrical).

3 Load model

3.1 General

3.1.1 Design wave method

The various load components which occur simultaneously may be combined by setting the characteristics of regular waves that maximize the dominant load parameters given in Part B, Chapter 5.

Any other method may be used provided that relevant documentation is submitted to the Society for review.

A recommended procedure to compute the characteristics of the design wave is provided in [3.2].

3.1.2 Loads

Still water loads include:

- the still water sea pressure, defined in Ch 5, Sec 5, [1]
- the still water internal loads, defined in Ch 5, Sec 6 for the various types of cargoes and for ballast.

Wave loads, determined by mean of hydrodynamic calculations according to [3.2], include:

- the wave pressure
- the inertial loads.

3.1.3 Lightweight

The lightweight of the ship is to be uniformly distributed over the model length, in order to obtain the actual longitudinal distribution of the still water bending moment.

3.1.4 Models extended over half breadth of ship

When the ship is symmetrical with respect to her centreline longitudinal plane and the hull structure is modelled over half the ship breadth, non-symmetrical loads are to be broken down into symmetrical and anti-symmetrical loads and applied separately to the model with symmetry and anti-symmetry boundary conditions in way of the ship centreline longitudinal plane (see [2.5.2]).

3.2 Procedure for the selection of design waves

3.2.1 Summary of the loading procedure

Applicable cargo loading conditions given in Part D are analysed through:

- the computation of the characteristics of the finite element model under still water loads (see [3.3.1])
- the election of the load cases critical for the strength of the resistant structural members (see [3.3.2]).

The determination of the design wave characteristics for each load case includes the following steps:

- computation of the response operators (amplitude and phase) of the dominant load effect
- selection of the wave length and heading according to the guidelines in [3.3]
- computation of the wave amplitude corresponding to the design value of the dominant load effect
- determination of the wave phase such that the dominant load effect reaches its maximum.

3.2.2 Dominant load effects

Each critical load case maximizes the value of one of the following load effects having a dominant influence on the strength of some parts of the structure:

- vertical wave bending moment in hogging condition at midship section
- vertical wave bending moment in sagging condition at midship section
- vertical wave shear force on transverse bulkheads
- horizontal wave bending moment at midship section
- vertical acceleration at centreline in midship and fore body sections
- transverse acceleration at deck at sides at midship section
- vertical relative motion at sides in upright ship condition, at midship section
- vertical relative motion at sides in inclined ship condition, at midship section.

3.2.3 Response Amplitude Operators

The Response Amplitude Operators (RAO's) and associated phase characteristics are to be computed for wave periods between 4 and 22 seconds, using a seakeeping program, for the following motions and load effects:

- heave, pitch, roll and yaw motions
- vertical wave bending moment at 0,50 L
- vertical wave shear force at 0,25 L and 0,50 L
- horizontal wave bending moment at 0,50 L
- wave torque at 0,25 L, 0,50 L and 0,75 L (for ships with large deck openings).

The response amplitude operators are to be calculated for wave headings ranging from following seas (0 degree) to head seas (180 degrees) by increment of 15 degrees, using a ship speed of 60% of the maximum service speed.

The amplitude and phase of other dominant load effects may be computed at relevant wave period, using the RAO's listed above.

3.2.4 Design waves

For each load case, the ship is considered to encounter a regular wave, defined by its parameters (see Fig 1):

- wave length λ or period T
- heading angle α
- wave height (double amplitude)
- wave phase.

The wave length λ and the wave period T are linked by the following relation:

$\lambda = g\,T^2 / 2\,\pi$

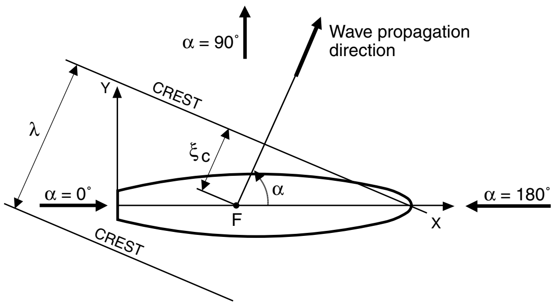
The range of variation of design wave period is between T1 and 22 seconds, where T1 is equal to:

$$T1 = 2\sqrt{\frac{\pi B_{WS}}{g}}$$

The possible wave height H, in m, is limited by the maximum wave steepness according to the relation (see Fig 2):

$H = 0{,}02\,g\,T^2$

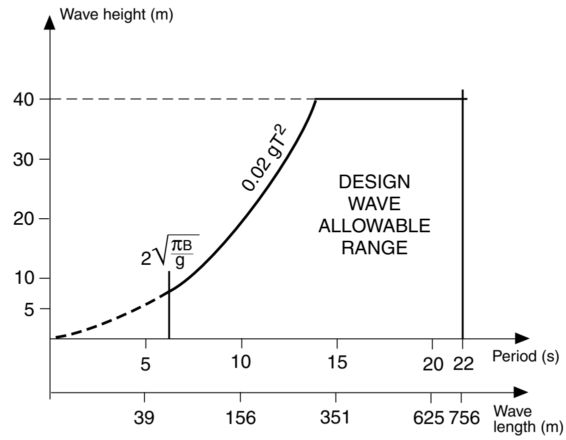
Figure 1 : Wave heading



Phase angle = 360 ξ_C / λ (in degrees)

F : Centre of rotation.

Figure 2 : Allowable range of design waves



3.2.5 Design wave amplitude

The amplitude of the design wave is obtained by dividing the design value of the dominant load effect by the value of the response amplitude operator of this effect computed for the relevant heading and wave length.

The design values of load effect, heading and wave length are given for each load case in [3.3.2].

When positioning the finite element model of the ship on the design wave, the amplitude of the wave is to be corrected to obtain the design value of the dominant load effect in order to take into account the non linear effects due to the hull shape and to the pressure distribution above the mean waterline given in [3.2.7].

The design wave phase is the phase of the dominant load effect.

3.2.6 Combined load cases

For the wave characteristics and crest position selected according to [3.2.5], the value of the wave-induced motions, accelerations and other load effects is obtained by the following formula:

$E_i = RAO_i \, a \cos(\varphi_d - \varphi_i)$

where:

- E_i : Value of amplitude of the load component i
- RAO_i : Response amplitude operator of the load component i computed for the design heading and wave length
- a : Design wave amplitude
- φ_d : Phase of the dominant load effect
- φ_i : Phase of the load component i.

As a rule, the amplitude of the load components computed above are not to exceed their rule reference value by a factor C_{max} given in Tab 3.

3.2.7 Finite element model loading

The loads are applied to the finite element model according to the following indications:

a) For fatigue analysis of structural members located in the vicinity of the mean waterline, the sum of the wave and hydrostatic parts of the pressure is zero above the deformed wave profile and varies linearly between the mean waterline and the wave crest levels.

b) The fluid pressure in tanks is affected by the change of direction of the total acceleration vector defined in Ch 5, Sec 6, [1.2.2].

c) For dry unit cargoes, the inertial forces are computed at the centre of mass, taking into account the mass moment of inertia.

d) Inertial loads for structure weight and dry uniform cargo are computed using local accelerations calculated at their location.

Table 3 : Values of factor C_{max}

Load component	C_{max}
Wave bending moments (see Ch 5, Sec 2, [3])	1,10
Wave shear forces (see Ch 5, Sec 2, [3])	1,40
Absolute motions and accelerations (see Ch 5, Sec 3, [2])	1,10
Relative vertical motions (see Ch 5, Sec 3, [3])	1,20

Table 4 : Load cases and load effect values

Load case	Dominant load effect	Wave parameters **(1)**		Location(s)
		Wave length λ, in m	Heading angle α	
1	Vertical wave bending moment in hogging condition	peak value of vertical wave bending moment RAO without being taken less than 0,9 L	180°	Midship section
2	Vertical wave bending moment in sagging condition	same as load case 1	180°	Midship section
3	Vertical wave shear force	peak value of vertical wave shear force RAO: • at 0,50 L for 0,35 L < x < 0,65 L • at 0,25 L elsewhere	0° or 180°	Each transverse bulkhead
4	Horizontal wave bending moment	peak value of horizontal wave bending moment RAO or 0,5 L	120° or 135° **(2)**	Midship section
5	Vertical acceleration in inclined ship condition	$\lambda = \dfrac{12{,}3 C_\beta \Delta}{B_{WS} L C_W}$ where: C_β = 1,00 for 90° heading C_β = 1,15 for 105° heading C_W : Waterplane coefficient at load waterline	90° or 105°	Midship section
6	Vertical acceleration in upright ship condition	$\lambda = 1{,}6\ L\ (0{,}575 + 0{,}8\ F)^2$	180°	from forward end of cargo area to F.P.
7	Transverse acceleration	$\lambda = 1{,}35\ g\ T_R^2 / (2\ \pi)$ without being taken greater than 756	90°	Midship section
8	Vertical relative motion at sides in upright ship condition	0,7 L **(3)**	180° or 0°	Midship section
9	Vertical relative motion at sides in inclined ship condition	$\lambda = 0{,}35\ g\ T_R^2 / (2\ \pi)$ without being taken less than 2,0 B_{WS}	90°	Midship section

(1) The forward ship speed is to be taken equal to 0,6 V_{max}.
(2) Select the heading such that the value of C_{max} for vertical wave bending moment is not exceeded.
(3) λ may have to be increased to keep the wave steepness below wave breaking limit.

3.2.8 Equilibrium check

The finite element model is to be in equilibrium condition with all the still water and wave loads applied.

The unbalanced forces in the three axes are not to exceed 2% of the displacement.

The unbalanced moments are not to exceed 2% of $\Delta.B_{WS}$ around Y and Z axes and 0,2% of $\Delta.B_{WS}$ around X axis.

3.3 Load cases

3.3.1 Hydrostatic calculation

For each cargo loading condition given in the relevant chapter of Part D, the longitudinal distribution of still water shear force and bending moment is to be computed and checked by reference to the approved loading manual (see Ch 11, Sec 2).

The convergence of the displacement, trim and vertical bending moment is deemed satisfactory if within the following tolerances:

- 2% of the displacement
- 0,1 degrees of the trim angle
- 10% of the still water wave bending moment.

Table 5 : Dominant load effect values

Dominant load effect	Design value	Combined load components	References
Vertical wave bending moment in hogging condition	$0{,}625\ \gamma_{W1}\ M_{WV,\ H}$	vertical relative motion at sides at F.P.	$M_{WV,\ H}$ defined in Ch 5, Sec 2, [3.1.1]
Vertical wave bending moment in sagging condition	$0{,}625\ \gamma_{W1}\ F_D\ M_{WV,\ S}$		$M_{WV,\ S}$ defined in Ch 5, Sec 2, [3.1.1] F_D defined in Ch 5, Sec 2, [4.2.2]
Vertical wave shear force	$0{,}625\ \gamma_{W1}\ Q_{WV}$	–	Q_{WV} defined in Ch 5, Sec 2, [3.4]
Horizontal wave bending moment	$0{,}625\ \gamma_{W1}\ M_{WH}$	–	M_{WH} defined in Ch 5, Sec 2, [3.2.1]
Vertical acceleration at centreline in upright ship condition	γ_{W2} AZ1	–	AZ1 defined in Ch 5, Sec 3, [3.4.1]
Vertical acceleration at centreline in inclined ship condition	γ_{W2} AZ2	–	AZ2 defined in Ch 5, Sec 3, [3.4.1]
Transverse acceleration at deck at sides	γ_{W2} AY2	roll angle	AY2 defined in Ch 5, Sec 3, [3.4.1]
Vertical relative motion at sides in upright ship condition	$\gamma_{W2}\ h_1$	wave pressure on bottom	h_1 defined in Ch 5, Sec 3, [3.3.1]
Vertical relative motion at sides in inclined ship condition	$\gamma_{W2}\ h_2$	–	h_2 defined in Ch 5, Sec 3, [3.3.2]

3.3.2 Value of load effects

The wave length and heading which maximize each dominant load effect are specified in Tab 4. Where two values of heading angle are indicated in the table, the angle which corresponds to the highest peak value of the load effect's RAO is to be considered.

The design value of dominant load effects is specified in Tab 5.

4 Stress calculation

4.1 Stress components

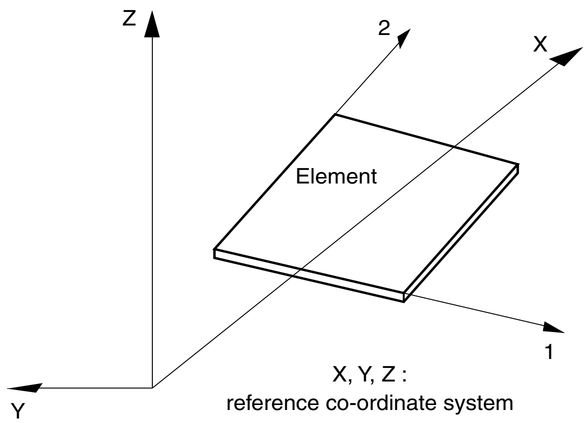
4.1.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by way of example, in Fig 3. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 2, [10].

The following stress components are to be calculated at the centroid of each element:

- the normal stresses σ_1 and σ_2 in the directions of element co-ordinate system axes
- the shear stress τ_{12} with respect to the element co-ordinate system axes
- the Von Mises equivalent stress, obtained from the following formula:

$$\sigma_{VM} = \sqrt{\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 + 3\tau_{12}^2}$$

Figure 3 : Reference and element co-ordinate systems



CHAPTER 8
OTHER STRUCTURES

Section 1	Fore Part
Section 2	Aft Part
Section 3	Machinery Space
Section 4	Superstructures and Deckhouses
Section 5	Bow Doors and Inner Doors
Section 6	Side Doors and Stern Doors
Section 7	Hatch Covers
Section 8	Movable Decks and Inner Ramps - External Ramps
Section 9	Arrangement of Hull and Superstructure Openings
Section 10	Helicopter Decks

Section 1 Fore Part

Symbols

L_1 , L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

ρ_L : Density, in t/m^3, of the liquid carried

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

p_S , p_W : Still water pressure and wave pressure defined in [2.3]

p_{BI} : Bottom impact pressure, defined in [3.2]

p_{FI} : Bow impact pressure, defined in [4.2]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1 + 0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0,5\ s / r$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b , β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS} , λ_{bW} , λ_{sS} , λ_{sW} : Coefficients defined in Ch 7, Sec 2, [3.4.3]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L / 32,5$ for $65\text{ m} < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient to be taken equal to:

$c_F = 0,9$ for forecastle sides

$c_F = 1,0$ in the other cases

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case-by-case basis, for other boundary conditions.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of structures located forward of the collision bulkhead, i.e.:

- fore peak structures
- stem.

In addition, the requirements of this Section apply to structure subjected to impact loads, i.e.:

- flat bottom forward area, according to Article [3]
- bow flare area, according to Article [4].

1.1.2 Fore peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Part B, Chapter 6 or Part B, Chapter 7, as applicable.

1.2 Connections of the fore part with structures located aft of the collision bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the fore part and those aft of the collision bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.2.2 Supports of fore peak structures

Aft of the collision bulkhead, side girders are to be fitted as specified in Ch 4, Sec 5, [2.2] or Ch 4, Sec 5, [3.2], as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for the checking of fore peak structures are specified in Tab 1.

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure p_S includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the still water internal pressure due to uniform loads, defined in Tab 5.

Wave pressure p_W includes:

- the wave pressure, defined in Tab 2
- the inertial internal pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial internal pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressures, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

Table 1 : Fore peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave induced pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

Table 2 : Still water and wave pressures

Location	Still water sea pressure p_S, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho g (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho g (T + h_1 - z)$ without being taken less than $0,15\,\varphi_1\,\varphi_2\,L$
Exposed deck	Pressure due to the load carried**(1)**	$19,6\varphi_1\varphi_2\sqrt{H}$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than 10 φ_1 φ_2 kN/m², where φ_1 ανδ φ_2 are defined hereafter.
The Society may accept pressure values lower than 10 φ_1 φ_2 kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 3

φ_2 = Min (L / 90 ; 1,0) without being taken less than 0,42

$$H = \left[2,66\left(\frac{x}{L} - 0,7\right)^2 + 0,14\right]\sqrt{\frac{VL}{C_B}} - (z - T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 3 : Coefficient φ_1 for pressure on exposed deck

Exposed deck location	φ_1
Watertight deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse and above	0,25

Table 4 : Still water and inertial internal pressures due to liquids

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho_L g(z_L - z)$	$\rho_L a_{Z1}(z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0,5\,(z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer; in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m.	$p_S \frac{a_{Z1}}{g}$

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

2.4 Longitudinally framed bottom

2.4.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 6 and the minimum values in the same Table.

Table 6 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Minimum net thickness, in mm **(1)**: • in general: $t = c_F (0{,}03 L + 5{,}5) k^{1/2} - c_E$ • for inner bottom: $t = 2 + 0{,}017 L k^{1/2} + 4{,}5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	
(1) L need not be taken greater than 300 m. **Note 1:** σ_{X1} : Hull girder normal stress, taken equal to: • the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress • $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.		

2.4.2 Floors

Floors are to be fitted at every four frame spacings and generally spaced no more than 2,5 m apart.

The floor dimensions and scantlings are to be not less than those specified in Tab 7.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

2.4.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder having the same dimensions and scantlings required in [2.4.2] for floors is to be provided.

The centre bottom girder is to be connected to the collision bulkhead by means of a large end bracket.

2.4.4 Side girders

Side girders, having the same dimensions and scantlings required in [2.4.2] for floors, are generally to be fitted every two longitudinals, in line with bottom longitudinals located aft of the collision bulkhead. Their extension is to be compatible in each case with the shape of the bottom.

2.5 Transversely framed bottom

2.5.1 Plating

The net scantling of plating is to be not less than the value obtained from the formulae in Tab 6 and the minimum values in the same Table.

2.5.2 Floors

Solid floors are to be fitted at every frame spacing.

The solid floor dimensions and scantlings are to be not less than those specified in Tab 8.

Table 7 : Longitudinally framed bottom - Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0{,}085\ D + 0{,}15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm²	$A_P = 3{,}15\ D$
Floor face plate net thickness, in mm	$t_P = 0{,}4\ D + 5$ May be assumed not greater than 14 mm.

Table 8 : Transversely framed bottom - Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height, in m	$h_M = 0,085\ D + 0,15$
Web net thickness, in mm	To be not less than that required for double bottom floors aft of the collision bulkhead; in any case, it may be taken not greater than 10 mm.
Floor face plate net sectional area, in cm^2	$A_P = 1,67\ D$

2.5.3 Centre girder

Where no centreline bulkhead is to be fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

2.6 Longitudinally framed side

2.6.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same Table.

2.6.2 Side transverses

Side transverses are to be located in way of bottom transverse and are to extend to the upper deck. Their ends are to be amply faired in way of bottom and deck transverses.

Their net section modulus w, in cm^3, and net shear sectional area A_{Sh}, in cm^2, are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2}\lambda_{bS} p_S + \gamma_{W2}\lambda_{bW} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2}\lambda_{sS} p_S + \gamma_{W2}\lambda_{sW} p_W}{R_y} s \ell$$

2.7 Transversely framed side

2.7.1 Plating and ordinary stiffeners (side frames)

Side frames fitted at every frame space are to have the same vertical extension as the collision bulkhead.

The net scantlings of plating and side frames are to be not less than the values obtained from the formulae in Tab 9 and the minimum values in the same Table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

Table 9 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F (0,03 L + 5,5) k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.
Note 1:
σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.

2.7.2 Side girders

Depending on the hull body shape and structure aft of the collision bulkhead, one or more adequately spaced side girders per side are to be fitted.

Their net section modulus w, in cm³, and net shear sectional area A_{Sh}, in cm², are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Moreover, the depth b_A, in mm, and the net thickness t_A, in mm, of the side girder web are generally to be not less than the values obtained from the following formulae:

$b_A = 2,5\ (180 + L)$

$t_A = (6 + 0,018\ L)\ k^{1/2}$

2.7.3 Panting structures

In order to withstand the panting loads, horizontal structures are to be provided. These structures are to be fitted at a spacing generally not exceeding 2 m and consist of side girders supported by panting beams or side transverses whose ends are connected to deck transverses, located under the tank top, so as to form a strengthened ring structure.

Panting beams, which generally consist of sections having the greater side vertically arranged, are to be fitted every two frames.

2.7.4 Connection between panting beams, side frames and side girders

Each panting beam is to be connected to the side transverses by means of brackets whose arms are generally to be not less than twice the panting beam depth.

2.7.5 Connection between side frames and side girders

Side transverses not supporting panting beams are to be connected to side girders by means of brackets having the same thickness as that of the side girder and arms which are to be not less than one half of the depth of the side girder.

2.7.6 Panting beam scantlings

The net area A_B, in cm², and the net inertia J_B, in cm⁴, of the panting beam section are to be not less than the values obtained from the following formulae:

$A_B = 0,5\ L - 18$

$J_B = 0,34\ (0,5\ L - 18)\ b_B^2$

where:

b_B : Beam length, in m, measured between the internal edges of side girders or the internal edge of the side girder and any effective central or lateral support.

Where side girder spacing is other than 2 m, the values A_B and J_B are to be modified according to the relation between the actual spacing and 2 m.

2.7.7 Panting beams of considerable length

Panting beams of considerable length are generally to be supported at the centreline by a wash bulkhead or pillars arranged both horizontally and vertically.

2.7.8 Non-tight platforms

Non-tight platforms may be fitted in lieu of side girders and panting beams. Their openings and scantlings are to be in accordance with [2.9.1].

Their spacing is to be not greater than 2,5 m.

If the peak exceeds 10 m in depth, a non-tight platform is to be arranged at approximately mid-depth.

2.7.9 Additional transverse bulkheads

Where the peak exceeds 10 m in length and the frames are supported by panting beams or non-tight platforms, additional transverse wash bulkheads or side transverses are to be fitted.

2.8 Decks

2.8.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than the values obtained from the formulae in Tab 10 and the minimum values in the same Table.

2.8.2 Primary supporting members

Scantlings of primary supporting members are to be in accordance with Ch 7, Sec 3, considering the loads in [2.3].

Table 10 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = 2{,}1 + 0{,}013 L k^{1/2} + 4{,}5 s$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.
Note 1:
σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress.

2.9 Platforms

2.9.1 Non-tight platforms

Non-tight platforms located inside the peak are to be provided with openings having a total area not less than 10% of that of the platforms. Moreover, the thickness of the plating and the section modulus of ordinary stiffeners are to be not less than those required in [2.10] for the non-tight central longitudinal bulkhead.

The number and depth of non-tight platforms within the peak is considered by the Society on a case-by-case basis.

The platforms may be replaced by equivalent horizontal structures whose scantlings are to be supported by direct calculations.

2.9.2 Platform transverses

The net sectional area of platform transverses, calculated considering a width of attached plating whose net sectional area is equal to that of the transverse flange, is to be not less than the value obtained, in cm², from the following formula:

$$A = 10 \gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{C_P R_y} d_S h_S$$

where:

p_S , p_W : Still water pressure and wave pressure, defined in [2.9.1], acting at the ends of the platform transverse in the direction of its axis

d_S : Half of the longitudinal distance, in m, between the two transverses longitudinally adjacent to that under consideration

h_S : Half of the vertical distance, in m, between the two transverses vertically adjacent to that under consideration

C_P : Coefficient, to be taken equal to:

$$C_P = 1 \quad \text{for } \frac{d_P}{r_P} \le 70$$

$$C_P = 1{,}7 - 0{,}01 \frac{d_P}{r_P} \quad \text{for } 70 < \frac{d_P}{r_P} \le 140$$

When $d_P / r_P > 140$, the scantlings of the struts are considered by the Society on a case-by-case basis

d_P : Distance, in cm, from the face plate of the side transverse and that of the bulkhead vertical web, connected by the strut, measured at the level of the platform transverse

r_P : Radius of gyration of the strut, to be obtained, in cm, from the following formula:

$$r_P = \sqrt{\frac{J}{A_E}}$$

J : Minimum net moment of inertia, in cm⁴, of the strut considered

A_E : Actual net sectional area, in cm², of the transverse section of the strut considered.

2.9.3 Breasthooks

Breasthooks are to have the same thickness of that required for platforms. They are to be arranged on the stem, in way of every side longitudinal, or at equivalent spacing in the case of transverse framing, extending aft for a length equal to approximately twice the breasthook spacing.

Other dispositions may be accepted by the Society if deemed equivalent.

2.10 Central longitudinal bulkhead

2.10.1 General

Unless otherwise agreed by the Society on a case-by-case basis, a centreline non-tight longitudinal bulkhead is not to be fitted. In case such a bulkhead is fitted, the following requirements apply.

2.10.2 Extension

In the case of a bulbous bow, such bulkhead is generally to extend for the whole length and depth of the fore peak.

Where hull structures are flared, such as those situated above the bulb and in the fore part of the peak, the bulkhead may be locally omitted.

Similarly, the extension of the bulkhead may be limited for bows without a bulb, depending on the shape of the hull. However, the bulkhead is to be fitted in the higher part of the peak.

2.10.3 Plating thickness

The net plating thickness of the lower part of the longitudinal bulkhead over a height at least equal to h_M defined in [2.4.2] is to be not less than that required for the centre girder in [2.4.3].

Elsewhere, the net thickness of the longitudinal bulkhead plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 6,5 + 0,013\ L_1$$

2.10.4 Ordinary stiffeners

The net section modulus of ordinary stiffeners is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 3,5\ s\ \ell^2\ k\ (z_{TOP} - z_M)$$

where:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_M : Z co-ordinate, in m, of the stiffener mid-span.

2.10.5 Primary supporting members

Vertical and longitudinal primary supporting members, to be made preferably with symmetrical type sections, are to have a section modulus not less than 50% of that required for the corresponding side or longitudinal webs.

The vertical and longitudinal webs are to be provided with adequate fairing end brackets and to be securely connected to the struts, if any.

2.10.6 Openings

Bulkhead openings are to be limited in the zone corresponding to the centre girder to approximately 2% of the area, and, in the zone above, to not less than 10% of the area. Openings are to be located such as to affect as little as possible the plating sections adjacent to primary supporting members.

2.11 Bulbous bow

2.11.1 General

Where a bulbous bow is fitted, fore peak structures are to effectively support the bulb and are to be adequately connected to its structures.

When the bulbous bow is intended to contain a sonar device, the requirements in [2.11.7] apply.

2.11.2 Shell plating

The thickness of the shell plating of the fore end of the bulb and the first strake above the keel is generally to be not less than that required in [5.2.1] for plate stems. This thickness is to be extended to the bulbous zone, which, depending on its shape, may be damaged by anchors and chains during handling.

2.11.3 Connection with the fore peak

Fore peak structures are to be extended inside the bulb as far as permitted by the size and shape of the latter.

2.11.4 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.5 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.6 Transverse wash bulkhead

In way of a long bulb, transverse wash bulkheads or side transverses of adequate strength arranged not more than 5 frame spaces apart may be required by the Society in certain cases.

2.11.7 Bulbous bow intended to contain a sonar device

The fore part of the bulbous bow is generally constituted by a GRP dome bolted to the fore structures. The aft part of the bulbous bow, of metallic construction, is to be connected with the fore structures according to [2.11.3] to [2.11.6] as far as practicable.

The sonar space is generally filled with water and is provided with a system for filling and emptying it. The hull watertightness is to be ensured by means of an horizontal flat and a transverse watertight floor, which contour the sonar dome. The scantlings of these watertight elements are to be checked considering them as being part of the outer shell.

If the access, in floating condition, to the sonar dome is to be ensured, for inspection and maintenance, two watertight hatches are, in general, to be fitted. For small domes, one hatch only may be accepted provided that its clear opening is such to allow contemporary easy access and ventilation. For the scantlings of these hatches, the sea pressures acting on the outer shell are to be considered.

3 Reinforcements of the flat bottom forward area

3.1 Area to be reinforced

3.1.1 In addition to the requirements in Article [2], the structures of the flat bottom forward area are to be able to sustain the dynamic pressures due to the bottom impact. The flat bottom forward area is:

- longitudinally, over the bottom located between ξL and 0,05L aft of the fore end, where the coefficient ξ is obtained from the following formula:

  $\xi = 0,25\ (1,6 - C_B)$

  without being taken less than 0,20 or greater than 0,25
- transversely, over the whole flat bottom and the adjacent zones up to a height, from the base line, not less than 2 L, in mm. In any case, it is not necessary that such height is greater than 300 mm.

3.1.2 The bottom dynamic impact pressure is to be considered if:

$T_F < \text{Min}\ (0,04\ L\ ;\ 8,6)$

where T_F is the minimum forward draught, in m, among those foreseen in operation in ballast conditions or conditions of partial loading.

3.1.3 The value of the minimum forward draught T_F adopted for the calculations is to be specified in the loading manual.

3.1.4 An alternative arrangement and extension of strengthening with respect to the above may also be required where the minimum forward draught exceeds 0,04 L, depending on the shape of the forward hull body and the ship length and service speed.

3.2 Bottom impact pressure

3.2.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m², from the following formula:

$$p_{BI} = 25\left[0,004 - \left(\frac{T_F}{L}\right)^2\right]\frac{L_1 L}{T_F}$$

where T_F is the draught defined in [3.1.2].

3.3 Partial safety factors

3.3.1 The partial safety factors to be considered for checking the reinforcements of the flat bottom forward area are specified in Tab 11.

Table 11 : Reinforcements of the flat bottom forward area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,15

3.4 Scantlings

3.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.4.1] and [2.5.1], the net scantlings of plating and ordinary stiffeners of the flat bottom forward area, defined in [3.1], are to be not less than the values obtained from the formulae in Tab 12 and the minimum values in the same Table.

3.4.2 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

Table 12 : Reinforcements of plating and ordinary stiffeners of the flat bottom forward area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 13{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{W2} p_{BI}}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F(0{,}03L + 5{,}5)k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{W2} p_{BI}}{16 c_P R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{W2} p_{BI}}{R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell$	
(1) L need not be taken greater than 300 m.		
Note 1:		
c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.		

3.5 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.5.1 The requirements in [3.5.2] to [3.5.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.4].

3.5.2 Bottom longitudinals and side girders, if any, are to extend as far forward as practicable, and their spacing may not exceed that adopted aft of the collision bulkhead.

3.5.3 The spacing of solid floors in a single or double bottom is to be not greater than:

- either the spacing required in Ch 4, Sec 4 for the midship section, or
- (1,35 + 0,007 L) m,

whichever is the lesser.

However, where the minimum forward draught T_F is less than 0,02 L, the spacing of floors forward of 0,2 L from the stem is to be not greater than (0,9 + 0,0045 L) m.

3.5.4 The Society may require adequately spaced side girders having a depth equal to that of the floors. As an alternative to the above, girders with increased scantlings may be fitted.

3.6 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.6.1 The requirements from [3.6.2] to [3.6.4] apply to the structures of the flat bottom forward area, defined in [3.1], in addition to the requirements of [2.5].

3.6.2 Solid floors are to be fitted:

- at every second frame between 0,75 L and 0,80 L from the aft end
- at every frame space forward of 0,80 L from the aft end.

3.6.3 Side girders with a depth equal to that of the floors are to be fitted at a spacing generally not exceeding 2,4 m. In addition, the Society may require intermediate half height girders, half the depth of the side girders, or other equivalent stiffeners.

3.6.4 Intercostal longitudinal ordinary stiffeners are to be fitted at a spacing generally not exceeding 1,2 m. Their section modulus is to be not less than 250 cm³.

4 Reinforcements of the bow flare area

4.1 Area to be reinforced

4.1.1 In addition to the requirements in [2], the structures of the bow flare area are to be able to sustain the dynamic pressures due to the bow impact pressure.

4.1.2 The bow area to be reinforced is that extending forward of 0,9 L from the aft end of L and above the full load waterline up to the level at which a knuckle with an angle greater than 15° is located on the side shell.

4.2 Bow impact pressure

4.2.1 The bow impact pressure p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = C_S C_L C_Z (0{,}22 + 0{,}15 \tan\alpha)(0{,}4 V \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the bow impact pressure is considered to be acting:

- $C_S = 1{,}8$ for plating and ordinary stiffeners
- $C_S = 0{,}5$ for primary supporting members

C_L : Coefficient depending on the ship length:

- $C_L = 0{,}0125\ L$ for $L < 80$ m
- $C_L = 1{,}0$ for $L \geq 80$ m

C_Z : Coefficient depending on the distance between the full load waterline and the calculation point:

- $C_Z = C - 0{,}5\ (z - T)$ for $z \geq 2\ C + T - 11$
- $C_Z = 5{,}5$ for $z < 2\ C + T - 11$

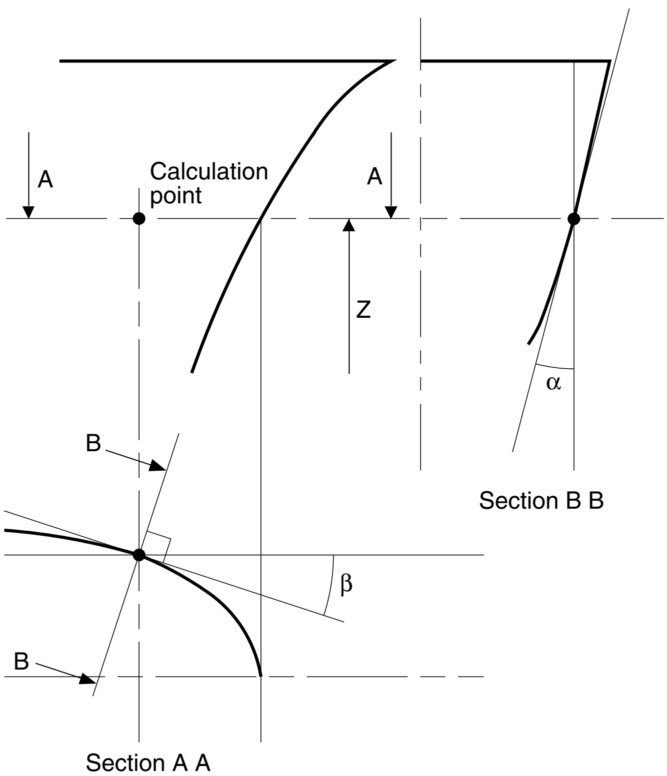
C : Wave parameter, defined in Ch 5, Sec 2

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1)

V : Maximum service speed, in knots.

Figure 1 : Definition of angles α and β



4.3 Partial safety factors

4.3.1 The partial safety factors to be considered to check the reinforcements of the bow flare area are specified in Tab 13.

4.4 Scantlings

4.4.1 Plating and ordinary stiffeners

In addition to the requirements in [2.6.1] and [2.7.1], the net scantlings of plating and ordinary stiffeners of the bow flare area, defined in [4.1], are to be not less than the values obtained from the formulae in Tab 14 and the minimum values in the same Table.

4.4.2 Tapering

Outside the bow flare area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

4.4.3 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

4.4.4 Primary supporting members

In addition to the requirements in [2.6] and [2.7], primary supporting members are generally to be verified through direct calculations carried out according to Ch 7, Sec 3, considering the bow impact pressures defined in [4.2].

Table 13 : Reinforcements of the bow flare area - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

Table 14 : Reinforcements of plating and ordinary stiffeners of the bow flare area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{W2} p_{FI}}{R_y}}$	Minimum net thickness, in mm **(1)**: $t = c_F(0{,}03L + 5{,}5)k^{1/2} - c_E$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{W2} p_{FI}}{18 c_P R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1{,}5 L_2^{1/3} k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell$	

(1) L need not be taken greater than 300 m.

Note 1:

c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

5 Stems

5.1 General

5.1.1 Arrangement

Adequate continuity of strength is to be ensured at the connection of stems to the surrounding structure.

Abrupt changes in sections are to be avoided.

5.1.2 Gross scantlings

With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [5.2] and [5.3] are gross, i.e. they include the margins for corrosion.

5.2 Plate stems

5.2.1 Where the stem is constructed of shaped plates, the gross thickness of the plates below the load waterline is to be not less than the value obtained, in mm, from the following formula:

$$t_S = 1{,}37(0{,}95 + \sqrt{L_3})\sqrt{k}$$

where:

L_3 : Ship length L, in m, but to be taken not greater than 300.

Above the load waterline this thickness may be gradually tapered towards the stem head, where it is to be not less than that required for side plating at ends.

5.2.2 The plating forming the stems is to be supported by horizontal diaphragms spaced not more than 1200 mm apart and connected, as far as practicable, to the adjacent frames and side stringers.

5.2.3 If considered necessary, and particularly where the stem radius is large, a centreline stiffener or web of suitable scantlings is to be fitted.

5.3 Bar stems

5.3.1 The gross area of bar stems constructed of forged or rolled steel is to be not less than the value obtained, in cm^2, from the following formulae:

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(0{,}009L^2 + 20)\sqrt{k} \quad \text{for } L \le 90$$

$$A_P = \left(0{,}40 + \frac{10T}{L}\right)(1{,}8L - 69)\sqrt{k} \quad \text{for } 90 < L \le 200$$

where the ratio T/L in the above formulae is to be taken neither less than 0,050 nor greater than 0,075.

5.3.2 The gross thickness t_B of the bar stem is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (0{,}4L + 13)\sqrt{k}$$

5.3.3 The cross-sectional area of the stem may be gradually tapered from the load waterline to the upper end, where it may be equal to the two thirds of the value as calculated above.

5.3.4 The lower part of the stem may be constructed of cast steel subject to the examination by the Society; where necessary, a vertical web is to be fitted for welding of the centre keelson.

5.3.5 Welding of the bar stem with the bar keel and the shell plating is to be in accordance with Ch 11, Sec 1, [3.4].

6 Transverse thrusters

6.1 Scantlings of the thruster tunnel and connection with the hull

6.1.1 The thickness of the tunnel is to be not less than the thickness of the adjacent hull plating.

6.1.2 When the tunnel is not welded to the hull, the connection devices are examined by the Society on a case-by-case basis.

Section 2 Aft Part

Symbols

L_1 , L_2 : Lengths, in m, defined in Ch 1, Sec 2, [2.1.1]

h_1 : Reference value of the ship relative motion, defined in Ch 5, Sec 3, [3.3]

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 5, Sec 3, [3.4]

ρ : Sea water density, in t/m^3

g : Gravity acceleration, in m/s^2:

$g = 9,81$ m/s^2

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

p_S , p_W : Still water pressure and wave pressure defined in [2.3]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as applicable

ℓ : Span, in m, of ordinary stiffeners or primary supporting members, as applicable

c_a : Aspect ratio of the plate panel, equal to:

$$c_a = 1,21\sqrt{1+0,33\left(\frac{s}{\ell}\right)^2} - 0,69\frac{s}{\ell}$$

to be taken not greater than 1,0

c_r : Coefficient of curvature of the panel, equal to:

$c_r = 1 - 0,5\ s / r$

to be taken not less than 0,75

r : Radius of curvature, in m

β_b , β_s : Coefficients defined in Ch 7, Sec 2, [3.7.3]

λ_{bS} , λ_{bW} , λ_{sS} , λ_{sW} : Coefficients defined in Ch 7, Sec 2, [3.4.3]

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65\text{ m} < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0,8$ for poop sides

$c_F = 1,0$ in the other cases

m : Boundary coefficient, to be taken equal to:

- m = 12 in general, for stiffeners considered as clamped
- m = 8 for stiffeners considered as simply supported
- other values of m may be considered, on a case-by-case basis, for other boundary conditions.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantlings of structures located aft of the after peak bulkhead and for the reinforcements of the flat bottom aft area.

1.1.2 Aft peak structures which form the boundary of spaces not intended to carry liquids, and which do not belong to the outer shell, are to be subjected to lateral pressure in flooding conditions. Their scantlings are to be determined according to the relevant criteria in Part B, Chapter 7, as applicable.

1.2 Connections of the aft part with structures located fore of the after peak bulkhead

1.2.1 Tapering

Adequate tapering is to be ensured between the scantlings in the aft part and those fore of the after peak bulkhead. The tapering is to be such that the scantling requirements for both areas are fulfilled.

1.3 Net scantlings

1.3.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 4, Sec 2.

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for the checking of aft peak structures are specified in Tab 1.

Table 1 : Aft peak structures - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Material	γ_m	1,02	1,02	1,02
Resistance	γ_R	1,20	1,40	1,60

2.2 Load point

2.2.1 Unless otherwise specified, lateral pressure is to be calculated at:

- the lower edge of the elementary load panel considered, for plating
- mid-span, for stiffeners.

2.3 Load model

2.3.1 General

The still water and wave lateral pressures in intact conditions are to be considered. They are to be calculated as specified in [2.3.2] for the elements of the outer shell and in [2.3.3] for the other elements.

Still water pressure p_S includes:

- the still water sea pressure, defined in Tab 2
- the still water internal pressure due to liquid or ballast, defined in Tab 4
- for decks, the still water internal pressure due to dry uniform weights, defined in Tab 5.

Wave pressure p_W includes:

- the wave pressure, defined in Tab 2
- the inertial pressure due to liquids or ballast, defined in Tab 4
- for decks, the inertial pressure due to uniform loads, defined in Tab 5.

2.3.2 Lateral pressures for the elements of the outer shell

The still water and wave lateral pressures are to be calculated considering separately:

- the still water and wave external sea pressures
- the still water and wave internal pressure, considering the compartment adjacent to the outer shell as being loaded.

If the compartment adjacent to the outer shell is not intended to carry liquids, only the external sea pressures are to be considered.

2.3.3 Lateral pressures for elements other than those of the outer shell

The still water and wave lateral pressures to be considered as acting on an element which separates two adjacent compartments are those obtained considering the two compartments individually loaded.

Table 2 : Still water and wave pressures

Location	Still water sea pressure p, in kN/m²	Wave pressure p_W, in kN/m²
Bottom and side below the waterline: $z \le T$	$\rho\, g\, (T - z)$	$\rho g h_1 e^{\frac{-2\pi(T-z)}{L}}$
Side above the waterline: $z > T$	0	$\rho\, g\, (T + h_1 - z)$ without being taken less than $0{,}15\, \varphi_1\, \varphi_2\, L$
Exposed deck	Pressure due to the load carried **(1)**	$17{,}5\, \varphi_1\, \varphi_2$

(1) The pressure due to the load carried is to be defined by the Designer and, in any case, it may not be taken less than $10\, \varphi_1\, \varphi_2$ kN/m², where φ_1 ανδ φ_2 are defined hereafter.
The Society may accept pressure values lower than $10\, \varphi_1\, \varphi_2$ kN/m² when considered appropriate on the basis of the intended use of the deck.

Note 1:

φ_1 : Coefficient defined in Tab 3

φ_2 = Min (L / 90 ; 1,0) without being taken less than 0,42.

Table 3 : Coefficient φ_1 for pressure on exposed deck

Exposed deck location	φ_1
Watertight deck	1,00
Superstructure deck	0,75
1st tier of deckhouse	0,56
2nd tier of deckhouse	0,42
3rd tier of deckhouse	0,32
4th tier of deckhouse	0,25
5th tier of deckhouse	0,20
6th tier of deckhouse	0,15
7th tier of deckhouse and above	0,10

Table 4 : Still water and wave internal pressures due to liquids

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
$\rho\, g\, (z_L - z)$	$\rho\, a_{Z1}\, (z_{TOP} - z)$

Note 1:

z_{TOP} : Z co-ordinate, in m, of the highest point of the tank

z_L : Z co-ordinate, in m, of the highest point of the liquid:
$z_L = z_{TOP} + 0{,}5\, (z_{AP} - z_{TOP})$

z_{AP} : Z co-ordinate, in m, of the moulded deck line of the deck to which the air pipes extend, to be taken not less than z_{TOP}.

Table 5 : Still water and inertial internal pressures due to uniform loads

Still water pressure p_S, in kN/m²	Inertial pressure p_W, in kN/m²
The value of p_S is, in general, defined by the Designer: in any case it may not be taken less than 10 kN/m². When the value of p_S is not defined by the Designer, it may be taken, in kN/m², equal to 6,9 h_{TD}, where h_{TD} is the compartment 'tweendeck height at side, in m.	$p_S \dfrac{a_{Z1}}{g}$

3 After peak

3.1 Arrangement

3.1.1 General

The provisions of this sub-article apply to transversely framed after peak structure.

3.1.2 Floors

Solid floors are to be fitted at every frame spacing.

The floor height is to be adequate in relation to the shape of the hull. Where a sterntube is fitted, the floor height is to extend at least above the sterntube. Where the hull lines do not allow such extension, plates of suitable height with upper and lower edges stiffened and securely fastened to the frames are to be fitted above the sterntube.

In way of and near the rudder post, propeller post and rudder horn, floors are to be extended up to the peak tank top and are to be increased in thickness; the increase will be considered by the Society on a case-by-case basis, depending on the arrangement proposed.

Floors are to be fitted with stiffeners having spacing not greater than 800 mm.

3.1.3 Side frames

Side frames are to be extended up to a deck located above the full load waterline.

Side frames are to be supported by one of the following types of structure:

- non-tight platforms, to be fitted with openings having a total area not less than 10% of the area of the platforms
- side girders supported by side primary supporting members connected to deck transverses.

The distance between the above side frame supports is to be not greater than 2,5 m.

3.1.4 Platforms and side girders

Platforms and side girders within the peak are to be arranged in line with those located in the area immediately forward.

Where this arrangement is not possible due to the shape of the hull and access needs, structural continuity between the peak and the structures of the area immediately forward is to be ensured by adopting wide tapering brackets.

Where the after peak is adjacent to a machinery space whose side is longitudinally framed, the side girders in the after peak are to be fitted with tapering brackets.

3.1.5 Longitudinal bulkheads

A longitudinal non-tight bulkhead is to be fitted on the centreline of the ship, in general in the upper part of the peak, and stiffened at each frame spacing.

Where either the stern overhang is very large or the maximum breadth of the peak is greater than 20 m, additional longitudinal wash bulkheads may be required.

3.2 Scantlings

3.2.1 Plating and ordinary stiffeners (side frames)

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained from the formulae in:

- Tab 6 for plating
- Tab 7 for ordinary stiffeners,

and not less than the minimum values in the same Tables.

3.2.2 Floors

The net thickness of floors is to be not less than that obtained, in mm, from the following formula:

$t_M = 6,5 + 0,02\ L_2\ k^{1/2}$

3.2.3 Side transverses

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

Table 6 : Net thickness of plating

Plating location	Net thickness, in mm	Minimum net thickness, in mm**(1)**
Bottom and side	$14,9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}}$	$c_F\ (0,03\ L + 5,5)\ k^{1/2} - c_E$
Inner bottom		$2 + 0,017\ L\ k^{1/2} + 4,5\ s$
Deck		For strength deck: $2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Platform and wash bulkhead		$1,3 + 0,004\ L\ k^{1/2} + 4,5\ s$ for $L < 120$ m $2,1 + 2,2\ k^{1/2} + s$ for $L \geq 120$ m
(1) L need not be taken greater than 300 m.		

Table 7 : Net scantlings of ordinary stiffeners

Ordinary stiffener location	Formulae	Minimum value
Bottom, side and deck	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web minimum net thickness, in mm, to be not less than the lesser of: • $t = 1,5 \, L_2^{1/3} \, k^{1/6}$ • the net thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	
Platform and wash bulkhead	Net section modulus, in cm³: $w = 3{,}5 \, s \, \ell^2 \, k \, (z_{TOP} - z_M)$	

Note 1:

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 7, Sec 2, [3.3.7], for stiffeners contributing to the hull girder longitudinal stress
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal stress

Z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank

Z_M : Z co-ordinate, in m, of the stiffener mid-span.

3.2.4 Side girders

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of side girders are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

3.2.5 Deck primary supporting members

Scantlings of deck primary supporting members are to be in accordance with Ch 7, Sec 3, as applicable, considering the loads in [2.3].

4 Reinforcements of the flat area of the bottom aft

4.1 General

4.1.1 In the flat area of the bottom aft, if any, increased bottom plating thickness as well as additional bottom stiffeners may be considered by the Society on a case-by-case basis.

5 Connection of hull structures with the rudder horn

5.1 Connection of after peak structures with the rudder horn

5.1.1 General

The requirement of this sub-article apply to the connection between peak structure and rudder horn where the sternframe is of an open type and is fitted with the rudder horn.

5.1.2 Rudder horn

Horn design is to be such as to enable sufficient access for welding and inspection.

The scantlings of the rudder horn, which are to comply with Ch 9, Sec 1, [9.2], may be gradually tapered inside the hull.

Connections by slot welds are not acceptable.

5.1.3 Hull structures

Direct calculations are to be performed to check the connection of the rudder horn to the structure of the vessel, taking into account of the reactions induced by the rudder on the rudder horn.

In general, between the horn intersection with the shell and the peak tank top, the vertical extension of the hull structures is to be not less than the horn height, defined as the distance from the horn intersection with the shell to the mid-point of the lower horn gudgeon.

The thickness of the structures adjacent to the rudder horn, such as shell plating, floors, platforms and side girders, the centreline bulkhead and any other structures, is to be adequately increased in relation to the horn scantlings.

5.2 Structural arrangement above the after peak

5.2.1 Side transverses

Where a rudder horn is fitted, side transverses, connected to deck beams, are to be arranged between the platform forming the peak tank top and the weather deck.

The side transverse spacing is to be not greater than:

- 2 frame spacings in way of the horn
- 4 frame spacings for and aft of the rudder horn
- 6 frame spacings in the area close to the after peak bulkhead.

The side transverses are to be fitted with end brackets and located within the poop. Where there is no poop, the scantlings of side transverses below the weather deck are to be adequately increased.

5.2.2 Side girders

Where the depth from the peak tank top to the weather deck is greater than 2,6 m and the side is transversely framed, one or more side girders are to be fitted, preferably in line with similar structures existing forward.

6 Sternframes

6.1 General

6.1.1 Sternframes may be made of cast or forged steel, with a hollow section, or fabricated from plate.

6.1.2 Cast steel and fabricated sternframes are to be strengthened by adequately spaced horizontal plates.

Abrupt changes of section are to be avoided in castings; all sections are to have adequate tapering radius.

6.2 Connections

6.2.1 Connection with hull structure

The requirements below are applicable to single screw ships.

Sternframes are to be effectively attached to the aft structure and the lower part of the sternframe is to be extended forward of the propeller post to a length not less than (1500 + 6 L) mm, in order to provide an effective connection with the keel. However, the sternframe need not extend beyond the after peak bulkhead.

The net thickness of shell plating connected with the sternframe is to be not less than that obtained, in mm, from the following formula:

$t = 0{,}045\ L\ k^{1/2} + 8{,}5$

6.2.2 Connection with the keel

The requirements below are applicable to single screw ships.

The thickness of the lower part of the sternframes is to be gradually tapered to that of the solid bar keel or keel plate.

Where a keel plate is fitted, the lower part of the sternframe is to be so designed as to ensure an effective connection with the keel.

6.2.3 Connection with transom floors

The requirements below are applicable to single screw ships.

Rudder posts and, in the case of ships greater than 90 m in length, propeller posts are to be connected with transom floors having height not less than that of the double bottom and net thickness not less than that obtained, in mm, from the following formula:

$t = 9 + 0{,}023\ L_1\ k^{1/2}$

6.2.4 Connection with centre keelson

The requirements below are applicable to single screw ships.

Where the sternframe is made of cast steel, the lower part of the sternframe is to be fitted, as far as practicable, with a longitudinal web for connection with the centre keelson.

6.3 Propeller posts

6.3.1 Gross scantlings

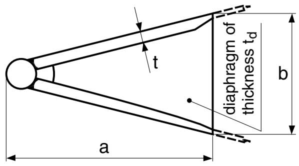
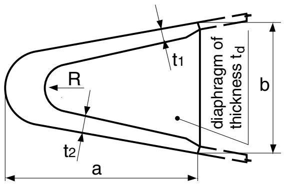
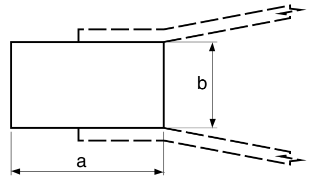
With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in [6.3.2] to [6.3.4] are gross, i.e. they include the margins for corrosion.

6.3.2 Gross scantlings of propeller posts

The gross scantlings of propeller posts are to be not less than those obtained from the formulae in Tab 8 for single screw ships and Tab 9 for twin screw ships.

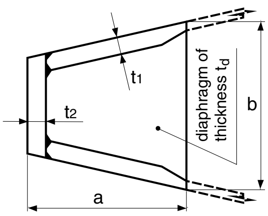
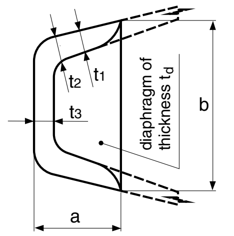
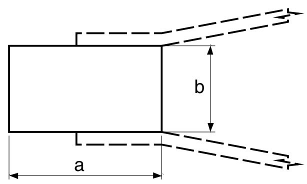
Scantlings and proportions of the propeller post which differ from those above may be considered acceptable provided that the section modulus of the propeller post section about its longitudinal axis is not less than that calculated with the propeller post scantlings in Tab 8 or Tab 9, as applicable.

Table 8 : Single screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	$50\ L^{1/2}$	$33\ L^{1/2}$	$10\sqrt{2,5(L+10)}$ for $L \le 60$ $10\sqrt{7,2L-256}$ for $L > 60$
b	$35\ L^{1/2}$	$23\ L^{1/2}$	$10\sqrt{1,6(L+10)}$ for $L \le 60$ $10\sqrt{4,6L-164}$ for $L > 60$
t_1 **(1)**	$2,5\ L^{1/2}$	$3,2\ L^{1/2}$ to be taken not less than 19 mm	N.A.
t_2 **(1)**	N.A.	$4,4\ L^{1/2}$ to be taken not less than 19 mm	N.A.
t_D	$1,3\ L^{1/2}$	$2,0\ L^{1/2}$	N.A.
R	N.A.	$50\ L^{1/2}$	N.A.

(1) Propeller post thicknesses t_1 and t_2 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1: N.A. = not applicable.

Table 9 : Twin screw ships - Gross scantlings of propeller posts

Gross scantlings of propeller posts, in mm	**Fabricated propeller post** 	**Cast propeller post** 	**Bar propeller post, cast or forged, having rectangular section** 
a	$25\ L^{1/2}$	$12,5\ L^{1/2}$	0,72 L + 90 for $L \le 50$ 2,40 L + 6 for $L > 50$
b	$25\ L^{1/2}$	$25\ L^{1/2}$	0,24 L + 30 for $L \le 50$ 0,80 L + 2 for $L > 50$
t_1 **(1)**	$2,5\ L^{1/2}$	$2,5\ L^{1/2}$	N.A.
t_2 **(1)**	$3,2\ L^{1/2}$	$3,2\ L^{1/2}$	N.A.
t_3 **(1)**	N.A.	$4,4\ L^{1/2}$	N.A.
t_D	$1,3\ L^{1/2}$	$2,0\ L^{1/2}$	N.A.

(1) Propeller post thicknesses t_1 , t_2 and t_3 are, in any case, to be not less than (0,05 L + 9,5) mm.
Note 1: N.A. = not applicable.

6.3.3 Section modulus below the propeller shaft bossing

In the case of a propeller post without a sole piece, the section modulus of the propeller post may be gradually reduced below the propeller shaft bossing down to 85% of the value calculated with the scantlings in Tab 8 or Tab 9, as applicable.

In any case, the thicknesses of the propeller posts are to be not less than those obtained from the formulae in the Tables.

6.3.4 Welding of fabricated propeller post with the propeller shaft bossing

Welding of a fabricated propeller post with the propeller shaft bossing is to be in accordance with Ch 11, Sec 1, [3.3].

6.4 Integral rudder posts

6.4.1 Net section modulus of integral rudder post

The net section modulus around the horizontal axis X (see Fig 1) of an integral rudder post is to be not less than that obtained, in cm^3, from the following formula:

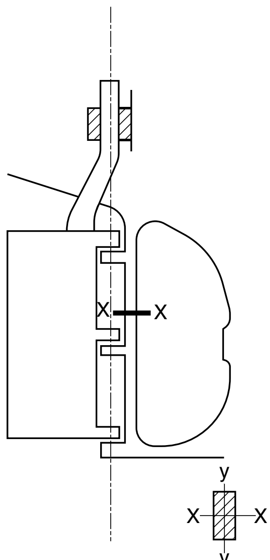
$w_{RP} = 14{,}4\ C_R\ L_D\ 10^{-6}$

where:

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.2] and Ch 9, Sec 1, [2.2.2], as the case may be

L_D : Length of rudder post, in m.

Figure 1 : Integral rudder post



6.5 Propeller shaft bossing

6.5.1 In single screw ships, the thickness of the propeller shaft bossing, included in the propeller post, is to be not less than 60% of the dimension "b" required in [6.3.2] for bar propeller posts with a rectangular section.

6.6 Rudder gudgeon

6.6.1 Rudder gudgeons

In general, gudgeons are to be solidly forged or cast with the sternframe.

The height of the gudgeon is to be not greater than 1,2 times the pintle diameter. In any case, the height and diameter of the gudgeons are to be suitable to house the rudder pintle.

The thickness of the metal around the finished bore of the gudgeons is to be not less than half the diameter of the pintle.

6.7 Sterntubes

6.7.1 The sterntube thickness is considered by the Society on a case-by-case basis. In no case, however, may it be less than the thickness of the side plating adjacent to the sternframe.

Where the materials adopted for the sterntube and the plating adjacent to the sternframe are different, the sterntube thickness is to be at least equivalent to that of the plating.

Section 3 Machinery Space

Symbols

L_2 : Length, in m, defined in Ch 1, Sec 2, [2.1.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3]

s : Spacing, in m, of ordinary stiffeners

P : Maximum power, in kW, of the engine

n_r : Number of revolutions per minute of the engine shaft at power equal to P

L_E : Effective length, in m, of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the arrangement and scantling of machinery space structures as regards general strength. It is no substitute to machinery manufacturer's requirements which have to be dealt with at Shipyard diligence.

1.2 Scantlings

1.2.1 Net scantlings

As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.2.2 General

Unless otherwise specified in this Section, the scantlings of plating, ordinary stiffeners and primary supporting members in the machinery space are to be determined according to the relevant criteria in Part B, Chapter 7 as applicable. In addition, the minimum thickness requirements specified in this Section apply.

1.2.3 Primary supporting members

The Designer may propose arrangements and scantlings alternative to the requirements of this Section, on the basis of direct calculations which are to be submitted to the Society for examination on a case-by-case basis.

The Society may also require such direct calculations to be carried out whenever deemed necessary.

1.3 Connections of the machinery space with structures located aft and forward

1.3.1 Tapering

Adequate tapering is to be ensured between the scantlings in the machinery space and those aft and forward. The tapering is to be such that the scantling requirements for all areas are fulfilled.

1.3.2 Deck discontinuities

Decks which are interrupted in the machinery space are to be tapered on the side by means of horizontal brackets.

2 Double bottom

2.1 Arrangement

2.1.1 General

Where the machinery space is immediately forward of the after peak, the double bottom is generally to be transversely framed. In all other cases it may be transversely or longitudinally framed.

2.1.2 Double bottom height

The double bottom height at the centreline, irrespective of the location of the machinery space, is to be not less than the value defined in Ch 4, Sec 4, [4.2.1]. This depth may need to be considerably increased in relation to the type and depth of main machinery seatings.

The above height is to be increased by the Shipyard where the machinery space is very large and where there is a considerable variation in draught between light ballast and full load conditions.

Where the double bottom height in the machinery space differs from that in adjacent spaces, structural continuity of longitudinal members is to be ensured by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the sloped inner bottom are to be located close to the floors.

2.1.3 Centre bottom girder

In general, the centre bottom girder may not be provided with holes. In any case, in way of any openings for manholes on the centre girder, permitted only where absolutely necessary for double bottom access and maintenance, local strengthening is to be arranged.

2.1.4 Side bottom girders

In the machinery space the number of side bottom girders is to be adequately increased, with respect to the adjacent areas, to ensure adequate rigidity of the structure.

The side bottom girders are to be a continuation of any bottom longitudinals in the areas adjacent to the machinery space and are generally to have a spacing not greater than 3 times that of longitudinals and in no case greater than 3 m.

2.1.5 Side bottom girders in way of machinery seatings

Additional side bottom girders are to be fitted in way of machinery seatings.

Side bottom girders arranged in way of main machinery seatings are to extend for the full length of the machinery space.

Where the machinery space is situated amidships, the bottom girders are to extend aft of the after bulkhead of such space for at least three frame spaces, and beyond to be connected to the hull structure by tapering.

Where the machinery space is situated aft, the bottom girders are to extend as far aft as practicable in relation to the shape of the bottom and to be supported by floors and side primary supporting members at the ends.

Forward of the machinery space forward bulkhead, the bottom girders are to be tapered for at least three frame spaces and are to be effectively connected to the hull structure.

2.1.6 Floors in longitudinally framed double bottom

Where the double bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery space.

Additional floors are to be fitted in way of other important machinery.

2.1.7 Floors in transversely framed double bottom

Where the double bottom in the machinery space is transversely framed, floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

2.1.8 Floors stiffeners

In addition to the requirements in Ch 4, Sec 3, [4.7], floors are to have web stiffeners sniped at the ends and spaced not more than approximately 1 m apart.

The section modulus of web stiffeners is to be not less than 1,2 times that required in Ch 4, Sec 3, [4.7].

2.1.9 Manholes and wells

The number and size of manholes in floors located in way of seatings and adjacent areas are to be kept to the minimum necessary for double bottom access and maintenance.

The depth of manholes is generally to be not greater than 40% of the floor local depth, and in no case greater than 750 mm, and their width is to be equal to approximately 400 mm.

In general, manhole edges are to be stiffened with flanges; failing this, the floor plate is to be adequately stiffened with flat bars at manhole sides.

Manholes with perforated portable plates are to be fitted in the inner bottom in the vicinity of wells arranged close to the aft bulkhead of the engine room.

Drainage of the tunnel is to be arranged through a well located at the aft end of the tunnel.

2.2 Minimum thicknesses

2.2.1 The net thicknesses of inner bottom, floor and girder webs are to be not less than the values given in Tab 1.

The Society may consider lower thicknesses than those in Tab 1, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all type s of loading cases.

Table 1 : Double bottom - Minimum net thicknesses of inner bottom, floors and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Inner bottom	$[0,75\ L^{1/2} + 1,35 + 4,5\ (s - 0,23\ L^{1/4})]\ k^{1/2}$ The Society may require the thickness of the inner bottom in way of the main machinery seatings and on the main thrust blocks to be increased, on a case-by-case basis	
Margin plate	$L^{1/2}\ k^{1/4} + 1$	$0,9\ L^{1/2}\ k^{1/4} + 1$
Centre girder	$1,8\ L^{1/3}\ k^{1/6} + 4$	$1,55\ L^{1/3}\ k^{1/6} + 3,5$
Floors and side girders	$1,7\ L^{1/3}\ k^{1/6} + 1$	
Girder bounding a duct keel	$0,8\ L^{1/2}\ k^{1/4} + 2,5$ to be taken not less than that required for the centre girder	

3 Single bottom

3.1 Arrangement

3.1.1 Bottom girder

For single bottom girder arrangement, the requirements of Ch 4, Sec 4, [2.1] and Ch 4, Sec 4, [3.1] apply for longitudinally framed and transversely framed single bottoms respectively.

3.1.2 Floors in longitudinally framed single bottom

Where the single bottom is longitudinally framed, the floor spacing is to be not greater than:

- 1 frame spacing in way of the main engine and thrust bearing
- 2 frame spacings in other areas of the machinery spaces.

Additional floors are to be fitted in way of other important machinery.

3.1.3 Floors in transversely framed single bottom

Where the single bottom is transversely framed, the floors are to be arranged at every frame.

Furthermore, additional floors are to be fitted in way of boiler foundations or other important machinery.

3.1.4 Floor height

The height of floors in way of machinery spaces located amidships is to be not less than B/14,5. Where the top of the floors is recessed in way of main machinery, the height of the floors in way of this recess is generally to be not less than B/16. Lower values will be considered by the Society on a case-by-case basis.

Where the machinery space is situated aft or where there is considerable rise of floor, the depth of the floors will be considered by the Society on a case-by-case basis.

3.1.5 Floor flanging

Floors are to be fitted with welded face plates in way of:

- engine bed plates
- thrust blocks
- auxiliary seatings.

3.2 Minimum thicknesses

3.2.1 The net thicknesses of floor and girder webs are to be not less than the values given in Tab 2.

The Society may consider lower thicknesses than those in Tab 2, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all types of loading cases.

Table 2 : Single bottom Minimum net thicknesses of floors and girder webs

Element	Minimum net thickness, in mm	
	Machinery space within 0,4L amidships	Machinery space outside 0,4L amidships
Centre girder	$7 + 0,05\ L_2\ k^{1/2}$	$6 + 0,05\ L_2\ k^{1/2}$
Floors and side girders	$6,5 + 0,05\ L_2\ k^{1/2}$	$5 + 0,05\ L_2\ k^{1/2}$

4 Side

4.1 Arrangement

4.1.1 General

The type of side framing in machinery spaces is generally to be the same as that adopted in the adjacent areas.

4.1.2 Extension of the hull longitudinal structure within the machinery space

In ships where the machinery space is located aft and where the side is longitudinally framed, the longitudinal structure is preferably to extend for the full length of the machinery space.

In any event, the longitudinal structure is to be maintained for at least 0,3 times the length of the machinery space, calculated from the forward bulkhead of the latter, and abrupt structural discontinuities between longitudinally and transversely framed structures are to be avoided.

4.1.3 Side transverses

Side transverses are to be aligned with floors. One is preferably to be located in way of the forward end and another in way of the after end of the machinery casing.

For a longitudinally framed side, the side transverse spacing is to be not greater than 4 frame spacings.

For a transversely framed side, the side transverse spacing is to be not greater than 5 frame spaces. The web height is to be not less than twice that of adjacent frames and the section modulus is to be not less than four times that of adjacent frames.

Side transverse spacing greater than that above may be accepted provided that the scantlings of ordinary frames are increased, according to the Society's requirements to be defined on a case-by-case basis.

5 Platforms

5.1 Arrangement

5.1.1 General

The location and extension of platforms in machinery spaces are to be arranged so as to be a continuation of the structure of side longitudinals, as well as of platforms and side girders located in the adjacent hull areas.

5.1.2 Platform transverses

In general, platform transverses are to be arranged in way of side or longitudinal bulkhead transverses.

For longitudinally framed platforms, the spacing of platform transverses is to be not greater than 4 frame spacings.

5.2 Minimum thicknesses

5.2.1 The net thickness of platforms is to be not less than that obtained, in mm, from the following formula:

$t = 0{,}018\ L_2\ k^{1/2} + 4{,}5$

The Society may consider lower thicknesses, on a case-by-case basis, based on scantling calculations with appropriate loadings.

6 Pillaring

6.1 Arrangement

6.1.1 General

The pillaring arrangement in machinery spaces is to account both for the concentrated loads transmitted by machinery and superstructures and for the position of main machinery and auxiliary engines.

6.1.2 Pillars

Pillars are generally to be arranged in the following positions:

- in way of machinery casing corners and corners of large openings on platforms; alternatively, two pillars may be fitted on the centreline (one at each end of the opening)
- in way of the intersection of platform transverses and girders
- in way of transverse and longitudinal bulkheads of the superstructure.

In general, pillars are to be fitted with brackets at their ends.

6.1.3 Pillar bulkheads

In general, pillar bulkheads, fitted 'tweendecks below the upper deck, are to be located in way of load-bearing bulkheads in the superstructures.

Longitudinal pillar bulkheads are to be a continuation of main longitudinal hull structures in the adjacent spaces forward and aft of the machinery space.

Pillar bulkhead scantlings are to be not less than those required in [7.3] for machinery casing bulkheads.

7 Machinery casing

7.1 Arrangement

7.1.1 Ordinary stiffener spacing

Ordinary stiffeners are to be located:

- at each frame, in longitudinal bulkheads
- at a distance of about 750 mm, in transverse bulkheads.

The ordinary stiffener spacing in portions of casings which are particularly exposed to wave action is considered by the Society on a case-by-case basis.

7.2 Openings

7.2.1 General

All machinery space openings, which are to comply with the requirements in Ch 8, Sec 9, [6], are to be enclosed in a steel casing leading to the highest open deck. Lower parts of casings are to be reinforced at the ends by deck beams and girders associated to pillars.

In the case of large openings, the arrangement of cross-ties as a continuation of deck beams may be required.

7.2.2 Access doors

Access doors to casings are to comply with Ch 8, Sec 9, [6.2].

7.3 Scantlings

7.3.1 Plating and ordinary stiffeners

The net scantlings of plating and ordinary stiffeners are to be not less than those obtained according to the applicable requirements in Ch 8, Sec 4.

7.3.2 Minimum thicknesses

The net thickness of bulkheads is to be not less than:

- 5,5 mm for bulkheads in way of cargo holds
- 4,0 mm for bulkheads in way of accommodation spaces.

The Society may consider lower thicknesses, on a case-by-case basis, based on scantling calculations with appropriate loadings.

8 Main machinery seatings

8.1 Arrangement

8.1.1 General

The scantlings of main machinery seatings and thrust bearings are to be adequate in relation to the weight and power of engines and the static and dynamic forces transmitted by the propulsive installation.

8.1.2 Seating supporting structure

Transverse and longitudinal members supporting the seatings are to be located in line with floors and double or single bottom girders, respectively.

They are to be so arranged as to avoid discontinuity and ensure sufficient accessibility for welding of joints and for surveys and maintenance.

8.1.3 Seatings included in the double bottom structure

Where high-power internal combustion engines or turbines are fitted, seatings are to be integral with the double bottom structure. Girders supporting the bedplates in way of seatings are to be aligned with double bottom girders and are to be extended aft in order to form girders for thrust blocks.

The girders in way of seatings are to be continuous from the bedplates to the bottom shell.

8.1.4 Seatings above the double bottom plating

Where the seatings are situated above the double bottom plating, the girders in way of seatings are to be fitted with flanged brackets, generally located at each frame and extending towards both the centre of the ship and the sides.

The extension of the seatings above the double bottom plating is to be limited as far as practicable while ensuring adequate spaces for the fitting of bedplate bolts. Bolt holes are to be located such that they do not interfere with seating structures.

8.1.5 Seatings in a single bottom structure

For ships having a single bottom structure within the machinery space, seatings are to be located above the floors and to be adequately connected to the latter and to the girders located below.

8.1.6 Number of girders in way of machinery seatings

In general, at least two girders are to be fitted in way of main machinery seatings.

One girder may be fitted only where the following three formulae are complied with:

$L < 150$ m

$P < 7100$ kW

$P < 2{,}3\ n_r\ L_E$

8.2 Minimum scantlings

8.2.1 The net scantlings of the structural elements in way of the internal combustion engine seatings are to be not less than those obtained from the formulae in Tab 3.

Table 3 : Minimum scantlings of structural elements in way of engine seatings

Scantling	Minimum value
Net cross-sectional area, in cm², of each bedplate of the seatings	$40 + 70\dfrac{P}{n_r L_E}$
Net thickness, in mm, of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\sqrt{240 + 175\dfrac{P}{n_r L_E}}$ • Bedplate supported by one longitudinal member: $5 + \sqrt{240 + 175\dfrac{P}{n_r L_E}}$
Web net thickness, in mm, of longitudinal members fitted in way of each bedplate of the seatings	• Bedplate supported by two or more longitudinal members: $\dfrac{1}{n_G}\sqrt{320 + 215\dfrac{P}{n_r L_E}}$ where n_G is the number of longitudinal members in way of the bedplate considered • Bedplate supported by one longitudinal member: $\sqrt{95 + 65\dfrac{P}{n_r L_E}}$
Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating**(1)**	$\sqrt{55 + 40\dfrac{P}{n_r L_E}}$
(1) When intermediate transverse members welded to the bedplate are fitted, the web minimum net thickness may be reduced on a case-by-case basis.	

Section 4 Superstructures and Deckhouses

Symbols

x, y, z : X, Y and Z co-ordinates, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 2, [10]

s : Spacing, in m, of ordinary stiffeners

k : Material factor, defined in:
- Ch 4, Sec 1, [2.3], for steel
- Ch 4, Sec 1, [4.4], for aluminium alloys

t_c : Corrosion addition, in mm, defined in Ch 4, Sec 2, Tab 2.

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the scantling of plating and associated structures of front, side and aft bulkheads and decks of superstructures and deckhouses, which may or may not contribute to the longitudinal strength.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Definitions

1.3.1 Superstructures and deckhouses contributing to the longitudinal strength

Superstructures and deckhouses contributing to the longitudinal strength are defined in Ch 6, Sec 1, [2.2].

1.3.2 Tiers of superstructures and deckhouses

The lowest tier is normally that which is directly situated above the main watertight deck.

Where the difference of height between the deepest subdivision loadline and the watertight deck exceeds the value given, in m, by the following formula:

1,80 + 0,01 (L – 75) to be taken neither less than 1,80 m, nor greater than 2,30 m, the lowest tier may be considered as an upper tier when calculating the scantlings of superstructures and deckhouses.

The second tier is that located immediately above the lowest tier, and so on.

1.4 Connections of superstructures and deckhouses with the hull structure

1.4.1 Superstructure and deckhouse frames are to be fitted as far as practicable as extensions of those underlying and are to be effectively connected to both the latter and the deck beams above.

Ends of superstructures and deckhouses are to be efficiently supported by bulkheads, diaphragms, webs or pillars.

Where hatchways are fitted close to the ends of superstructures, additional strengthening may be required.

1.4.2 Connection to the deck of corners of superstructures and deckhouses is considered by the Society on a case-by-case basis. Where necessary, doublers or reinforced welding may be required.

1.4.3 As a rule, the frames of sides of superstructures and deckhouses are to have the same spacing as the beams of the supporting deck.

Web frames are to be arranged to support the sides and ends of superstructures and deckhouses.

1.4.4 The side plating at ends of superstructures is to be tapered into the bulwark or sheerstrake of the strength deck.

Where a raised deck is fitted, this arrangement is to extend over at least 3 frame spacings.

1.5 Structural arrangement of superstructures and deckhouses

1.5.1 Strengthening in way of superstructures and deckhouses

Web frames, transverse partial bulkheads or other equivalent strengthening are to be fitted inside deckhouses of at least 0,5 B in breadth extending more than 0,15 L in length within 0,4 L amidships. These transverse strengthening reinforcements are to be spaced approximately 9 m apart and are to be arranged, where practicable, in line with the transverse bulkheads below.

Web frames are also to be arranged in way of large openings, boats davits and other areas subjected to point loads.

Web frames, pillars, partial bulkheads and similar strengthening are to be arranged, in conjunction with deck transverses, at ends of superstructures and deckhouses.

1.5.2 Strengthening of the raised quarter deck stringer plate

When a superstructure is located above a raised quarter deck, the thickness of the raised quarter deck stringer plate is to be increased by 30% and is to be extended within the superstructure.

The increase above may be reduced when the raised quarter deck terminates outside 0,5 L amidships.

1.5.3 Openings

Openings are to be in accordance with Ch 6, Sec 1.

Continuous coamings are to be fitted above and below doors or similar openings.

1.5.4 Access and doors

Access openings cut in sides of enclosed superstructures are to be fitted with doors made of steel or other equivalent material, and permanently attached.

Special consideration is to be given to the connection of doors to the surrounding structure.

Securing devices which ensure watertightness are to include tight gaskets, clamping dogs or other similar appliances, and are to be permanently attached to the bulkheads and doors. These doors are to be operable from both sides.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Stiffening of sides of deckhouses in way of lifeboats and rescue boats is to be compatible with the launching operation. Deckhouses in way of launching appliances are to be adequately strengthened.

1.5.6 Constructional details

Lower tier stiffeners are to be welded to the decks at their ends.

Brackets are to be fitted at the upper and preferably also the lower ends of vertical stiffeners of exposed front bulkheads of engine casings and superstructures or deckhouses protecting pump room openings.

1.5.7 Use of aluminium alloys

Unprotected front bulkheads of first tier superstructures or deckhouses are generally to be built of steel and not of aluminium alloy.

Aluminium alloys may be adopted for front bulkheads of superstructures or deckhouses above the first tier.

2 Design loads

2.1 Sides contributing to the longitudinal strength

2.1.1 Load point

Lateral pressure is to be calculated at:

- the lower edge of the elementary plate panel, for plating
- mid-span, for stiffeners.

2.1.2 Lateral pressure

The lateral pressure is constituted by the still water sea pressure p_S and the wave pressure p_W, defined in Ch 5, Sec 5.

Moreover, when the side is a tank boundary, the lateral pressure constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [1] is also to be considered.

2.2 Front, side and aft bulkheads not contributing to the longitudinal strength

2.2.1 Load point

Lateral pressure is to be calculated at:

- mid-height of the bulkhead, for plating
- mid-span, for stiffeners.

2.2.2 Lateral pressure

The lateral pressure to be used for the determination of scantlings of the structure of front, side and aft bulkheads of superstructures and deckhouses is to be obtained, in kN/m², from the following formula:

$p = 10\ a\ c\ [b\ f - (z - T)]$

without being less than p_{min}

where:

a : Coefficient defined in Tab 1

c : Coefficient taken equal to:

$$c = 0{,}3 + 0{,}7\frac{b_1}{B_1}$$

For exposed parts of machinery casings, c is to be taken equal to 1

b_1 : Breadth of deckhouse, in m, at the position considered, to be taken not less than 0,25 B_1

B_1 : Actual maximum breadth of ship on the exposed weather deck, in m, at the position considered

b : Coefficient defined in Tab 2

f : Coefficient defined in Tab 3

p_{min} : Minimum lateral pressure defined in Tab 4.

2.3 Decks

2.3.1 The lateral pressure for decks which may or may not contribute to the longitudinal strength is constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [5] or Ch 5, Sec 6, [6] as applicable.

Moreover, when the deck is a tank boundary, the lateral pressure constituted by the still water internal pressure p_S and the inertial pressure p_W, defined in Ch 5, Sec 6, [1] is also to be considered.

Table 1 : Lateral pressure for superstructures and deckhouses - Coefficient a

Type of bulkhead	Location	a	a maximum
Unprotected front	Lowest tier	$2 + \frac{L}{120}$	4,5
	Second tier	$1 + \frac{L}{120}$	3,5
	Third tier	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Protected front	Lowest, second and third tiers	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Side	Lowest, second and third tiers	$0{,}5 + \frac{L}{150}$	2,5
	Fourth tier	$0{,}9\left(0{,}5 + \frac{L}{150}\right)$	2,25
	Fifth tier and above	$0{,}8\left(0{,}5 + \frac{L}{150}\right)$	2,0
Aft end	All tiers, when: $x/L \leq 0{,}5$	$0{,}7 + \frac{L}{1000} - 0{,}8\frac{x}{L}$	$1 - 0{,}8\frac{x}{L}$
	All tiers, when: $x/L > 0{,}5$	$0{,}5 + \frac{L}{1000} - 0{,}4\frac{x}{L}$	$0{,}8 - 0{,}4\frac{x}{L}$

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bulkhead **(1)**	b
$\frac{x}{L} \le 0{,}45$	$1 + \left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right)^2$
$\frac{x}{L} > 0{,}45$	$1 + 1{,}5\left(\frac{\frac{x}{L} - 0{,}45}{C_B + 0{,}2}\right)^2$

(1) For deckhouse sides, the deckhouse is to be subdivided into parts of approximately equal length, not exceeding 0,15 L each, and x is to be taken as the co-ordinate of the centre of each part considered.

Note 1:

C_B : Block coefficient, with $0{,}6 \le C_B \le 0{,}8$

Table 3 : Lateral pressure for superstructures and deckhouses - Coefficient f

Length L of ship, in m	f
$L < 150$	$\frac{L}{10}e^{-L/300} - \left[1 - \left(\frac{L}{150}\right)^2\right]$
$150 \le L < 300$	$\frac{L}{10}e^{-L/300}$
$L \ge 300$	11,03

Table 4 : Minimum lateral pressurefor superstructures and deckhouses

Location and type of bulkhead	p_{min}, in kN/m²
Lowest tier of unprotected fronts	$30 \le 25{,}0 + 0{,}10L \le 50$
Elsewhere:	
• if $z \le T + 0{,}5\ B\ A_R + 0{,}5\ h_w$	$15 \le 12{,}5 + 0{,}05\ L \le 25$
• if $T + 0{,}5\ B\ A_R + 0{,}5\ h_w < z$ and $z \le T + 0{,}5\ B\ A_R + h_w$	linear interpolation
• if $z > T + 0{,}5\ B\ A_R + h_w$	2,5

Note 1:

A_R : Roll amplitude, in rad, defined in Ch 5, Sec 3, [2.4] or taken equal to 0,35 for ships less than 65 m in length

h_w : Wave parameter, in m, defined in Ch 5, Sec 3.

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating contributing to the longitudinal strength

The net thickness of side plate panels contributing to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1, as applicable, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating not contributing to the longitudinal strength

The net thickness of plating of front, side and aft bulkheads not contributing to the longitudinal strength is to be not less than the value obtained, in mm, from the following formula:

$$t = 0{,}95s\sqrt{kp} - t_c$$

without being less than the values indicated in Tab 5, where p is the lateral pressure, in kN/m², defined in [2.2].

The Society may consider lower thicknesses than those in Tab 5, on a case-by-case basis, when this is deemed appropriate on the basis of scantling calculations for all types of loading cases.

For plating which forms tank boundaries, the net thickness is to be determined in accordance with [3.1.1], considering the hull girder stress equal to 0.

Table 5 : Superstructures and deckhouses - Minimum thicknesses

Location	Minimum thickness, in mm
Lowest tier	$k_1\ (5 + 0{,}01\ L)\ k^{1/2} - t_C$
Second tier and above	$k_1\ (4 + 0{,}01\ L)\ k^{1/2} - t_C$
Note 1: L is to be taken not less than 100 m and not greater than 300 m. k_1 : • for steel: $k_1 = 1{,}00$ • for aluminium: $k_1 = 0{,}65$	

3.2 Decks

3.2.1 The net thickness of plate panels of decks which may or may not contribute to the longitudinal strength is to be determined in accordance with the applicable requirements of Ch 7, Sec 1 or Ch 8, Sec 3, as applicable.

3.2.2 For decks sheathed with wood, the net thickness obtained from [3.2.1] may be reduced by 10 percent.

4 Ordinary stiffeners

4.1 Front, side and aft bulkheads

4.1.1 Ordinary stiffeners of plating contributing to the longitudinal strength

The net scantlings of ordinary stiffeners of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

4.1.2 Ordinary stiffeners of plating not contributing to the longitudinal strength

The net section modulus w of ordinary stiffeners of plating not contributing to the longitudinal strength is to be not less than the value obtained, in cm^3, from the following formula:

$$w = 0{,}35\ \varphi\ k\ s\ \ell^2\ p\ (1 - \alpha\ t_c) - \beta\ t_c$$

where:

ℓ : Span of the ordinary stiffener, in m, equal to the ‘tweendeck height and to be taken not less than 2 m

p : Lateral pressure, in kN/m^2, defined in [2.2.2]

φ : Coefficient depending on the stiffener end connections, and taken equal to:

- 1 for lower tier stiffeners
- value defined in Tab 6 for stiffeners of upper tiers

α, β : Parameters defined in Ch 4, Sec 2, Tab 1.

The section modulus of side ordinary stiffeners need not be greater than that of the side ordinary stiffeners of the tier situated directly below taking account of spacing and span.

For ordinary stiffeners of plating forming tank boundaries, the net scantlings are to be determined in accordance with [4.1.1], considering the hull girder stress equal to 0.

In addition, the net section modulus, in cm^3, of ordinary stiffeners is not to be less than the values given in Tab 7.

4.2 Decks

4.2.1 The net scantlings of ordinary stiffeners of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 2.

Table 6 : Stiffeners of superstructures and deckhouses - Coefficient φ for end connections

Coefficient φ	Upper end welded to deck	Bracketed upper end	Sniped upper end
Lower end welded to deck	1,00	0,85	1,15
Bracketed lower end	0,85	0,85	1,00
Sniped lower end	1,15	1,00	1,15

Table 7 : Minimum ordinary stiffener section modulus (cm^3)

	Lowest tier	Second tier	Third tier	Fourth tier and above
Unprotected front	30 $k^{0.25}$	21 $k^{0.25}$	15 $k^{0.25}$	10 $k^{0.25}$
Side	20 $k^{0.25}$	14 $k^{0.25}$	10 $k^{0.25}$	
Aft end and protected front	27 $k^{0.25}$	19 $k^{0.25}$	13 $k^{0.25}$	

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of plating contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable.

5.1.2 Primary supporting members of plating not contributing to the longitudinal strength

The net scantlings of side primary supporting members of plating not contributing to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3, as applicable, using the lateral pressure defined in [2.2.2].

5.2 Decks

5.2.1 The net scantlings of primary supporting members of decks which may or may not contribute to the longitudinal strength are to be determined in accordance with the applicable requirements of Ch 7, Sec 3.

Section 5 Bow Doors and Inner Doors

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of bow doors and inner doors leading to a complete or long forward enclosed superstructure.

1.1.2 Two types of bow doors are provided for:

- visor doors opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary supporting members of the door by longitudinally arranged lifting arms
- side-opening doors opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the ship. It is anticipated that side-opening bow doors are arranged in pairs.

Other types of bow door are considered by the Society on a case-by-case basis in association with the applicable requirements of this Section.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Bow doors are to be situated above the watertight deck. A watertight recess in the watertight deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the watertight deck for the purpose of this requirement.

1.3.2 An inner door is to be fitted as part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, as per Ch 2, Sec 1, [3.1].

A vehicle ramp may be arranged for this purpose, provided its position complies with Ch 2, Sec 1, [3.1].

If this is not possible, a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

1.3.3 Bow doors are to be so fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors.

Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

1.3.4 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in [1.3.2].

1.3.5 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in stowed position.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Bow doors

2.1.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members and securing and supporting devices of bow doors is to be not less than that obtained, in kN/m², from the following formula:

$$p_E = 0,5 C_L C_Z (0,22 + 0,15 \tan\alpha)(0,4 V \sin\beta + 0,6\sqrt{L_1})^2$$

where:

V : Maximum ahead service speed, in knots

C_L : Coefficient depending on the ship length:

$C_L = 0,0125\ L$ for $L < 80$ m

$C_L = 1,0$ for $L \geq 80$ m

C_Z : Coefficient defined in Ch 8, Sec 1, [4.2.1], to be taken equal to 5,5

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the side plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1)

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1).

2.1.2 Design external forces

The design external forces F_X, F_Y, F_Z to be considered for the scantlings of securing and supporting devices of bow doors are to be not less than those obtained, in kN, from the following formulae:

$F_X = p_E A_X$

$F_Y = p_E A_Y$

$F_Z = p_E A_Z$

where:

p_E : External pressure, in kN/m², to be calculated according to [2.1.1], assuming the angles α and β measured at the point on the bow door located $\ell/2$ aft of the stem line on the plane h/2 above the bottom of the door, as shown in Fig 1

h : Height, in m, to be taken as the lesser of h_1 and h_2

h_1 : Height, in m, of the door between the levels of its bottom and the upper deck

h_2 : Height, in m, of the door between its bottom and top

ℓ : Length, in m, of the door at a height h/2 above the bottom of the door

A_X : Area, in m², to be taken as the lesser of A_{X1} and A_{X2}

A_Y : Area, in m², to be taken as the lesser of A_{Y1} and A_{Y2}

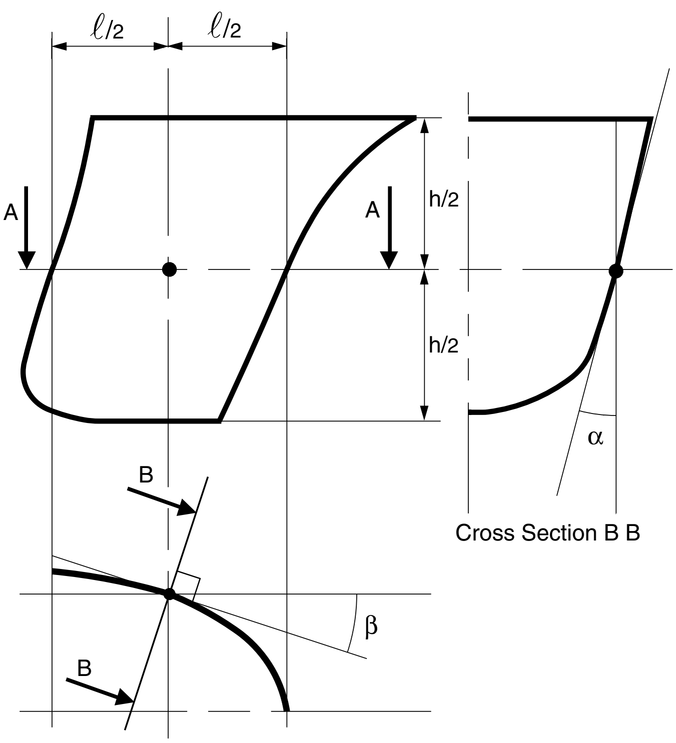
A_Z : Area, in m², to be taken as the lesser of A_{Z1} and A_{Z2}

A_{X1}, A_{Y1}, A_{Z1} : Areas, in m², of the vertical transverse, vertical longitudinal and horizontal projections, respectively, of the door between the levels of its bottom and the upper deck

A_{X2}, A_{Y2}, A_{Z2} : Areas, in m², of the vertical transverse, vertical longitudinal and horizontal projections, respectively, of the door between the levels of its bottom and top.

For bow doors, including bulwark, of unusual form or proportions, e.g. ships with a rounded nose and large stem angles, the areas and angles used for determination of the design values of external forces will be considered on a case-by-case basis.

Figure 1 : Definition of angles α and β



2.1.3 Closing moment

For visor doors, the closing moment under external loads is to be obtained, in kN·m, from the following formula:

$M_Y = F_X\ a + 10\ W\ c - F_Z\ b$

where:

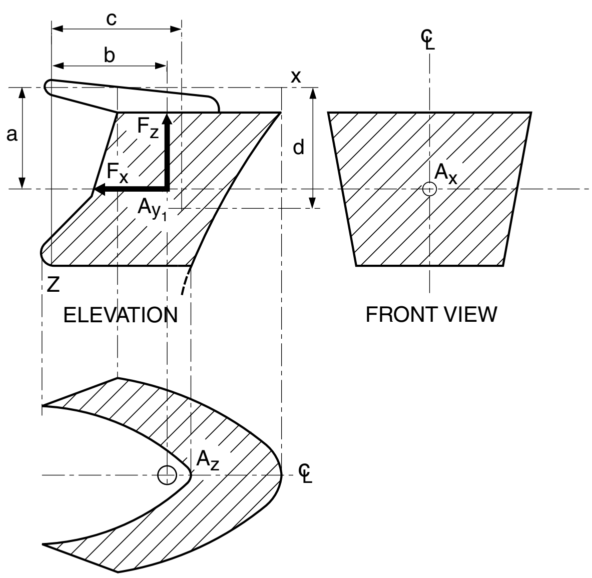
W : Mass of the visor door, in t

a : Vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig 2

b : Horizontal distance, in m, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig 2

c : Horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig 2.

Figure 2 : Bow doors of visor type



2.1.4 Forces acting on the lifting arms

The lifting arms of a visor door and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken into account.

2.2 Inner doors

2.2.1 Design external pressure

The design external pressure to be considered for the scantlings of primary supporting members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of the values obtained, in kN/m^2, from the following formulae:

$p_E = 0,45\ L_1$

$p_E = 10\ h$

where:

h : Distance, in m, from the calculation point to the top of the cargo space.

2.2.2 Design internal pressure

The design internal pressure p_I to be considered for the scantlings of securing devices of inner doors is to be not less than 25 kN/m^2.

3 Scantlings of bow doors

3.1 General

3.1.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

3.1.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed.

For visor doors, adequate strength for opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the ship structure.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the bow door plating is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing. In no case may it be less than the minimum required thickness of fore part shell plating.

3.2.2 Ordinary stiffeners

The section modulus of bow door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 8, Sec 1 for the fore part, using the bow door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of bow doors and those of the fore part shell.

3.3 Primary supporting members

3.3.1 Bow door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4 Scantlings of inner doors

4.1 General

4.1.1 The gross scantlings of the primary supporting members are generally to be verified through direct calculations on the basis of the external pressure p_E in [2.1.1] and the strength criteria in [6.1.1] and [6.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4.1.2 Where inner doors also serve as vehicle ramps, their scantlings are to be not less than those obtained according to Ch 8, Sec 8.

4.1.3 The distribution of the forces acting on the securing and supporting devices is generally to be supported by direct calculations taking into account the flexibility of the structure and the actual position and stiffness of the supports.

5 Securing and supporting of bow doors

5.1 General

5.1.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case-by-case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

5.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [5.2.5].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [5.2.6] and [5.2.7]and the available space for adequate support in the hull structure.

5.1.3 For visor doors which open outwards, the pivot arrangement is generally to be such that the visor is self-closing under external loads, i.e. it is to be checked that the closing moment M_Y, defined in [2.1.3], is in compliance with the following formula:

$M_Y > 0$

Moreover, the closing moment M_Y is to be not less than the value M_{Y0} , in kN.m, obtained from the following formula:

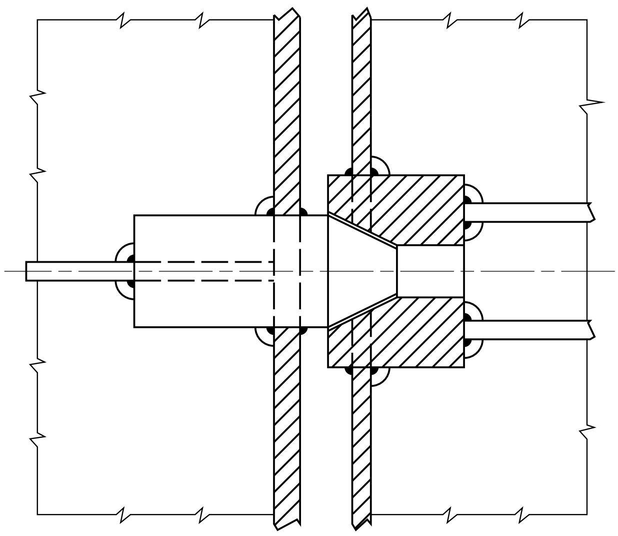
$$M_{Y0} = 10Wc + 0{,}1\sqrt{a^2+b^2}\sqrt{F_X^2+F_Z^2}$$

5.1.4 For side-opening doors, a thrust bearing is to be provided in way of girder ends at the closing of the two leaves to prevent one leaf from shifting towards the other under the effect of unsymmetrical pressure (see example in Fig 3).

The parts of the thrust bearing are to be kept secured to each other by means of securing devices.

The Society may consider any other arrangement serving the same purpose.

Figure 3 : Thrust bearing



5.2 Scantlings

5.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [6.1.1].

5.2.2 For visor doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X and F_Z
- Case 2: 0,7 F_Y acting on each side separately together with 0,7 F_X and 0,7 F_Z ,

where F_X, F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.3 For side-opening doors, the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

- Case 1: F_X , F_Y and F_Z acting on both doors
- Case 2: 0,7 F_X and 0,7 F_Z acting on both doors and 0,7 F_Y acting on each door separately,

where F_X , F_Y and F_Z are to be calculated as indicated in [2.1.2] and applied at the centroid of projected areas.

5.2.4 The support forces as calculated according to Case 1 in [5.2.2] and Case 1 in [5.2.3] are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_X .

For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be in the forward direction.

5.2.5 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

5.2.6 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [6.1.1].

5.2.7 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the allowable stresses defined in [6.1.1].

The opening moment M_0 to be balanced by this reaction force is to be taken not less than that obtained, in kN.m, from the following formula:

$M_0 = 10\ W\ d + 5\ A_X\ a$

where:

d : Vertical distance, in m, from the hinge axis to the centre of gravity of the door, as shown in Fig 2

a : Vertical distance, in m, defined in [2.1.3].

5.2.8 For visor doors, the securing and supporting devices excluding the hinges are to be capable of resisting the vertical design force (F_Z – 10 W), in kN, within the allowable stresses defined in [6.1.1].

5.2.9 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices.

6 Strength criteria

6.1 Primary supporting members and securing and supporting devices

6.1.1 Yielding check

It is to be checked that the normal stresses σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of bow doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \le \sigma_{ALL}$

$\tau \le \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \le \sigma_{VM,ALL}$

where:

σ_{ALL} : Allowable normal stress, in N/mm², equal to: $\sigma_{ALL} = 120 / k$

τ_{ALL} : Allowable shear stress, in N/mm², equal to: $\tau_{ALL} = 80 / k$

$\sigma_{VM,ALL}$: Allowable equivalent stress, in N/mm^2, equal to: $\sigma_{VM,ALL} = 150 / k$

k : Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

6.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [5].

6.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm^2, is in compliance with the following formula:

$\sigma_B \leq 0,8\ R_{e,HB}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

F : Design force, in kN, defined in [2.1.2]

A_B : Projected bearing area, in cm^2

$R_{e,HB}$: Yield stress, in N/mm^2, of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

6.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm^2, equal to: $\sigma_{T,ALL} = 125 / k$

k : Material coefficient defined in [6.1.1].

7 Securing and locking arrangement

7.1 Systems for operation

7.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

7.1.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the main watertight deck, of:

- the closing and opening of the doors, and
- associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorized persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

7.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7.2 Systems for indication/monitoring

7.2.1 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned.

The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

7.2.2 The indicator system is to be designed on the fail safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured.

The power supply for the indicator system is to be independent of the power supply for operating and closing the doors.

The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

7.2.3 The indication panel on the navigation bridge is to be equipped with a mode selection function “harbour/sea voyage”, so arranged that an audible alarm is given if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

7.2.4 A water leakage detection system with an audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

7.2.5 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room.

The system is to monitor the position of doors and a sufficient number of their securing devices.

Special consideration is to be given to the lighting and contrasting colour of the objects under surveillance.

7.2.6 The indicator system for the closure of the doors and the television surveillance systems for the doors and water leakage detection, and for special category and ro-ro spaces are to be suitable to operate correctly in the ambient conditions on board and to be type approved on the basis of the applicable tests.

7.2.7 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door, where fitted.

The system is to be equipped with an audible alarm providing an indication on the navigation bridge when the water level in these areas exceeds 0,5 m above the car deck level.

8 Operating and maintenance manual

8.1 General

8.1.1 An Operating and Maintenance Manual (OMM) for the bow door and inner door is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer’s recommended testing for equipment
   - description of equipment:
     - bow doors
     - inner bow doors
     - bow ramp/doors
     - central power pack
     - control panels.

b) service conditions:
   - limiting heel and trim of ship for loading/unloading
   - limiting heel and trim for door operations
   - doors/ramps operating instructions
   - doors/ramps emergency operating instructions.

c) maintenance:
   - schedule and extent of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer’s maintenance procedures.

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval. It is to be checked that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance/rejection criteria.

Note 1: It is recommended that inspections of the doors and supporting and securing devices be carried out by ship’s personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage found during such inspections is to be reported to the Society.

8.1.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

Section 6 Side Doors and Stern Doors

Symbols

L_1 : Length, in m, defined in Ch 1, Sec 2, [2.1.1].

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement, strength and securing of side doors, located below the bulkhead deck and abaft the collision bulkhead, and to stern doors located below the bulkhead deck.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangement

1.3.1 Side doors and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure.

1.3.2 Where the sill of any side door is below the uppermost load line, the arrangement is considered by the Society on a case-by-case basis.

1.3.3 Doors are preferably to open outwards.

1.4 Definitions

1.4.1 Securing device

A securing device is a device used to keep the door closed by preventing it from rotating about its hinges or about pivoted attachments to the ship.

1.4.2 Supporting device

A supporting device is a device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, which transmits loads from the door to the ship structure.

1.4.3 Locking device

A locking device is a device that locks a securing device in the closed position.

2 Design loads

2.1 Side and stern doors

2.1.1 Design forces

The design external forces F_E and the design internal forces F_I to be considered for the scantlings of primary supporting members and securing and supporting devices of side doors and stern doors are to be obtained, in kN, from the formulae in Tab 1.

Table 1 : Design forces

Structural elements	External force F_E, in kN	Internal force F_I, in kN
Securing and supporting devices of doors opening inwards	$A\ p_E + F_P$	$F_0 + 10\ W$
Securing and supporting devices of doors opening outwards	$A\ p_E$	$F_0 + 10\ W + F_P$
Primary supporting members **(1)**	$A\ p_E$	$F_0 + 10\ W$

(1) The design force to be considered for the scantlings of the primary supporting members is the greater of F_E and F_I.

Note 1:

- A : Area, in m², of the door opening
- W : Mass of the door, in t
- F_P : Total packing force, in kN; the packing line pressure is normally to be taken not less than 5 N/mm
- F_0 : The greater of F_C and 5 A, in kN
- F_C : Accidental force, in kN, due to loose cargoes etc., to be uniformly distributed over the area A and to be taken not less than 300 kN. For small doors such as bunker doors and pilot doors, the value of F_C may be appropriately reduced. However, the value of F_C may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes
- p_E : External design pressure determined at the centre of gravity of the door opening and to be taken not less than that obtained, in kN/m², from the following formulae:

  $p_E = 10\ (T - Z_G) + 25$ for $Z_G < T$

  $p_E = 25$ for $Z_G \geq T$

  Moreover, for stern doors of ships fitted with bow doors, p_E is to be taken not less than that obtained, in kN/m², from the following formula:

  $$p_E = 0{,}6 C_L (0{,}8 + 0{,}6\sqrt{L_1})^2$$
- T : Draught, in m, at the highest subdivision load line
- Z_G : Height of the centre of the area of the door, in m, above the baseline
- C_L : Coefficient depending on the ship length:

  $C_L = 0{,}0125\ L$ for $L < 80$ m

  $C_L = 1{,}0$ for $L \geq 80$ m.

3 Scantlings of side doors and stern doors

3.1 General

3.1.1 The strength of side doors and stern doors is to be commensurate with that of the surrounding structure.

3.1.2 Side doors and stern doors are to be adequately stiffened and means are to be provided to prevent any lateral or vertical movement of the doors when closed.

Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

3.1.3 Where doors also serve as vehicle ramps, the design of the hinges is to take into account the ship angle of trim and heel which may result in uneven loading on the hinges.

3.1.4 Shell door openings are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below.

3.2 Plating and ordinary stiffeners

3.2.1 Plating

The thickness of the door plating is to be not less than that obtained according to the requirements in Ch 7, Sec 1 for side plating, using the door stiffener spacing. In no case may it be less than the minimum required thickness of side plating.

Where doors also serve as vehicle ramps, the thickness of the door plating is to be not less than that obtained according to Ch 8, Sec 8.

3.2.2 Ordinary stiffeners

The scantling of door ordinary stiffeners is to be not less than that obtained according to the requirements in Ch 7, Sec 2 for the side, using the door stiffener spacing.

Consideration is to be given, where necessary, to differences in conditions of fixity between the ends of ordinary stiffeners of doors and those of the side.

Where doors also serve as vehicle ramps, the scantling of ordinary stiffeners is to be not less than that obtained according to Ch 8, Sec 8.

3.3 Primary supporting members

3.3.1 The door ordinary stiffeners are to be supported by primary supporting members constituting the main stiffening of the door.

3.3.2 The primary supporting members and the hull structure in way are to have sufficient stiffness to ensure structural integrity of the boundary of the door.

3.3.3 Scantlings of primary supporting members are generally to be verified through direct calculations on the basis of the design forces in [2.1.1] and the strength criteria in [5.1.1] and [5.1.2].

In general, isolated beam models may be used to calculate the loads and stresses in primary supporting members.

4 Securing and supporting of doors

4.1 General

4.1.1 Side doors and stern doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure.

The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices.

Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered by the Society on a case-by-case basis.

The maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

A means is to be provided for mechanically fixing the door in the open position.

4.1.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide local compression of the packing material may generally not be included in the calculation in [4.2.2].

The number of securing and supporting devices is generally to be the minimum practical while taking into account the requirements for redundant provision given in [4.2.3] and the available space for adequate support in the hull structure.

4.2 Scantlings

4.2.1 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the allowable stresses defined in [5.1.1].

4.2.2 The distribution of the reaction forces acting on the securing and supporting devices may need to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position of the supports.

4.2.3 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that, in the event of failure of any single securing or supporting device, the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20% the allowable stresses defined in [5.1.1].

4.2.4 All load transmitting elements in the design load path, from the door through securing and supporting devices into the ship structure, including welded connections, are to be of the same strength standard as required for the securing and supporting devices.

5 Strength criteria

5.1 Primary supporting members and securing and supporting devices

5.1.1 Yielding check

It is to be checked that the normal stress σ, the shear stress τ and the equivalent stress σ_{VM}, induced in the primary supporting members and in the securing and supporting devices of doors by the design load defined in [2], are in compliance with the following formulae:

$\sigma \le \sigma_{ALL}$

$\tau \le \tau_{ALL}$

$\sigma_{VM} = (\sigma^2 + 3\ \tau^2)^{0,5} \le \sigma_{VM,ALL}$

where:

σ_{ALL}	:	Allowable normal stress, in N/mm²: $\sigma_{ALL} = 120 / k$
τ_{ALL}	:	Allowable shear stress, in N/mm²: $\tau_{ALL} = 80 / k$
$\sigma_{VM,ALL}$	:	Allowable equivalent stress, in N/mm²: $\sigma_{VM,ALL} = 150 / k$
k	:	Material factor, defined in Ch 4, Sec 1, [2.3], but to be taken not less than 0,72 unless a fatigue analysis is carried out.

5.1.2 Buckling check

The buckling check of primary supporting members is to be carried out according to Ch 7, Sec 3, [5].

5.1.3 Bearings

For steel to steel bearings in securing and supporting devices, it is to be checked that the nominal bearing pressure σ_B, in N/mm², is in compliance with the following formula:

$\sigma_B \leq 0,8\ R_{eH,B}$

where:

$$\sigma_B = 10\frac{F}{A_B}$$

with:

F : Design force, in KN, defined in [2.1.1]

A_B : Projected bearing area, in cm²

$R_{eH,B}$: Yield stress, in N/mm², of the bearing material.

For other bearing materials, the allowable bearing pressure is to be determined according to the manufacturer's specification.

5.1.4 Bolts

The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces.

It is to be checked that the tension σ_T in way of threads of bolts not carrying support forces is in compliance with the following formula:

$\sigma_T \leq \sigma_{T,ALL}$

where:

$\sigma_{T,ALL}$: Allowable tension in way of threads of bolts, in N/mm²: $\sigma_{T,ALL} = 125 / k$

k : Material factor, defined in [5.1.1].

6 Securing and locking arrangement

6.1 Systems for operation

6.1.1 Securing devices are to be simple to operate and easily accessible.

Securing devices are to be equipped with mechanical locking arrangement (self-locking or separate arrangement), or to be of the gravity type.

The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

6.1.2 Doors which are located partly or totally below the watertight deck with a clear opening area greater than 6 m² are to be provided with an arrangement for remote control, from a position above the main watertight deck, of:

- the closing and opening of the doors
- associated securing and locking devices.

For doors which are required to be equipped with a remote control arrangement, indication of the open/closed position of the door and the securing and locking device is to be provided at the remote control stations.

The operating panels for operation of doors are to be inaccessible to unauthorized persons.

A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

6.1.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position. This means that, in the event of loss of hydraulic fluid, the securing devices remain locked.

The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits, when in closed position.

7 Operating and maintenance manual

7.1 General

7.1.1 An Operating and Maintenance Manual (OMM) for the side doors and stern doors is to be provided on board and is to contain the necessary information on:

a) main particulars and design drawings:
   - special safety precautions
   - details of ship
   - equipment and design loading (for ramps)
   - key plan of equipment (doors and ramps)
   - manufacturer's recommended testing for equipment
   - description of equipment:
     - side doors
     - stern doors
     - central power pack
     - control panels.

b) service conditions:
   - limiting heel and trim of ship for loading / unloading
   - limiting heel and trim for door operations
   - doors / ramps operating instructions
   - doors / ramps emergency operating instructions.

c) maintenance:
   - schedule and extend of maintenance
   - trouble shooting and acceptable clearances
   - manufacturer's maintenance procedures.

d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This manual is to be submitted to the Society for approval. It is to be checked that the above mentioned items are contained in the OMM and that the maintenance part includes the necessary information with regard to inspections, trouble-shooting and acceptance / rejection criteria.

Note 1: It is recommended that inspections of the door and supporting and securing devices be carried out by ship's personnel at monthly intervals or following any incidents which could result in damage, including heavy weather or contact in the region of the shell doors. A record is to be kept and any damage recorded during such inspections is to be reported to the Society.

7.1.2 Documented operating procedures for closing and securing the side and stern doors are to be kept on board and posted at an appropriate place.

Section 7 Hatch Covers

Symbols

p_S : Still water pressure, in kN/m² (see [5.1])

p_{SF} : Still water pressure for flooding, in kN/m², defined in Ch 5, Sec 6, Tab 9

p_W : Wave pressure, in kN/m² (see [5.1])

p_{WF} : Wave pressure for flooding, in kN/m², defined in Ch 5, Sec 6, Tab 9

p_T : Test pressure, in kN/m²

s : Length, in m, of the shorter side of the plate panel

ℓ : Length, in m, of the longer side of the plate panel

b_P : Width, in m, of the plating attached to the ordinary stiffener or primary supporting member, defined in [4]

w : Net section modulus, in cm³, of the ordinary stiffener or primary supporting member, with an attached plating of width b_p

A_{Sh} : Net shear sectional area, in cm², of the ordinary stiffener or primary supporting member, to be calculated as specified in Ch 4, Sec 3, [3.4], for ordinary stiffeners, and Ch 4, Sec 3, [4.3], for primary supporting members

m : Boundary coefficient for ordinary stiffeners and primary supporting members, taken equal to:

- m = 8 in the case of ordinary stiffeners and primary supporting members simply supported at both ends or supported at one end and clamped at the other
- m = 12 in the case of ordinary stiffeners and primary supporting members clamped at both ends

t_C : Corrosion additions, in mm, defined in [1.6]

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_m : Minimum ultimate tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_y : Yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm², unless otherwise specified

k : Material factor, defined in Ch 4, Sec 1, [2.3]

c_S : Coefficient, taken equal to:

- $c_S = 1 - (s / 2\ell)$ for ordinary stiffeners
- $c_S = 1{,}0$ for primary supporting members

g : Gravity acceleration, in m/s²: g = 9,81 m/s².

1 General

1.1 Application

1.1.1 The requirements of this Section apply to steel hatch covers in positions 1 and 2 on weather decks, defined in Ch 1, Sec 2, [9.1] as well as hatches installed in watertight boundaries and in emergency escape routes.

1.2 Definitions

1.2.1 Large hatches

Large hatches are hatches with openings greater than 2,5 m².

1.2.2 Small hatches

Small hatches are hatches designed for access to spaces below the deck and are capable to be closed weathertight or watertight, as applicable. Their opening is generally equal to or less than 2,5 m².

1.3 Materials

1.3.1 Steel

The formulae for scantlings given in the requirements in Article [6] are applicable to steel hatch covers.

Materials used for the construction of steel hatch covers are to comply with the applicable requirements of NR216 Materials and Welding, Chapter 2.

1.3.2 Other materials

The use of materials other than steel is considered by the Society on a case-by-case basis, by checking that criteria adopted for scantlings are such as to ensure strength and stiffness equivalent to those of steel hatch covers.

1.4 Net scantlings

1.4.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.5 Partial safety factors

1.5.1 The partial safety factors to be considered for checking hatch cover structures are specified in Tab 1.

Table 1 : Hatch covers - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners and primary supporting members
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20
Material	γ_m	1,02	1,02
Resistance	γ_R	1,20	1,02

1.6 Corrosion additions

1.6.1 General

The requirements of Ch 4, Sec 2, [1] and Ch 4, Sec 2, [2] apply.

1.6.2 Corrosion additions for hatch covers on exposed decks

In general, for steel other than stainless steel the corrosion addition to be considered for the plating and internal members of hatch covers on exposed decks is the value specified in Tab 2 for the total thickness of the member under consideration.

Table 2 : Corrosion additions t_C for steel hatch covers on exposed decks

Steel hatch covers	t_C, in mm
Plating and stiffeners of single skin hatch cover	2,0
Top and bottom plating of pontoon hatch cover	2,0
Internal structures of pontoon hatch cover	1,5

1.6.3 Corrosion addition for hatch covers on non-exposed decks

For hatch covers on non-exposed decks, the corrosion addition t_C is to be taken equal to that of the adjacent deck.

1.6.4 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_C is to be taken equal to 0.

1.6.5 Corrosion additions for aluminium alloys

For structural members made of aluminium alloys, the corrosion addition t_C is to be taken equal to 0.

2 Arrangement of large hatches

2.1 Height of hatch coamings

2.1.1 The height above the deck of hatch coamings for large hatches is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

2.1.2 The height of hatch coamings in positions 1 and 2 closed by steel covers provided with gaskets and securing devices may be reduced with respect to the above values or the coamings may be omitted entirely, on condition that the Society is satisfied that the safety of the ship is not thereby impaired in any sea conditions.

In such cases the scantlings of the covers, their gasketing, their securing arrangements and the drainage of recesses in the deck are considered by the Society on a case-by-case basis.

2.1.3 Regardless of the type of closing arrangement adopted, the coamings may have reduced height or be omitted in way of openings in closed superstructures or decks below the main watertight deck.

2.2 Hatch covers

2.2.1 Hatch covers on exposed decks are to be weathertight.

Hatch covers in closed superstructures need not be weathertight.

However, hatch covers fitted in way of ballast tanks, fuel oil tanks or other tanks are to be watertight.

2.2.2 The covers used in 'tweendecks are to be fitted with an appropriate system ensuring an efficient stowing when the ship is sailing with open 'tweendecks.

2.2.3 The ends of hatch covers are normally to be protected by efficiently secured galvanized steel strips.

2.2.4 The width of each bearing surface for hatch covers is to be at least 65 mm.

2.3 Hatch coamings

2.3.1 Coamings, stiffeners and brackets are to be capable of withstanding the local forces in way of the clamping devices and handling facilities necessary for securing and moving the hatch covers as well as those due to cargo stowed on the latter.

2.3.2 Special attention is to be paid to the strength of the fore transverse coaming of the forward hatch and to the scantlings of the closing devices of the hatch cover on this coaming.

2.3.3 Longitudinal coamings are to be extended at least to the lower edge of deck beams.

Where they are not part of continuous deck girders, longitudinal coamings are to extend for at least two frame spaces beyond the end of the openings.

Where longitudinal coamings are part of deck girders, their scantlings are to be as required in Ch 7, Sec 3.

2.3.4 Transverse coamings are to extend below the deck at least to the lower edge of longitudinals.

Transverse coamings not in line with ordinary deck beams below are to extend below the deck at least three longitudinal frame spaces beyond the side coamings.

3 Arrangement of small hatches

3.1 General

3.1.1 Hatchways of special design are considered by the Society on a case-by-case basis.

3.2 Height of hatch coamings

3.2.1 The height above the deck of hatch coamings for small hatches is to be not less than:

- 600 mm in position 1
- 450 mm in position 2.

3.2.2 Where the closing appliances are in the form of hinged steel covers secured weathertight by gaskets and swing bolts, the height of the coamings may be reduced or the coamings may be omitted altogether.

3.2.3 The height of coamings for hatches in escape routes are to be determined considering the rules in Pt C, Ch 4, Sec 8, [4.1].

3.3 Hatch covers fitted on exposed decks

3.3.1 Small hatch covers on exposed decks are to be weathertight.

3.3.2 Hold accesses located on the weather deck are to be provided with watertight metallic hatch covers, unless they are protected by a closed superstructure. The same applies to accesses located on the forecastle deck and leading directly to a dry cargo hold through a trunk.

3.4 Hatch covers fitted on non-exposed decks

3.4.1 Small hatch covers on non-exposed decks need not be weathertight.

3.4.2 Small hatch covers fitted on non-exposed decks are to have a level of tightness equivalent to that required for adjacent compartment(s).

3.5 Watertight hatch covers

3.5.1 Hatches defined as per the Internal Watertight Plan which constitute boundaries intended to stop vertical and horizontal flooding shall have the same level of tightness as the structure in which they are installed.

3.5.2 Accesses to cofferdams and ballast tanks are to be manholes fitted with watertight covers fixed with bolts which are sufficiently closely spaced (refer to Ch 3, Sec 3, [2.2.2], c)).

4 Width of attached plating

4.1 Ordinary stiffeners

4.1.1 The width of the attached plating to be considered for the check of ordinary stiffeners is to be obtained, in m, from the following formulae:

- where the attached plating extends on both sides of the stiffener:

  $b_P = s$

- where the attached plating extends on one side of the stiffener:

  $b_P = 0{,}5\ s$

4.2 Primary supporting members

4.2.1 Primary supporting members parallel to ordinary stiffeners

The width of the attached plating to be considered for the check of primary supporting members parallel to ordinary stiffeners is to be obtained, in m, from the following formulae:

- if $\beta \le 1{,}0$:

  $b_P = S_P$

- if $\beta > 1{,}0$:

$$b_P = \left(\frac{1,8}{\beta} - \frac{0,8}{\beta^2}\right) S_P$$

where:

$$\beta = 10^3 \frac{s}{t} \sqrt{\frac{R_{eH}}{E}}$$

E : Young's modulus, in N/mm², to be taken equal to $2{,}06 \cdot 10^5$ N/mm² for steels in general

S_P : Spacing, in m, of primary supporting members.

Where the attached plating extends on one side of the primary supporting member, the width b_P calculated as required above is to be multiplied by 0,5.

4.2.2 Primary supporting members perpendicular to ordinary stiffeners

The width of the attached plating to be considered for the check of primary supporting members perpendicular to ordinary stiffeners is to be obtained, in m, from the following formula:

$$b_P = \left[b_{P,L}\frac{s}{\ell} + 0,115\left(1 - \frac{s}{\ell}\right)\left(1 + \frac{1}{\beta^2}\right)^2\right]\ell$$

to be taken not greater than ℓ

where:

$$b_{P,L} = \frac{1,8}{\beta} - \frac{0,8}{\beta^2} \qquad \text{for } \beta > 1,0$$

$$b_{P,L} = 1,0 \qquad \text{for } \beta \le 1,0$$

β : Defined in [4.2.1].

Where the attached plating extends on one side of the primary supporting member, the width b_P calculated as required above is to be multiplied by 0,5.

5 Load model

5.1 Lateral pressures and concentrated loads

5.1.1 General

The still water and wave lateral pressures p_S and p_W and the concentrated loads, to be considered as acting on hatch covers are those in [5.1.2] to [5.1.9].

All hatch covers are to be subject to the still water and wave lateral pressures in either [5.1.2] or [5.1.3], according to their position in exposed or non-exposed decks. In addition to this, the requirements in [5.1.4] to [5.1.9] are to be applied where applicable, depending upon the intended use and location of each cover. The applicable checks in [5.1.2] to [5.1.9] are to be conducted separately. Multiple checks as defined in [5.1.4] to [5.1.9] may apply to any individual hatch.

5.1.2 Hatch covers on exposed decks

The still water and wave lateral pressures p_S and p_W to be considered and are defined in Ch 5, Sec 5, [3].

5.1.3 Hatch covers on non-exposed decks

The still water and wave pressures p_S and p_W to be considered are those applicable to the adjacent deck structure, determined as per Ch 5, Sec 6, [5].

When a hatch cover is installed with a coaming in an emergency escape route on a non-exposed deck, a still water pressure of 3 kN/m² may be considered in lieu of the value applicable to the adjacent deck structure. In this case, a warning notice must be applied to ensure that the hatch cover remains unloaded and clear of obstacles as per Pt C, Ch 4, Sec 8, [2.1.1].

5.1.4 Additional lateral pressures for hatch covers in way of liquid cargo or ballast tanks

Additional checks shall be conducted for the still water and wave lateral pressures p_S and p_W defined in Ch 5, Sec 6, [1].

5.1.5 Additional lateral pressures for hatch covers carrying uniform cargoes

Additional checks shall be conducted for the still water and wave lateral pressures p_S and p_W defined in Ch 5, Sec 6, [2].

5.1.6 Additional loads for hatch covers carrying containers

Additional checks shall be conducted for the still water and wave loads defined in Ch 5, Sec 6, [3].

5.1.7 Additional loads for hatch covers carrying wheeled loads

Additional checks shall be conducted for the still water and wave loads defined in Ch 5, Sec 6, [4].

5.1.8 Additional lateral pressures for hatch covers carrying special cargoes

In the case of carriage on the hatch covers of special cargoes (e.g. pipes, etc.) which may temporarily retain water during navigation, the lateral pressure to be applied is considered by the Society on a case-by-case basis.

5.1.9 Additional lateral pressures for hatch covers in ammunition magazines

Attention is to be given to hatches in ammunition magazines which are subject to fire-extinguishing by flooding. In this case, additional checks are to be conducted for the still water and wave lateral pressures p_S and p_W determined as per Ch 5, Sec 6, [5.1.4].

5.2 Conventional pressure for hatch covers on exposed decks

5.2.1 The conventional pressure p_0 is defined in Tab 3 according to the hatch cover position.

Table 3 : Conventional pressure on hatch covers

Conventional pressure p_0, in kN/m²	
Position 1	Position 2
$g\left(\frac{58+0{,}75L}{76}\right)$	$g\left(\frac{43{,}8+0{,}55L}{76}\right)$
Note 1: L is to be taken not greater than 100 m.	

5.3 Load point

5.3.1 Wave lateral pressure for hatch covers on exposed decks

The wave lateral pressure to be considered as acting on each hatch cover is to be calculated at a point located:

- longitudinally, at the hatch cover mid-length
- transversely, on the longitudinal plane of symmetry of the ship
- vertically, at the top of the hatch coaming.

5.3.2 Lateral pressures other than the wave pressure

The lateral pressure is to be calculated:

- in way of the geometrical centre of gravity of the plate panel, for plating
- at mid-span, for ordinary stiffeners and primary supporting members.

6 Strength check

6.1 General

6.1.1 Application

The strength check is applicable to rectangular hatch covers with primary supporting members arranged in one direction and subjected to a uniform pressure.

In the case of hatch covers with primary supporting members with arrangement of a grillage type or of non-rectangular hatch covers, the scantlings are to be determined by direct calculations. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [6.3.4].

6.1.2 Hatch covers supporting wheeled loads

The scantlings of hatch covers supporting wheeled loads are to be obtained in accordance with:

- the applicable requirements of Ch 7, Sec 1 for plating
- the applicable requirements of Ch 7, Sec 2 for ordinary stiffeners
- the applicable requirements of Ch 7, Sec 3 for primary supporting members.

6.1.3 Hatch covers subjected to concentrated loads

For hatch covers supporting concentrated loads, ordinary stiffeners and primary supporting members are generally to be checked by direct calculations, taking into account the stiffener arrangements and their relative inertia. It is to be checked that stresses induced by concentrated loads are in accordance with the criteria in [6.3.4].

6.2 Plating

6.2.1 Net thickness

The net thickness of steel hatch cover plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9s\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{R_y}}$$

where p_S and p_W are the lateral pressures, in kN/m^2, defined in [5.1].

6.2.2 Flooding

For watertight hatches defined as per the Internal Watertight Plan which constitute boundaries intended to stop vertical and horizontal flooding, the net thickness of steel hatch cover plating is to be not less than the value obtained, in mm, from the following formula:

$$t = 14{,}9s\sqrt{\gamma_R\gamma_m\frac{\gamma_{S2}p_{SF} + \gamma_{W2}p_{WF}}{R_y}}$$

where p_{SF} and p_{WF} are the lateral pressures, in kN/m2, defined in Ch 5, Sec 6, Tab 9.

6.2.3 Minimum net thickness of small hatch cover plating

The minimum net thickness of plating of small hatch covers fitted on exposed decks shall be no less than 6 mm.

The minimum net thickness of plating of small hatch covers fitted on non-exposed decks shall be no less than 5 mm.

This thickness is to be increased or an efficient stiffening fitted to the Society's satisfaction where the greatest horizontal dimension of the cover exceeds 1,20 m.

6.2.4 Minimum net thickness of large hatch cover plating

In addition to the requirements in [6.2.1] to [6.2.3], the net thickness, in mm, of large hatch cover plating is to be not less than the values indicated in Tab 4.

Table 4 : Minimum net thicknesses for steel hatch covers

Type of hatch covers	Minimum net thickness, in mm		
	Single skin hatch cover	Double skin hatch cover	
	Plating and stiffeners	Top and bottom plating	Internal structure
Cargo tank hatch cover	6,0	6,0	6,5
Ballast tank hatch cover and fuel oil tank hatch cover	5,0	5,0	5,5
Dry cargo hold hatch cover	4,0	4,0	4,5

6.3 Ordinary stiffeners and primary supporting members

6.3.1 General

Ordinary stiffeners and primary supporting members of hatch covers located on exposed decks are also to fulfil the requirements in [6.4].

6.3.2 Application

The requirements in [6.3.3] to [6.3.9] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [6.3.4].

6.3.3 Normal and shear stress

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm^2, from the following formulae:

$$\sigma = \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{mw} c_S s \ell^2 10^3$$

$$\tau = 5\frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{A_{Sh}} c_S s \ell$$

6.3.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [6.3.3], are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

6.3.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to lateral pressure, complying with the checking criteria indicated in [6.3.4].

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of an ordinary stiffener or a primary supporting member subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{mR_y} c_S s \ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{R_y} c_S s \ell$$

6.3.6 Net section modulus and net shear sectional area for lateral pressure in flooding conditions

For watertight hatches defined as per the Internal Watertight Plan which constitute boundaries intended to stop vertical and horizontal flooding, the net section modulus w, in cm^3, and the net shear sectional area A_{Sh} , in cm^2, of ordinary stiffeners and primary supporting members are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \frac{\gamma_{S2}p_S + \gamma_{W2}p_W}{mR_y} c_S s \ell^2 10^3$$

$$A_{Sh} = 10\gamma_R \gamma_m \frac{\gamma_{S2}p_{SF} + \gamma_{W2}p_{WF}}{R_y} c_S s \ell$$

where p_{SF} and p_{WF} are the lateral pressures, in kN/m^2, defined in Ch 5, Sec 6, Tab 9.

6.3.7 Minimum net thickness of webs for small hatch covers

Minimum net web thickness of ordinary stiffeners and primary supporting members for small hatch covers is not to be less than the net thickness of the attached plating.

6.3.8 Minimum net thickness of webs for large hatch covers

The net thickness of the ordinary stiffeners and primary supporting members, in mm, is to be not less than the minimum values given in Tab 4.

6.3.9 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm³, from the following formulae:

$$w = w_{CS}$$

$$w = \left(1 + \frac{3,2\alpha - \psi - 0,8}{7\psi + 0,4}\right) w_{CS}$$

where:

w_{CS} : Section modulus, in cm³, for a constant cross-section, obtained according to [6.3.5] or, where applicable, according to [6.3.6] or [6.4.5].

$$\alpha = \frac{\ell_1}{\ell_0}$$

$$\psi = \frac{w_1}{w_0}$$

ℓ_1 : Length of the variable section part, in m (see Fig 1)

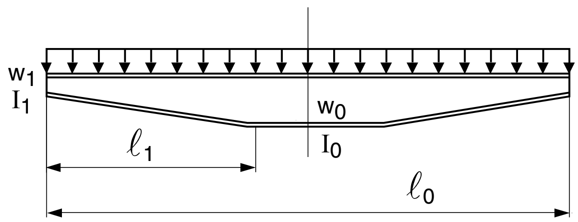
ℓ_0 : Span measured, in m, between end supports (see Fig 1)

w_1 : Section modulus at end, in cm³ (see Fig 1)

w_0 : Section modulus at mid-span, in cm³ (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

Figure 1 : Variable cross-section stiffener



6.4 Additional requirements for ordinary stiffeners and primary supporting members of hatch covers on exposed decks

6.4.1 General

In addition to those in [6.3], ordinary stiffeners and primary supporting members of hatch covers on exposed decks are also to fulfil the requirements in [6.4.2] to [6.4.7].

6.4.2 Application

The requirements in [6.4.3] to [6.4.7] apply to:

- ordinary stiffeners
- primary supporting members which may be analysed through isolated beam models.

Primary supporting members whose arrangement is of a grillage type and which cannot be analysed through isolated beam models are to be checked by direct calculations, using the checking criteria in [6.4.4].

6.4.3 Normal and shear stress

The maximum normal stress σ and shear stress τ are to be obtained, in N/mm², from the following formulae:

$$\sigma = \frac{p_0}{mw} c_S s \ell^2 10^3$$

$$\tau = 5 \frac{p_0}{A_{Sh}} c_S s \ell$$

where p_0 is the conventional pressure, in kN/m², defined in [5.2].

6.4.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ, calculated according to [6.4.3], are in compliance with the following formulae:

$$\frac{R_m}{\gamma_{LL}} \geq \sigma$$

$$0,57 \frac{R_m}{\gamma_{LL}} \geq \tau$$

where γ_{LL} is a safety factor, taken equal to:

- 4,25 for hatch covers
- 5,00 for pontoon hatch covers and portable hatch covers.

6.4.5 Net section modulus and net shear sectional area

This requirement provides the minimum net section modulus and net shear sectional area of an ordinary stiffener or a primary supporting member subjected to conventional pressure, complying with the checking criteria indicated in [6.4.4].

The net section modulus w, in cm^3, and the net shear sectional area A_{Sh}, in cm^2, of an ordinary stiffener or a primary supporting member subjected to conventional pressure are to be not less than the values obtained from the following formulae:

$$w = \frac{\gamma_{LL} p_0}{m R_m} c_S s \ell^2 10^3$$

$$A_{Sh} = 8{,}8 \frac{\gamma_{LL} p_0}{R_m} c_S s \ell$$

where γ_{LL} is as defined in [6.4.4].

6.4.6 Moment of inertia of ordinary stiffeners and primary supporting members

The moment of inertia I_{CS} of an ordinary stiffener or a primary supporting member, calculated for the conventional pressure p_0, is to be such that the deflection does not exceed $\mu\ell$, where μ is defined in Tab 5.

Table 5 : Hatch covers - Deflection coefficient for ordinary stiffeners and primary supporting members

	μ
Weathertight hatch cover	0,0028
Pontoon hatch cover Portable beam	0,0022

6.4.7 Ordinary stiffeners and primary supporting members of variable cross-section

The section modulus of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the value obtained according to [6.3.9], where w_{CS} is the section modulus for a constant cross-section obtained according to [6.4.5].

Moreover, the moment of inertia of ordinary stiffeners and primary supporting members with a variable cross-section is to be not less than the greater of the values obtained, in cm^4, from the following formulae:

$$I = I_{CS}$$

$$I = \left[1 + 8\alpha^3\left(\frac{1-\varphi}{0{,}2 + 3\sqrt{\varphi}}\right)\right] I_{CS}$$

where:

I_{CS} : Moment of inertia with a constant cross-section, in cm^4, obtained according to [6.4.6]

α : Coefficient defined in [6.3.9]

$$\varphi = \frac{I_1}{I_0}$$

I_1 : Moment of inertia at end, in cm^4 (see Fig 1)

I_0 : Moment of inertia at mid-span, in cm^4 (see Fig 1).

The use of this formula is limited to the determination of the strength of ordinary stiffeners and primary supporting members in which abrupt changes in the cross-section do not occur along their length.

7 Hatch coamings

7.1 Stiffening

7.1.1 Coamings are to be stiffened on their upper edges with a stiffener suitably shaped to fit the hatch cover closing appliances.

Moreover, when covers are fitted with tarpaulins, an angle or a bulb section is to be fitted all around coamings of more than 3 m in length or 600 mm in height; this stiffener is to be fitted at approximately 250 mm below the upper edge. The width of the horizontal flange of the angle is not to be less than 180 mm.

7.1.2 Where hatch covers are fitted with tarpaulins, coamings are to be strengthened by brackets or stays with a spacing not greater than 3 m.

Where the height of the coaming exceeds 900 mm, additional strengthening may be required.

However, reductions may be granted for transverse coamings in protected areas.

7.1.3 When two hatches are close to each other, underdeck stiffeners are to be fitted to connect the longitudinal coamings with a view to maintaining the continuity of their strength.

Similar stiffening is to be provided over 2 frame spacings at ends of hatches exceeding 9 frame spacings in length.

In some cases, the Society may require the continuity of coamings to be maintained above the deck.

7.1.4 Where watertight metallic hatch covers are fitted, other arrangements of equivalent strength may be adopted.

7.2 Scantlings

7.2.1 General

The scantlings of continuous side coamings are considered by the Society on a case-by-case basis.

7.2.2 Plating

The plate thickness of hatch coamings on the weather deck is generally to be not less than 11 mm.

In ships intended for the carriage of liquid cargoes, the plate thickness of coamings is also to be checked under liquid internal pressures.

7.2.3 Coamings of small hatchways

As a Rule, the coaming plate thickness is to be not less than the lesser of the following values:

- the thickness for the deck inside line of openings calculated for that position, assuming as spacing of stiffeners the lesser of the values of the height of the coaming and the distance between its stiffeners, if any, or
- 10 mm.

Coamings are to be suitably strengthened where their height exceeds 0,80 m or their greatest horizontal dimension exceeds 1,20 m, unless their shape ensures an adequate rigidity.

8 Weathertightness, closing arrangement and securing devices of large hatches

8.1 Weathertightness

8.1.1 Where the hatchway is exposed and closed with a single panel, the weathertightness is to be ensured by gaskets and clamping devices sufficient in number and quality.

Weathertightness may also be ensured means of tarpaulins.

8.1.2 The mean spacing of swing bolts or equivalent devices is, in general, to be not greater than:

- 2,0 m for dry cargo holds
- 1,5 m for ballast compartments
- 1,0 m for liquid cargo holds.

8.2 Gaskets

8.2.1 The weight of hatch covers and any cargo stowed thereon, together with inertia forces generated by ship motions, are to be transmitted to the ship structure through steel to steel contact.

This may be achieved by continuous steel to steel contact of the hatch cover skirt plate with the ship structure or by means of defined bearing pads.

8.2.2 The sealing is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary weathertightness. Similar sealing is to be arranged between cross-joint elements.

Where fitted, compression flat bars or angles are to be well rounded where in contact with the gasket and to be made of a corrosion-resistant material.

8.2.3 The gasket and the securing arrangements are to maintain their efficiency when subjected to large relative movements between the hatch cover and the ship structure or between hatch cover elements.

If necessary, suitable devices are to be fitted to limit such movements.

8.2.4 The gasket material is to be of a quality suitable for all environmental conditions likely to be encountered by the ship, and is to be compatible with the cargoes transported.

The material and form of gasket selected are to be considered in conjunction with the type of hatch cover, the securing arrangement and the expected relative movement between the hatch cover and the ship structure.

The gasket is to be effectively secured to the hatch cover.

8.2.5 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

8.2.6 Metallic contact is required for an earthing connection between the hatch cover and the hull structures. If necessary, this is to be achieved by means of a special connection for the purpose.

8.3 Closing arrangement and securing devices

8.3.1 General

Panel hatch covers are to be secured by appropriate devices (bolts, wedges or similar) suitably spaced alongside the coamings and between cover elements.

The securing and stop arrangements are to be fitted using appropriate means which cannot be easily removed.

In addition to the requirements above, all hatch covers, and in particular those carrying deck cargo, are to be effectively secured against horizontal shifting due to the horizontal forces resulting from ship motions.

Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices according to [8.3.5] to [8.3.7] Lifting forces from cargo secured on the hatch cover during rolling are also to be taken into account.

Hatch coamings and supporting structure are to be adequately stiffened to accommodate the loading from hatch covers.

Hatch covers provided with special sealing devices, insulated hatch covers, flush hatch covers and those having coamings of a reduced height (see [2.1]) are considered by the Society on a case-by-case basis.

In the case of hatch covers carrying containers, the scantlings of the closing devices are to take into account the possible upward vertical forces transmitted by the containers.

8.3.2 Arrangements

The securing and stopping devices are to be arranged so as to ensure sufficient compression on gaskets between hatch covers and coamings and between adjacent hatch covers.

Arrangement and spacing are to be determined with due attention to the effectiveness for weathertightness, depending on the type and the size of the hatch cover, as well as on the stiffness of the hatch cover edges between the securing devices.

At cross-joints of multipanel covers, (male/female) vertical guides are to be fitted to prevent excessive relative vertical deflections between loaded/unloaded panels.

The location of stoppers is to be compatible with the relative movements between hatch covers and the ship structure in order to prevent damage to them. The number of stoppers is to be as small as possible.

8.3.3 Spacing

The spacing of the securing arrangements is to be generally not greater than 6 m.

The spacing of securing arrangements of tank hatch covers in ‘tweendecks is to be not greater than 600 mm.

8.3.4 Construction

Securing arrangements with reduced scantlings may be accepted provided it can be demonstrated that the possibility of water reaching the deck is negligible.

Securing devices are to be of reliable construction and securely attached to the hatchway coamings, decks or hatch covers.

Individual securing devices on each hatch cover are to have approximately the same stiffness characteristics.

8.3.5 Area of securing devices

The net cross area of each securing device is to be not less than the value obtained, in cm², from the following formula:

$$A = 1{,}4 S_S \left(\frac{235}{R_{eH}}\right)^f$$

where:

S_S : Spacing, in m, of securing devices

f : Coefficient taken equal to:

- 0,75 for $R_{eH} > 235$ N/mm²
- 1,00 for $R_{eH} \leq 235$ N/mm².

In the above calculations, R_{eH} may not be taken greater than 0,7 R_m.

Between hatch cover and coaming and at cross-joints, a packing line pressure sufficient to obtain weathertightness is to be maintained by securing devices. For packing line pressures exceeding 5 N/mm, the net cross area A is to be increased in direct proportion. The packing line pressure is to be specified.

In the case of securing arrangements which are particularly stressed due to the unusual width of the hatchway, the net cross area A of the above securing arrangements is to be determined through direct calculations.

8.3.6 Inertia of edges elements

The hatch cover edge stiffness is to be sufficient to maintain adequate sealing pressure between securing devices.

The moment of inertia of edge elements is to be not less than the value obtained, in cm⁴, from the following formula:

$$I = 6\, p_L\, S_S^4$$

where:

p_L : Packing line pressure, in N/mm, to be taken not less than 5 N/mm

S_S : Spacing, in m, of securing devices.

8.3.7 Diameter of rods or bolts

Rods or bolts are to have a net diameter not less than 19 mm for hatchways exceeding 5 m^2 in area.

8.4 Tarpaulins

8.4.1 Where weathertightness of hatch covers is ensured by means of tarpaulins, at least two layers of tarpaulins are to be fitted.

Tarpaulins are to be free from jute and waterproof and are to have adequate characteristics of strength and resistance to atmospheric agents and high and low temperatures.

The mass per unit surface of tarpaulins made of vegetable fibres, before the waterproofing treatment, is to be not less than:

- 0,65 kg/m^2 for waterproofing by tarring
- 0,60 kg/m^2 for waterproofing by chemical dressing
- 0,55 kg/m^2 for waterproofing by dressing with black oil.

In addition to tarpaulins made of vegetable fibres, those of synthetic fabrics or plastic laminates may be accepted by the Society provided their qualities, as regards strength, waterproofing and resistance to high and low temperatures, are equivalent to those of tarpaulins made of vegetable fibres.

8.5 Cleats

8.5.1 The arrangements for securing the tarpaulins to hatch coamings are to incorporate cleats of a suitable pattern giving support to battens and wedges and with edges rounded so as to minimise damage to the wedges.

8.5.2 Cleats are to be spaced not more than 600 mm from centre to centre and are to be not more than 150 mm from the hatch corners.

8.5.3 The thickness of cleats is to be not less than 9,5 mm for angle cleats and 11 mm for forged cleats.

8.5.4 Where rod cleats are fitted, resilient washers or cushions are to be incorporated.

8.5.5 Where hydraulic cleating is adopted, a positive means is to be provided to ensure that it remains mechanically locked in the closed position in the event of failure of the hydraulic system.

8.6 Wedges, battens and locking bars

8.6.1 Wedges

Wedges are to be of tough wood, generally not more than 200 mm in length and 50 mm in width.

They are generally to be tapered not more than 1 in 6 and their thickness is to be not less than 13 mm.

8.6.2 Battens and locking bars

For all hatchways in exposed positions, battens or transverse bars in steel or other equivalent means are to be provided in order to efficiently secure the portable covers after the tarpaulins are battened down.

Portable covers of more than 1,5 m in length are to be secured by at least two such securing appliances.

9 Tightness, closing arrangement and securing devices of small hatches

9.1 Tightness and gaskets

9.1.1 The seal for weathertight or watertight hatches is to be obtained by a continuous gasket of relatively soft elastic material compressed to achieve the necessary tightness.

9.1.2 Coamings and steel parts of hatch covers in contact with gaskets are to have no sharp edges.

9.1.3 For non-bolted hatch covers, metal-to-metal contacts are to be provided in order to prevent over compression of the gasket. Gasket sealing arrangements are to be designed in order to withstand the bearing force induced by any relevant lateral load on the hatch cover.

9.2 Closing arrangement and securing devices

9.2.1 At least one securing device is to be fitted at each side. The hinges of scuttles and round hatch covers are considered equivalent to securing devices.

9.2.2 Securing arrangements and stiffening of hatch cover edges are to be such that the required degree of tightness can be maintained in any sea condition, for all loads acting on the hatch cover.

9.2.3 Towards the ends of the ship, vertical acceleration forces may exceed the gravity force. The resulting lifting forces are to be considered when dimensioning the securing devices.

9.2.4 The primary securing method is to be designed and manufactured such that the designed compression pressure is achieved by one person without the need of any tools.

9.2.5 Small hatches located on exposed fore deck are to be fitted with primary securing devices such that their hatch covers can be secured in place and made weathertight by means of a mechanism employing any one of the following methods:

a) butterfly nuts tightening onto forks (clamps)

b) quick acting cleats

c) central locking device.

Dogs (twist tightening handles) with wedges are not acceptable.

9.2.6 For a primary securing method using butterfly nuts, the forks (clamps) are to be of robust design. They are to be designed to minimize the risk of butterfly nuts being dislodged while in use by means of curving the forks upwards, a raised surface on the free end, or a similar method. The plate thickness of unstiffened steel forks is to be not less than 16 mm. An example arrangement is shown in Fig 2.

9.2.7 Small hatches on the fore deck are to be fitted with an independent secondary securing device, e.g. by means of a sliding bolt, a hasp or a backing bar of slack fit, which is capable of keeping the hatch cover in place, even in the event that the primary securing device became loosened or dislodged. It is to be fitted on the side opposite to the hatch cover hinges.

9.2.8 For small hatch covers located on the exposed deck forward of the foremost cargo hatch, the hinges are to be fitted such that the predominant direction of green seas is to cause the cover to close, which means that the hinges are normally to be located on the fore edge.

9.2.9 On small hatches located between the main hatches, for example between Nos. 1 and 2, the hinges are to be placed on the fore edge or outboard edge, whichever is practicable for protection from green water in beam sea and bow quartering conditions.

9.2.10 Securing devices of hatches designed for emergency escape shall, in general, be operable from both sides of the hatch cover.

9.2.11 Where wear of securing elements may eventually lead to degraded hatch tightness, the design of the securing arrangements shall permit the necessary periodic adjustment or renewal of elements in order to ensure the continued performance of the seal and hatch tightness.

9.2.12 The metal-to-metal contacts are to be arranged close to each securing device and shall be of a sufficient capacity to withstand the bearing force. Where stiffeners are fitted, they shall be aligned with the metal-to-metal contact points.

10 Testing

10.1 Initial test of watertight hatches

10.1.1 Watertight hatches are to be tested by water pressure to at least a test pressure p_T, in kN/m², equal to the sum of p_{SF} and p_{WF}, as defined in Ch 5, Sec 6, Tab 9 at the location in which the hatch is to be installed.

10.2 Prototype test

10.2.1 Testing of individual hatches may be replaced by a prototype pressure test of each type and size of hatch with a test pressure corresponding at least to the head required for the individual location. The prototype test is to be carried out before the hatch is fitted. The installation method and procedure for fitting the hatch on board is to correspond to that of the prototype test. When fitted on board, each hatch is to be checked for proper seating between the deck, the coaming and the hatch cover.

11 Drainage

11.1 Arrangement

11.1.1 If drain channels are provided inside the line of the gasket by means of a gutter bar or vertical extension of the hatch side and end coaming, drain openings are to be provided at appropriate positions in the drain channels.

11.1.2 Drain openings in hatch coamings are to be arranged with sufficient distance to areas of stress concentration (e.g. hatch corners).

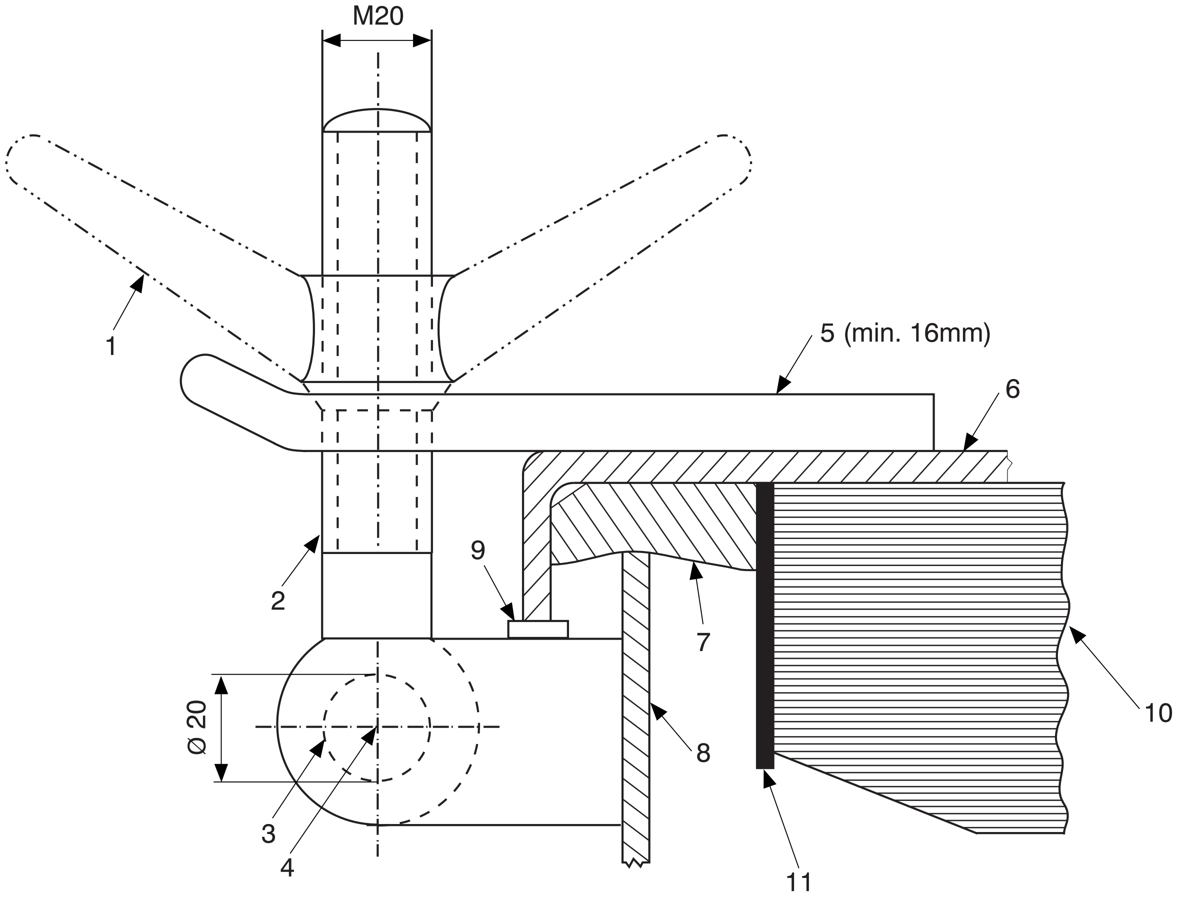
11.1.3 Drain openings are to be arranged at the ends of drain channels and are to be provided with efficient means for preventing ingress of water from outside, such as non-return valves or equivalent.

11.1.4 Cross-joints of multipanel hatch covers are to be arranged with drainage of water from the space above the gasket and a drainage channel below the gasket.

11.1.5 If a continuous outer steel contact is arranged between the cover and the ship structure, drainage from the space between the steel contact and the gasket is also to be provided.

11.1.6 Requirements [11.1.1] to [11.1.5] are not applicable to hatches of less than 0,6 m^2 and hatches on non-exposed decks.

Figure 2 : Example of a primary securing method



1 : Butterfly nut
2 : Bolt
3 : Pin
4 : Centre of pin
5 : Fork (clamp) plate
6 : Hatch cover
7 : Gasket
8 : Hatch coaming
9 : Bearing pad welded on the bracket of a toggle bolt for metal to metal contact
10 : Stiffener
11 : Inner edge stiffener.

Section 8 Movable Decks and Inner Ramps - External Ramps

1 Movable decks and inner ramps

1.1 Materials

1.1.1 The decks and inner ramps are to be made of steel or aluminium alloys complying with the requirements of NR216 Materials and Welding. Other materials of equivalent strength may be used, subject to a case-by-case examination by the Society.

1.2 Net scantlings

1.2.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The gross scantlings are obtained as specified in Ch 4, Sec 2.

1.3 Plating

1.3.1 The net thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from Ch 7, Sec 1, [4.3], where ($n\ P_0$) is not to be taken less than 50 kN.

1.4 Supporting structure

1.4.1 General

The supporting structure of movable decks and inner ramps is to be verified through direct calculation, considering the following cases:

- movable deck stowed in upper position, empty and locked, at sea
- movable deck in service, loaded, in lower position, resting on supports or supporting legs and locked, at sea
- movable inner ramp in sloped position, supported by hinges at one end and by a deck at the other, with possible intermediate supports, loaded, at harbour
- movable inner ramp in horizontal position, loaded and locked, at sea.

1.4.2 Loading cases

The scantlings of the structure are to be verified in both sea and harbour conditions for the following cases:

- loaded movable deck or inner ramp under loads according to the vehicle distribution indicated by the Designer
- loaded movable deck or inner ramp under uniformly distributed loads corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{n_V P_V + P_P}{A_P}$$

- empty movable deck under uniformly distributed masses corresponding to a pressure, in kN/m², taken equal to:

$$p = \frac{P_P}{A_P}$$

where:

n_V : Maximum number of vehicles loaded on the movable deck

P_V : Mass of a vehicle, in kN

P_P : Mass of the movable deck, in kN

A_P : Effective area of the movable deck, in m².

1.4.3 Still water and inertial pressures

The still water and inertial pressures transmitted to the movable deck or inner ramp structures are obtained, in kN/m², as specified in Tab 1.

Table 1 : Movable decks and inner ramps - Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Still water condition		$p_S = p$
Upright sea condition	"a"	No inertial pressure
	"b"	$p_{W,X} = p\dfrac{a_{X1}}{g}$ in x direction $p_{W,Z} = p\dfrac{a_{Z1}}{g}$ in z direction
Inclined sea condition (negative roll angle)	"c"	$p_{W,Y} = p\dfrac{C_{FA}a_{Y2}}{g}$ in y direction
	"d"	$p_{W,Z} = p\dfrac{C_{FA}a_{Z2}}{g}$ in z direction
Harbour condition (1)	during lifting	$p_{W,X} = 0{,}035\ p$ in x direction $p_{W,Y} = 0{,}087\ p$ in y direction $p_{W,Z} = 0{,}200\ p$ in z direction
	at rest	$p_{W,X} = 0{,}035\ p$ in x direction $p_{W,Y} = 0{,}087\ p$ in y direction $p_{W,Z} = 0{,}100\ p$ in z direction

(1) For harbour conditions, a heel angle of 5° and a trim angle of 2° are taken into account.

Note 1:

p : Pressure, in kN/m², to be calculated according to [1.4.2] for the condition considered

C_{FA} : Combination factor, to be taken equal to:
- $C_{FA} = 0{,}7$ for load case "c"
- $C_{FA} = 1{,}0$ for load case "d".

1.4.4 Checking criteria

It is to be checked that the combined stress σ_{VM} is in accordance with the criteria defined in Ch 7, Sec 3, [3.3.1].

1.4.5 Allowable deflection

The scantlings of main stiffeners and the distribution of supports are to be such that the deflection of the movable deck or inner ramp does not exceed 5 mm/m.

1.5 Supports, suspensions and locking devices

1.5.1 Scantlings of supports and wire suspensions are to be determined by direct calculation on the basis of the loads in [1.4.2] and [1.4.3], taking account of a safety factor at least equal to 5.

1.5.2 It is to be checked that the combined stress σ_{VM} in rigid supports and locking devices is in accordance with the criteria defined in Ch 7, Sec 3, [3.3.1].

2 External ramps

2.1 General

2.1.1 The external ramps are to be able to operate with a heel angle of 5° and a trim angle of 2°.

2.1.2 The external ramps are to be examined for their watertightness, if applicable, and as a support of vehicles at harbour.

2.1.3 The locking of external ramps in stowage position at sea is examined by the Society on a case-by-case basis.

2.1.4 The ship structure under the reactions due to the ramp is examined by the Society on a case-by-case basis.

Section 9 Arrangement of Hull and Superstructure Openings

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the arrangement of hull and superstructure openings excluding hatchways, for which the requirements in Ch 8, Sec 7 apply.

1.2 Definitions

1.2.1 Standard height of superstructure

The standard height of superstructure is defined in Tab 1.

Table 1 : Standard height of superstructure h_S

Length L in m	h_S, in m	
	Raised quarter deck	All the other superstructures
L ≤ 30	0,90	1,80
30 < L ≤ 75	0,9 + 0,00667 (L – 30)	1,80
75 < L ≤ 125	1,2 + 0,012 (L – 75)	1,8 + 0,01 (L – 75)
L > 125	1,80	2,30

1.2.2 Standard sheer

The standard sheer is that defined according to regulation 38 of the International Load Line Convention 1966, as amended.

1.2.3 Exposed zones

Exposed zones are the boundaries of superstructures or deckhouses set in from the ship side at a distance less than or equal to 0,04 B.

1.2.4 Unexposed zones

Unexposed zones are the boundaries of deckhouses set in from the ship side at a distance greater than 0,04 B.

2 External openings

2.1 General

2.1.1 All external openings leading to compartments assumed intact in the damage analysis, which are below the final damage waterline, are required to be watertight.

2.1.2 External openings required to be watertight in accordance with [2.1.1] are to be of sufficient strength and, except for cargo hatch covers, are to be fitted with indicators on the bridge.

2.1.3 Openings in the shell plating below the deck limiting the vertical extent of damage are to be kept permanently closed while at sea. Should any of these openings be accessible during the voyage, they are to be fitted with a device which prevents unauthorized opening.

2.1.4 Notwithstanding the requirements of [2.1.3], the Society may authorize that particular doors may be opened at the discretion of the Master, if necessary for the operation of the ship and provided that the safety of the ship is not impaired.

2.1.5 Other closing appliances which are kept permanently closed at sea to ensure the watertight integrity of external openings are to be provided with a notice affixed to each appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

For watertight doors, a plate called “Harlequin” may be fitted, in equivalence to this notice. This plate precise the opening condition for each tightness situation.

2.2 Closing devices subjected to weapon firing loads

2.2.1 In addition to the applicable requirements of this Section, the net scantlings of closing devices subjected to weapon firing loads are to be not less that those obtained from the applicable formulae in Part B, Chapter 7, where the pressures are to be calculated according to Ch 5, Sec 6, [9].

3 Sidescuttles, windows and skylights

3.1 General

3.1.1 Application

The requirements in [3.1] to [3.4] apply to sidescuttles and rectangular windows providing light and air, located in positions which are exposed to the action of sea and/or bad weather.

3.1.2 Sidescuttle definition

Sidescuttles are round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 are to be treated as windows.

3.1.3 Window definition

Windows are rectangular openings generally, having a radius at each corner relative to the window size in accordance with recognized national or international standards, and round or oval openings with an area exceeding 0,16 m^2.

3.1.4 Number of openings in the shell plating

The number of openings in the shell plating are to be reduced to the minimum compatible with the design and proper working of the ship.

3.1.5 Material and scantlings

Sidescuttles and windows together with their glasses, deadlights and storm covers, if fitted, are to be of approved design and substantial construction in accordance with, or equivalent to, recognized national or international standards.

Non-metallic frames are not acceptable. The use of ordinary cast iron is prohibited for sidescuttles below the main watertight deck.

3.1.6 Means of closing and opening

The arrangement and efficiency of the means for closing any opening in the shell plating are to be consistent with its intended purpose and the position in which it is fitted is to be generally to the satisfaction of the Society.

3.1.7 Opening of sidescuttles

All sidescuttles, the sills of which are below the bulkhead deck, are to be of such construction as to prevent effectively any person opening them without the consent of the Master of the ship. Please also refer to Ch 2, Sec 1, Tab 2.

Sidescuttles and their deadlights which are not accessible during navigation are to be closed and secured before the ship leaves port.

The Society, at its discretion, may prescribe that the time of opening such sidescuttles in port and of closing and locking them before the ship leaves port is to be recorded in a log book.

3.2 Opening arrangement

3.2.1 General

Sidescuttles may not be fitted in such a position that their sills are below a line drawn parallel to the watertight deck at side and having its lowest point 0,025 B or 0,5 m, whichever is the greater distance, above the deepest subdivision load line.

3.2.2 Sidescuttles below (1,4 + 0,025 B) m above the water

Where in ‘tweendecks the sills of any of the sidescuttles are below a line drawn parallel to the bulkhead deck at side and having its lowest point (1,4 + 0,025 B) m above the water when the ship departs from any port, all the sidescuttles in that ‘tweendecks are to be closed watertight and locked before the ship leaves port, and they may not be opened before the ship arrives at the next port. In the application of this requirement, the appropriate allowance for fresh water may be made when applicable.

For any ship that has one or more sidescuttles so placed that the above requirements apply when it is floating at its deepest subdivision load line, the Society may indicate the limiting mean draught at which these sidescuttles are to have their sills above the line drawn parallel to the bulkhead deck at side, and having its lowest point (1,4 + 0,025 B) above the waterline corresponding to the limiting mean draught, and at which it is therefore permissible to depart from port without previously closing and locking them and to open them at sea under the responsibility of the Master during the voyage to the next port. In tropical zones as defined in the International Convention on Load Lines in force, this limiting draught may be increased by 0,3 m.

3.2.3 Cargo spaces

No sidescuttles may be fitted in any spaces which are appropriated exclusively for the carriage of cargo.

Sidescuttles may, however, be fitted in spaces appropriated alternatively for the carriage of cargo or passengers, but they are to be of such construction as to prevent effectively any person opening them or their deadlights without the consent of the Master.

If cargo is carried in such spaces, the sidescuttles and their deadlights are to be closed watertight and locked before the cargo is shipped. The Society, at its discretion, may prescribe that the time of closing and locking is to be recorded in a log book.

3.2.4 Non-opening type sidescuttles

Sidescuttles are to be of the non-opening type in the following cases:

- where they become immersed by any intermediate stage of flooding or the final equilibrium waterplane in any required damage case for ships subject to damage stability regulations
- where they are fitted outside the space considered flooded and are below the final waterline for those ships where the freeboard is reduced on account of subdivision characteristics when a freeboard calculation is undertaken.

3.2.5 Manholes and flush scuttles

Manholes and flush scuttles in positions 1 or 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

3.2.6 Ships with several decks

In ships having several decks above the bulkhead deck, the arrangement of sidescuttles and rectangular windows is considered by the Society on a case-by-case basis.

Particular consideration is to be given to the ship side up to the upper deck and the front bulkhead of the superstructure.

3.2.7 Window arrangement

Windows may not be fitted below the watertight deck, in first tier end bulkheads or sides of enclosed superstructures and in first tier deckhouses considered as being buoyant in the stability calculations or protecting openings leading below.

In the front bulkhead of a superstructure situated on the upper deck, in the case of substantially increased watertight, rectangular windows with permanently fitted storm covers are acceptable.

3.2.8 Skylights

Fixed or opening skylights are to have glass thickness appropriate to their size and position as required for sidescuttles and windows. Skylight glasses in any position are to be protected from mechanical damage and, where fitted in positions 1 or 2, to be provided with permanently attached robust deadlights or storm covers.

3.2.9 Gangway and cargo ports

Gangway and cargo ports are to be of sufficient strength. They are to be effectively closed and secured watertight before the ship leaves port, and to be kept closed during navigation.

Such ports are in no case to be so fitted as to have their lowest point below the deepest subdivision load line.

3.3 Glasses

3.3.1 General

In general, toughened glasses with frames of special type are to be used in compliance with, or equivalent to, recognised national or international standards.

Direct metal to glass contact is to be avoided.

The use of clear plate glasses is considered by the Society on a case by case basis.

3.3.2 Design loads

The design load is to be determined in accordance with the applicable requirements of Ch 8, Sec 4, [2].

In damaged ship conditions, where windows or sidescuttles are located below the deepest equilibrium waterline, the design pressure p, in kN/m², is to be taken equal to:

$p = p_S + p_W$

where:

p_S : Still water pressure, taken equal to:

$p_S = \rho\, g\, d_F$

p_W : Wave pressure, taken equal to:

$$p_W = 0{,}6 \rho g h_1 e^{\frac{-2\pi(d_F)}{L}}$$

d_F : Distance, in m, from the calculation point to the deepest equilibrium waterline.

The deepest equilibrium waterlines are to be provided by the Designer under his own responsibility.

h_1 : Reference values of the ship relative motions in the upright ship condition, defined in Ch 5, Sec 3, [3.3].

3.3.3 Scantling

The windows and sidescuttles assessment methodology defined in this Article is equivalent to Standard ISO 11336-1:2012.

The scantling of windows and sidescuttle defined in this sub-article are provided for the following types of window or sidescuttle:

- monolithic window or sidescuttle (see [3.3.4])
- laminated window or sidescuttle (see [3.3.5])
- double windows unit with gap (see [3.3.9]).

All the window and sidescuttle edges are considered as simply supported.

3.3.4 Thickness of monolithic window

The thicknesses, in mm, of monolithic windows and sidescuttles are to be obtained from the following formula:

- rectangular window or sidescuttle:

$$t = 31,6s\sqrt{\frac{\beta p S_f}{R_m}}$$

- circular window or sidescuttle:

$$t = 17,4d\sqrt{\frac{p S_f}{R_m}}$$

where:

s : Shorter side, in m, of rectangular window or sidescuttle

Where the window is supported only on 2 edges, s is to be taken as the unsupported side

ℓ : Longer side, in m, of rectangular window or sidescuttle

d : Diameter, in m, of circular window or sidescuttle

R_m : Guaranteed minimum flexural strength, in N/mm², of material used. For guidance only, the guaranteed minimum flexural strength R_m for glass window is:

- for thermally or chemically toughened glass: R_m = 120 N/mm²
- for polymethylmethacrilate (PMMA) glass: R_m = 100 N/mm²
- for polycarbonate (PC) glass: R_m = 90 N/mm²

S_f : Safety factor taken equal to:

- 3,0 for thermally or chemically toughened glass:
- 3,5 for polymethylmethacrilate (PMMA) or polycarbonate (PC) glass:

β : Aspect ratio coefficient of the rectangular window or sidescuttle, obtained in Tab 1

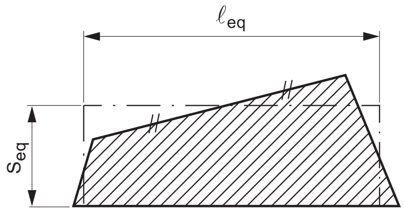
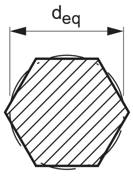
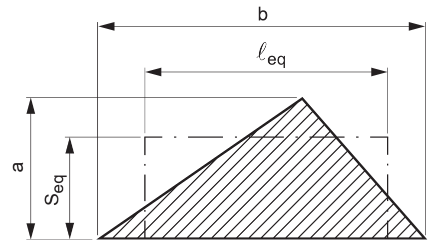
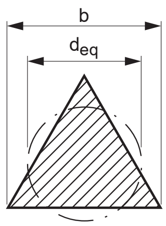
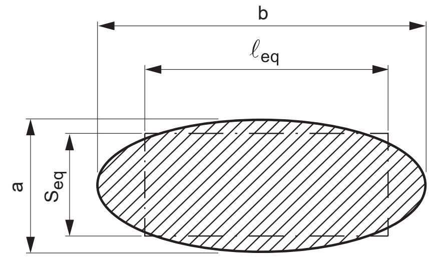
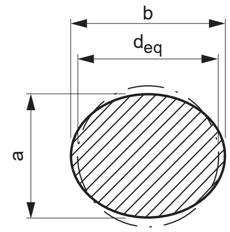
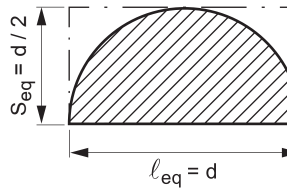
Where the window is supported only by 2 edges, β is to be taken equal to 1,0.

The thickness of windows or sidescuttles having other shapes may be obtained by considering rectangles or circles of equivalent dimensions s_{eq}, ℓ_{eq} or d_{eq} as defined in Tab 3.

Table 2 : Coefficient β

ℓ/s	β
1,0	0,284
1,5	0,475
2,0	0,608
2,5	0,684
3,0	0,716
3,5	0,734
≥ 4,0	0,750

Table 3 : Equivalent dimensions for windows having other shapes

<table>
<tr>
<td colspan="2">a) Quadrangle
The equivalent rectangle has the same area

</td>
<td>b) Polygon
The equivalent circle has the same area

</td>
<td colspan="2">c) Triangle
$s_{eq} = 2a/3$
$l_{eq} = 3b/4$

</td>
</tr>
<tr>
<td>d) Equilateral triangle
$d_{eq} = 3b/4$

</td>
<td colspan="2">e) Flat ellipse
$s_{eq} = 0,87a$
$l_{eq} = 0,87b$

</td>
<td>f) Round ellipse
$d_{eq} = \sqrt{ab}$

</td>
<td>g) Semi circle
$s_{eq} = d/2$
$l_{eq} = d$

</td>
</tr>
</table>

3.3.5 Laminated window

Laminated windows are windows realized by placing an interlayer of resin (polyvinyl butyral as a general rule) between plies of same or different materials.

For laminated windows made with plies of the same material:

- When the mechanical properties of the interlayer material (the laminating adhesive material) are not known, the plies of the laminated window are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.6].
- When the mechanical properties of the interlayer material are known in terms of shear modulus, G, in N/mm^2, the plies of the laminated window are considered as mechanically collaborating, and the equivalent thickness is to be calculated as defined in [3.3.7].

When the laminated window is made with plies of different materials, they are considered as mechanically independent, and the equivalent thickness is to be calculated as defined in [3.3.8].

3.3.6 Thickness of laminated window with independent plies

The equivalent thickness t_{eq}, in mm, of laminates made of n independent plies of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$, is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$$t_{eq} = \min[t_{eq,j}]$$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} t_{p,j}^3}{t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4].

3.3.7 Thickness of laminated window with collaborating plies

The equivalent thickness t_{eq}, in mm, of laminates made of two collaborating plies of the same material, and of thicknesses t_1 and t_2 separated by an interlayer of thickness t_I is to comply with the following formula:

$$t_{eq} \geq t$$

where:

$t_{eq} = \min[t_{1eq,s}, t_{2eq,s}]$

$t_{1eq,s}$, $t_{2eq,s}$: Equivalent thickness for strength as obtained from the following formulae:

$$t_{1eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_1 + 2\Gamma t_{s2}}}$$

$$t_{2eq,s} = \sqrt{\frac{t_{eq,d}^3}{t_2 + 2\Gamma t_{s1}}}$$

$t_{eq,d}$: Equivalent thickness for deflection as obtained from the following formula:

$$t_{1eq,d} = \sqrt[3]{t_1^3 + t_2^3 + 12\Gamma I_S}$$

Γ : Shear transfer coefficient as obtained from the following formula, without being taken less than 0 (independent plies behaviour) and more than 1,0 (monolithic behaviour):

$$\Gamma = \frac{1}{1 + 9{,}6\,\frac{E}{G} \cdot \frac{I_S}{hs^2} \cdot \frac{t_I}{s^2} \cdot \frac{1}{10^6}}$$

$$t_{s1} = \frac{hs \cdot t_1}{t_1 + t_2}$$

$$t_{s2} = \frac{hs \cdot t_2}{t_1 + t_2}$$

$$I_S = t_1 t_{s2}^2 + t_2 t_{s1}^2$$

$$hs = 0{,}5(t_1 + t_2) + t_I$$

G : Shear modulus of the interlayer at 25 °C, in N/mm², generally taken equal to 1,6 N/mm² for polyvinyl butyral (PVB).
For other interlayer materials the shear modulus value at 25 °C for short time duration load (60 s) shall be declared by the interlayer material manufacturer

E : Young's modulus of the plies, in N/mm²

s : Shorter side, in m, of rectangular window or sidescuttle.

In case of multiple (more than two plies) laminates the calculation is to be iterated. The iteration is to start from the outer ply (the one directly loaded by water pressure) and end with the inner ply.

3.3.8 Thickness of laminated window with plies of different materials

The equivalent thickness t_{eq}, in mm, of laminates made of n plies of different materials, of thicknesses $t_{p,1}$, $t_{p,2}$, …, $t_{p,n}$ and of Young's modulus $E_{p,1}$, $E_{p,2}$, ..., $E_{p,n}$ is to comply with the following formula:

$t_{eq} \geq t$

where:

$t_{eq} = \min[t_{eq,j}]$

$$t_{eq,j} = \sqrt{\frac{\sum_{j=1}^{n} E_{p,j} t_{p,j}^3}{E_{p,j} t_{p,j}}}$$

j : Ply index, ranging from 1 to n

t : Thickness, in mm, of a monolithic window, calculated according to [3.3.4] for the same material than the ply giving the minimum value of $t_{eq,j}$.

3.3.9 Thickness of double windows

Double windows are glass windows made of two plies of glass separated by an hermetically sealed spacebar.

The thickness of the ply exposed to the loads defined in [3.3.2] is to be calculated as per monolithic windows according to [3.3.4].

3.3.10 Thickness of glasses forming screen bulkheads or internal boundaries of deckhouses

The thickness of glasses forming screen bulkheads on the side of enclosed promenade spaces and that for rectangular windows in the internal boundaries of deckhouses which are protected by such screen bulkheads are considered by the Society on a case by case basis.

The Society may require both limitations on the size of rectangular windows and the use of glasses of increased thickness in way of front bulkheads which are particularly exposed to heavy sea.

3.3.11 Thickness of glasses subjected to weapon firing loads

The scantling of windows and side-scuttles exposed to weapon firing dynamic loads is to be as per [3.3.3], with pressure p, in kN/m², being taken equal to the relevant pressure calculated according to Ch 5, Sec 6, [9].

3.4 Deadlight arrangement

3.4.1 General

Sidescuttles to the following spaces are to be fitted with efficient, hinged inside deadlights:

- spaces within the first tier of enclosed superstructures
- first tier deckhouses on the watertight deck protecting openings leading below or considered buoyant in stability calculations.

3.4.2 Watertight deadlights

Efficient, hinged inside deadlights so arranged that they can be easily and effectively closed and secured watertight, are to be fitted to all sidescuttles except that abaft one eighth of the ship's length from the forward perpendicular and above a line drawn parallel to the bulkhead deck at side and having its lowest point at a height of (3,7 + 0,025 B) m above the deepest subdivision load line.

3.4.3 Openings at the side shell in the second tier

Sidescuttles and windows at the side shell in the second tier, protecting direct access below or considered buoyant in the stability calculations, are to be provided with efficient, hinged inside deadlights capable of being effectively closed and secured weathertight.

3.4.4 Openings set inboard in the second tier

Sidescuttles and windows set inboard from the side shell in the second tier, protecting direct access below to spaces listed in [3.4.1] are to be provided with either efficient, hinged inside deadlights or, where they are accessible, permanently attached external storm covers of approved design and substantial construction capable of being effectively closed and secured weathertight.

Cabin bulkheads and doors in the second tier separating sidescuttles and windows from a direct access leading below may be accepted in place of fitted deadlights or storm covers.

Note 1: Deadlights in accordance with recognized standards are fitted to the inside of windows and sidescuttles, while storm covers of comparable specifications to deadlights are fitted to the outside of windows, where accessible, and may be hinged or portable.

3.4.5 Deckhouses on superstructures of less than standard height

Deckhouses situated on a raised quarterdeck or on a superstructure of less than standard height may be treated as being on the second tier as far as the provision of deadlights is concerned, provided the height of the raised quarterdeck or superstructure is not less than the standard quarterdeck height.

3.4.6 Openings protected by a deckhouse

Where an opening in a superstructure deck or in the top of a deckhouse on the deck which gives access to a space below the waterteight deck or to a space within an enclosed superstructure is protected by a deckhouse, then it is considered that only those sidescuttles fitted in spaces which give direct access to an open stairway need to be fitted with deadlights.

4 Discharges

4.1 Arrangement of discharges

4.1.1 Inlets and discharges

All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing the accidental admission of water into the ship.

4.1.2 Inboard opening of ash-chute, rubbish-chute, etc.

The inboard opening of each ash-shoot, rubbish-shoot, etc. is to be fitted with an efficient cover.

If the inboard opening is situated below the watertight deck, the cover is to be watertight, and in addition an automatic non-return valve is to be fitted in the chute in an easily accessible position above the deepest subdivision load line . When the chute is not in use, both the cover and the valve are to be kept closed and secured.

4.2 Arrangement of garbage chutes

4.2.1 Inboard end above the waterline

The inboard end is to be located above the waterline formed by an 8,5° heel, to port or starboard, at a draught corresponding deepest subdivision load line , but not less than 1000 mm above the deepest subdivision load line. Where the inboard end of the garbage chute exceeds 0,01 L above the deepest subdivision load line, valve control from the watertight deck is not required, provided the inboard gate valve is always accessible under service conditions.

4.2.2 Inboard end below the waterline

Where the inboard end of a garbage chute is below the margin line or the Vline then:

- the inboard end hinged cover/valve is to be watertight
- the valve is to be a screw-down non-return valve fitted in an easily accessible position above the deepest subdivision load line
- the screw-down non-return valve is to be controlled from a position above the watertight deck and provided with open/shut indicators. The valve control is to be clearly marked: “Keep closed when not in use”.

4.2.3 Gate valves

For garbage chutes, two gate valves controlled from the working deck of the chute may be accepted instead of a non-return valve with a positive means of closing it from a position above the watertight deck. In addition, the lower gate valve is to be controlled from a position above the watertight deck. An interlock system between the two valves is to be arranged.

The distance between the two gate valves is to be adequate to allow the smooth operation of the interlock system.

4.2.4 Hinged cover and discharge flap

The upper gate valve, as required in [4.2.3], may be replaced by a hinged weathertight cover at the inboard end of the chute together with a discharge flap which replaces the lower gate valve.

The cover and discharge flap are to be arranged with an interlock so that the flap cannot be operated until the hopper cover is closed.

4.2.5 Marking of valve and hinged cover

The gate valve controls and/or hinged cover are to be clearly marked: “Keep closed when not in use”.

4.3 Scantlings of garbage chutes

4.3.1 Material

The chute is to be constructed of steel. Other equivalent materials are considered by the Society on a case-by-case basis.

4.3.2 Wall thickness

The wall thickness of the chute up to, and including, the cover is to be not less than that obtained, in mm, from Tab 4.

Table 4 : Wall thickness of garbage chutes

External diameter d, in mm	Thickness, in mm
$d \leq 80$	7,0
$80 < d < 180$	7,0 + 0,03 (d – 80)
$180 \leq d \leq 220$	10,0 + 0,063 (d – 180)

5 Freeing ports

5.1 General provisions

5.1.1 General

Where bulwarks on the weather portions of watertight or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of water and for draining them.

A well is any area on the deck exposed to the weather, where water may be entrapped. Wells are considered to be deck areas bounded on four sides by deck structures; however, depending on their configuration, deck areas bounded on three or even two sides by deck structures may be deemed wells.

5.1.2 Freeing port areas

The minimum required freeing port areas in bulwarks on the watertight deck are specified in Tab 5.

5.1.3 Freeing port arrangement

Where a sheer is provided, two thirds of the freeing port area required is to be provided in the half of the well nearer the lowest point of the sheer curve.

Where the exposed watertight deck or an exposed superstructure deck has little or no sheer, the freeing port area is to be spread along the length of the well.

However, bulwarks may not have substantial openings or accesses near the breaks of superstructures, unless they are effectively detached from the superstructure sides.

5.1.4 Freeing port positioning

The lower edge of freeing ports is to be as near the deck as practicable, at not more than 100 mm above the deck.

All the openings in the bulwark are to be protected by rails or bars spaced approximately 230 mm apart.

Table 5 : Freeing port area in bulwark located on watertight deck

Ship types or ship particulars	Area A of freeing ports, in m^2	Applicable requirement
Ships fitted with a trunk having breadth ≥ 0,6 B	$0,33\ \ell_B\ h_B$	[5.3.1]
Ships fitted with continuous or substantially continuous trunk and/or hatch coamings	A_2	[5.3.1]
Ships fitted with non-continuous trunk and/ or hatch coamings	A_3	[5.3.2]
Ships fitted with open superstructure	A_S for superstructures A_W for wells	[5.4.2] [5.4.3]
Other ships	A_1	[5.2.1]

Note 1:
ℓ_B : Length, in m, of bulwark in a well at one side of the ship
h_B : Mean height, in m, of bulwark in a well of length ℓ_B .

5.1.5 Freeing port closures

If shutters or closures are fitted to freeing ports, ample clearance is to be provided to prevent jamming. Hinges are to have pins or bearings of non-corrodible material. If shutters are fitted with securing appliances, these appliances are to be of approved construction.

5.1.6 Gutter bars

Gutter bars greater than 300 mm in height fitted around the weather decks are to be treated as bulwarks. The freeing port area is to be calculated in accordance with the applicable requirements of this Section.

5.2 Freeing port area in a well not adjacent to a trunk or hatchways

5.2.1 Freeing port area A_1

Where the sheer in way of the well is standard or greater than the standard, the freeing port area on each side of the ship for each well is to be not less than that obtained, in m^2, in Tab 6.

In ships with no sheer, the above area is to be increased by 50%. Where the sheer is less than the standard, the percentage of increase is to be obtained by linear interpolation.

5.2.2 Minimum freeing port area for a deckhouse having a breadth not less than 0,8 B

Where a flush deck ship is fitted amidships with a deckhouse having a breadth not less than 0,8 B and the width of the passageways along the side of the ship less than 1,5 m, the freeing port area is to be calculated for two separate wells, before and abaft the deckhouse. For each of these wells, the freeing port area is to be obtained from Tab 5, where ℓ_B is to be taken equal to the actual length of the well considered (in this case the limitation $\ell_B \le 0,7$ L may not be applied).

5.2.3 Minimum freeing port area for screen bulkhead

Where a screen bulkhead is fitted across the full breadth of the ship at the fore end of a midship deckhouse, the weather deck is to be considered as divided into two wells, irrespective of the width of the deckhouse, and the freeing port area is to be obtained in accordance with [4.1.2].

Table 6 : Freeing port area A_1 in a well not adjacent to a trunk or hatchways

Location	Freeing port area A_1 , in m^2	
	$\ell_B \le 20$	$\ell_B > 20$
Watertight deck and raised quarterdecks	$0,7 + 0,035\ell_B + A_C$	$0,070\ell_B + A_C$
Superstructure decks	$0,35 + 0,0175\ell_B + 0,5A_C$	$0,035\ell_B + 0,5A_C$

Note 1:
ℓ_B : Length, in m, of bulwark in the well, to be taken not greater than 0,7 L
A_C : Area, in m^2, to be taken, with its sign, equal to:

$$A_C = \frac{\ell_W}{25}(h_B - 1,2) \quad \text{for } h_B > 1,2$$

$$A_C = 0 \quad \text{for } 0,9 \le h_B \le 1,2$$

$$A_C = \frac{\ell_W}{25}(h_B - 0,9) \quad \text{for } h_B < 0,9$$

h_B : Mean height, in m, of the bulwark in a well of length ℓ_B .

5.3 Freeing port area in a well contiguous to a trunk or hatchways

5.3.1 Freeing port area A2 for a continuous trunk or continuous hatchway coamings

Where the ship is fitted with a continuous trunk not included in the stability calculation or where continuous or substantially continuous hatchway side coamings are fitted between detached superstructures, the freeing port area is to be not less than that obtained, in m², from Tab 7.

Where the ship is fitted with a continuous trunk having breadth not less than 0,6 B, included in the stability calculation and where open rails on the weather parts of the watertight deck in way of the trunk for at least half the length of these exposed parts are not fitted, the freeing port area in the well contiguous to the trunk is to be not less than 33% of the total area of the bulwarks.

Table 7 : Freeing port area A_2 in a well contiguous to a continuous trunk or continuous hatchway coamings

Breadth B_H, in m	Freeing port area A_2, in m²
$B_H \le 0{,}4\ B$	$0{,}2\ \ell_B\ h_B$
$0{,}4\ B < B_H < 0{,}75\ B$	$\left[0{,}2 - 0{,}286\left(\frac{B_H}{B} - 0{,}4\right)\right]\ell_B h_B$
$B_H \ge 0{,}75\ B$	$0{,}1\ \ell_B\ h_B$

Note 1:

B_H : Breadth of the trunk or the hatchway, in m

ℓ_B : Length, in m, of bulwark in a well at one side of the ship

h_B : Mean height, in m, of bulwark in a well of length ℓ_B.

5.3.2 Freeing port area A_3 for a non-continuous trunk or non-continuous hatchway coamings

Where the free flow of water across the deck of the ship is impeded due to the presence of a non-continuous trunk, hatchway coaming or deckhouse in the whole length of the well considered, the freeing port area in the bulwark of this well is to be not less than that obtained, in m², from Tab 8.

Table 8 : Freeing port area A_3 in a well contiguous to a non-continuous trunk or non-continuous hatchway coamings

Free flow area f_P, in m²	Freeing port area A_3, in m²
$f_p \le A_1$	A_2
$A_1 < f_P < A_2$	$A_1 + A_2 - f_P$
$f_P \ge A_2$	A_1

Note 1:

f_P : Free flow area on deck, equal to the net area of gaps between hatchways, and between hatchways and superstructures and deckhouses up to the actual height of the bulwark

A_1, A_2 : Freeing port areas, in m², to be obtained from, respectively, Tab 6 and Tab 7.

5.4 Freeing port area in an open space within superstructures

5.4.1 General

In ships having superstructures on the watertight or superstructure decks, which are open at either or both ends to wells formed by bulwarks on the open decks, adequate provision for freeing the open spaces within the superstructures is to be provided.

5.4.2 Freeing port area A_S for open superstructures

The freeing port area on each side of the ship for the open superstructure is to be not less than that obtained, in m², from the following formula:

$$A_S = A_1 c_{SH}\left[1 - \left(\frac{\ell_W}{\ell_T}\right)^2\right]\left(\frac{b_0 h_S}{2\,\ell_T h_W}\right)$$

where:

ℓ_T : Total well length, in m, to be taken equal to: $\ell_T = \ell_W + \ell_S$

ℓ_W : Length, in m, of the open deck enclosed by bulwarks

ℓ_S : Length, in m, of the common space within the open superstructures

A_1 : Freeing port area, in m², required for an open well of length ℓ_T, in accordance with Tab 6, where A_C is to be taken equal to zero

c_{SH} : Coefficient which accounts for the absence of sheer, if applicable, to be taken equal to:
- c_{SH} = 1,0 in the case of standard sheer or sheer greater than standard sheer
- c_{SH} = 1,5 in the case of no sheer

b_0 : Breadth, in m, of the openings in the end bulkhead of enclosed superstructures
h_S : Standard superstructure height, in m, defined in [1.2.1]
h_W : Distance, in m, of the well deck above the watertight deck.

5.4.3 Freeing port area A_W for open well

The freeing port area on each side of the ship for the open well is to be not less than that obtained, in m², from the following formula:

$$A_W = A_1 c_{SH}\left(\frac{h_S}{2h_W}\right)$$

where:

A_1 : Freeing port area, in m², required for an open well of length ℓ_W, in accordance with Tab 6
c_{SH}, h_S, h_W, ℓ_W: Defined in [5.4.2].

5.4.4 The resulting freeing port areas for the open superstructure A_S and for the open well A_W are to be provided along each side of the open space covered by the open superstructure and each side of the open well, respectively.

6 Machinery space openings

6.1 Engine room skylights

6.1.1 Engine room skylights in position 1 or 2 are to be properly framed, securely attached to the deck and efficiently enclosed by steel casings of suitable strength. Where the casings are not protected by other structures, their strength will be considered by the Society on a case-by-case basis.

Skylights, where fitted with openings for light and air, are to have coamings of a height not less than:
- 900 mm, if in position 1
- 760 mm, if in position 2.

6.2 Closing devices

6.2.1 Machinery casings

Openings in machinery space casings in position 1 or 2 are to be fitted with doors of steel or other equivalent materials, permanently and strongly attached to the bulkhead, and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead and weathertight when closed. The doors are to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Other openings in such casings are to be fitted with equivalent covers, permanently attached in their proper position.

6.2.2 Height of the sill of the door

The height of the sill of the door is generally to be not less than:
- 600 mm above the deck if in position 1
- 380 mm above the deck if in position 2
- 230 mm in all the other cases.

However, height of coamings are to be compatible with use at sea and are not to be less than 300mm in position 1 and 150mm in position 2 in any case.

6.2.3 Double doors

Where casings are not protected by other structures, double doors (i.e. inner and outer doors) are required. An inner sill of 230 mm in conjunction with the outer sill of 600 mm is normally to be provided.

However, the height of this sill is to be compatible with use at sea and is not to be less than 300mm in position 1 and 150mm in position 2 in any case.

6.2.4 Fiddly openings

Fiddly openings are to be fitted with strong covers of steel or other equivalent material permanently attached in their proper positions and capable of being secured weathertight.

6.3 Coamings

6.3.1 Coamings of any fiddly, funnel or machinery space ventilator in an exposed position on the watertight deck or superstructure deck are to be as high above the deck as is reasonable and practicable.

In general, ventilators necessary to continuously supply the machinery space and, on demand, the emergency generator room are to have coamings whose height is in compliance with [8.1.3], but need not be fitted with weathertight closing appliances.

Where, due to the ship size and arrangement, this is not practicable, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing appliances in accordance with [8.1.2], may be permitted by the Society in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

7 Companionway

7.1 General

7.1.1 Openings in watertight deck

Openings in watertight deck other than hatchways, machinery space openings, manholes and flush scuttles are to be protected by an enclosed superstructure or by a deckhouse or companionway of equivalent strength and weathertightness.

7.1.2 Openings in superstructures

Openings in an exposed superstructure deck or in the top of a deckhouse on the watertight deck which give access to a space below the watertight deck or a space within an enclosed superstructure are to be protected by an efficient deckhouse or companionway.

7.1.3 Openings in superstructures having a height less than standard height

Openings in the top of a deckhouse on a raised quarterdeck or superstructure of less than standard height, having a height equal to or greater than the standard quarterdeck height are to be provided with an acceptable means of closing but need not be protected by an efficient deckhouse or companionway provided the height of the deckhouse is at least the height of the superstructure.

7.2 Scantlings

7.2.1 Companionways on exposed decks protecting openings leading into enclosed spaces are to be of steel or equivalent material and strongly attached to the deck and are to have adequate scantlings.

7.3 Closing devices

7.3.1 Doors

Doorways in deckhouses or companionways leading to or giving access to spaces below the watertight deck or to enclosed superstructures are to be fitted with weathertight doors. The doors are to be made of steel or equivalent material, to be capable of being operated from both sides and generally to open outwards to give additional protection against wave impact.

Alternatively, if stairways within a deckhouse are enclosed within properly constructed companionways fitted with weathertight doors, the external door need not be watertight.

Where the closing appliances of access openings in superstructures and deckhouses are not weathertight, interior deck openings are to be considered exposed, i.e. situated in the open deck.

7.3.2 Height of sills

The height above the deck of sills to the doorways in companionways is to be not less than:

- 600 mm in position 1
- 380 mm in position 2.

Where access is not provided from above, the height of the sills to doorways in a poop bridge or deckhouse on the watertight deck is to be 600 mm.

Where access is provided to spaces inside a bridge or poop from the deck as an alternative to access from the watertight deck, the height of the sills into the bridge or poop is to be 380 mm. This also applies to deckhouses on the exposed deck.

However, height of sills are to be compatible with use at sea and are not to be less than 300mm in position 1 and 150 mm in position 2 in any case.

8 Ventilators

8.1 Closing appliances

8.1.1 General

Ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material, designed to offer equivalent strength compared to the adjacent bulkhead or coaming in which they are fitted.

8.1.2 Closing appliance exemption

Ventilators need not be fitted with closing appliances, unless specifically required by the Society, if the coamings extend for more than:

- 4,5 m above the deck in position 1
- 2,3 m above the deck in position 2.

8.1.3 Closing appliances for ships not greater than 100 m in length

In ships not greater than 100 m in length, the closing appliances are to be permanently attached to the ventilator coamings.

8.1.4 Closing appliances for ships greater than 100 m in length

Where, in ships greater than 100 m in length, the closing appliances are not permanently attached, they are to be conveniently stowed near the ventilators to which they are to be fitted.

8.1.5 Ventilation of machinery spaces and emergency generator room

In order to satisfactorily ensure, in all weather conditions:

- the continuous ventilation of machinery spaces, and
- when necessary, the immediate ventilation of the emergency generator room,

the ventilators serving such spaces are to comply with [8.1.2], i.e. their openings are to be so located that they do not require closing appliances.

8.1.6 Reduced height of ventilator coamings for machinery spaces and emergency generator room

Where, due to the ship size and arrangement, the requirements in [8.1.5] are not practicable, lesser heights may be accepted for machinery space and emergency generator room ventilator coamings fitted with weathertight closing appliances in accordance with [8.1.1], [8.1.3] and [8.1.4] in combination with other suitable arrangements, such as separators fitted with drains, to ensure an uninterrupted, adequate supply of ventilation to these spaces.

8.1.7 Closing arrangements of ventilators led overboard or through enclosed superstructures

Closing arrangements of ventilators led overboard to the ship side or through enclosed superstructures are considered by the Society on a case-by-case basis. If such ventilators are led overboard more than 4,5 m above the watertight deck, closing appliances may be omitted provided that satisfactory baffles and drainage arrangements are fitted.

8.2 Coamings

8.2.1 General

Ventilators in position 1 or 2 to spaces below watertight decks or decks of enclosed superstructures are to have coamings of steel or other equivalent material, substantially constructed and efficiently connected to the deck.

Ventilators passing through superstructures other than enclosed superstructures are to have substantially constructed coamings of steel or other equivalent material at the watertight deck.

8.2.2 Scantlings

The scantlings of ventilator coamings exposed to the weather are to be not less than those obtained from Tab 9.

In exposed locations or for the purpose of compliance with buoyancy calculations, the height of coamings may be required to be increased to the satisfaction of the Society.

9 Tank cleaning openings

9.1 General

9.1.1 Ullage plugs, sighting ports and tank cleaning openings may not be arranged in enclosed spaces.

Table 9 : Scantlings of ventilator coamings

Feature	Scantlings
Height of the coaming above the deck	$h = 900$ mm in position 1 $h = 760$ mm in position 2
Thickness of the coaming, in mm **(1)**	$t = 5,5 + 0,01\ d_V$ with $7,5 \leq t \leq 10,0$
Support	If $h > 900$ mm, the coaming is to be suitably stiffened or supported by stays

(1) Where the height of the ventilator exceeds the height h, the thickness of the coaming may be gradually reduced, above that height, to a minimum of 6,5 mm.

Note 1:

d_V : Internal diameter of the ventilator, in mm.

Section 10 Helicopter Decks

Symbols

W_H : Maximum weight of the helicopter, in t

g : Gravity acceleration, in m/s²:

$g = 9,81$ m/s²

R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm², unless otherwise specified

k : Material factor for steel, defined in Ch 4, Sec 1, [2.3].

1 Application

1.1 General

1.1.1 The requirements of this Section apply to areas equipped for the landing and take-off of helicopters with landing gears or landing skids, and located on a deck or on a platform permanently connected to the hull structure.

1.1.2 Helicopter deck or platform intended for the landing of helicopters having landing devices other than wheels or skids are to be examined by the Society on a case-by-case basis.

2 Definition

2.1 Landing gear

2.1.1 A landing gear may consist of a single wheel or a group of wheels.

3 General arrangement

3.1 Dimension of the landing area

3.1.1 The main dimensions of the landing area, its location on board, the approach sector for landing and take-off are to comply with the applicable requirements from the National or other Authorities, or contractual specifications.

3.2 Sheathing of the landing area

3.2.1 Within the landing area, a non-skid deck covering is recommended.

3.2.2 Where the deck or the platform is wood sheathed, special attention is to be paid to the fire protection.

3.3 Approach and landing area

3.3.1 The approach and the landing area are to be free of obstructions above the level of the deck or the platform.

Note 1: The following items may exceed the height of the landing area, but should not do so by more than 100 mm:

- the guttering or slightly raised kerb
- the lightning equipment
- the outboard edge of the safety net
- the foam monitors
- those handrails and other items associated with the landing area which are incapable of complete retraction or lowering for helicopter operations.

3.4 Safety net

3.4.1 It is recommended to provide a safety net at the sides of the deck or the platform.

3.5 Drainage system

3.5.1 Gutterways of adequate height and a drainage system are recommended on the periphery of the deck or the platform.

4 Design principles

4.1 General

4.1.1 Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

4.2 Partial safety factors

4.2.1 The partial safety factors to be considered for checking helicopter deck and platform structures are specified in Tab 1.

Table 1 : Helicopter decks and platforms - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors			
	Symbol	Plating	Ordinary stiffeners	Primary supporting members
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20
Note 1: Value of 1.1 may be considered instead of 1,2 when the deck is not located on the aft or the fore part of the ship				

5 Design loads

5.1 General

5.1.1 As a rule, the strength analysis for the situation of normal landing is not required as it is covered by the strength analysis in emergency landing, as defined in [5.2].

5.1.2 The following loads are to be considered for the scantling of the helicopter deck or landing platform:

- emergency landing load defined in [5.2]
- garage load, if any, defined in [5.3]
- loads due to ship accelerations and wind defined in [5.4]
- sea pressure obtained according to Ch 5, Sec 5, [3.2].

5.1.3 Helicopter having landing devices other than wheels

In case of a deck or a platform intended for the landing of helicopters having landing devices other than wheels (e.g. skates), the landing loads, the emergency loads and the garage loads, if any, are to be examined by the Society on a case-by-case basis.

5.2 Emergency landing load

5.2.1 The emergency landing force F_{EL} transmitted through one landing gear or one skid to the helicopter deck or platform is to be obtained, in kN, from the following formulae:

- helicopter with landing gears: $F_{EL} = 1,75\ g\ W_H$
- helicopter with landing skids: $F_{EL} = 2,50\ g\ W_H$

The point of application of the force F_{EL} is to be taken so as to produce the most severe stresses on the supporting structure.

5.3 Garage load

5.3.1 Where a garage zone is fitted in addition to the landing area, the still water and inertial forces transmitted trough each landing gear or each landing skid to the helicopter deck or platform, in kN, are to be obtained as specified in Ch 5, Sec 6, [4.1.1], where M is to be taken equal to:

- for helicopter with landing gears:

  M is the landing gear load, in t, to be specified by the Designer. If the landing gear load is not known, M is to be taken equal to:

  $$M = \frac{1,25}{n} W_H$$

  where n is the total number of landing gears

- for helicopter with landing skids:

  $M = 0,5\ W_H$

5.3.2 When helicopters are parked in an unprotected area, sea pressures on deck, as per Ch 5, Sec 5, [3], are to be considered simultaneously with the loads defined in [5.3.1].

5.4 Forces due to ship accelerations and wind

5.4.1 This Sub-Article applies to helicopter platforms which are not part of the ship hull structures.

5.4.2 The still water and inertial forces transmitted by the helicopter platform to the ship hull structures are to be determined, in kN, as specified in Tab 2.

Table 2 : Helicopter platforms - Still water and inertial forces

Ship condition	Load case	Still water force F_S and inertial force F_W, in kN
Still water condition		$F_S = (W_H + W_P)\,g$
Upright condition	"a"	No inertial force
	"b"	$F_{W,X} = (W_H + W_P)a_{X1} + 1{,}2A_{HX}$ in x direction $F_{W,Z} = (W_H + W_P)a_{Z1}$ in z direction
Inclined condition (negative roll angle) **(1)**	"c"	$F_{W,Y} = C_{FA}(W_H + W_P)a_{Y2} + 1{,}2A_{HY}$ in y direction
	"d"	$F_{W,Z} = C_{FA}(W_H + W_P)a_{Z2}$ in z direction

(1) Inclined condition is not applicable for ships less than 65 m in length.

Note 1:

- W_p : Structural weight of the helicopter platform, in t, to be evenly distributed, and to be taken not less than the value obtained from the following formula (W_p may be taken equal to zero when the structure of the landing area is part of the deck structure):
  $W_p = 0{,}2\ A_H$
- A_H : Area, in m², of the entire landing area
- a_{X1}, a_{Z1} : Accelerations, in m/s², determined at the helicopter center of gravity for the upright ship condition, and defined in Ch 5, Sec 3, [3.4]
- a_{Y2}, a_{Z2} : Accelerations, in m/s², determined at the helicopter center of gravity for the inclined ship condition, and defined in Ch 5, Sec 3, [3.4]
- A_{HX}, A_{HY} : Vertical areas, in m², of the helicopter platform in x and y directions respectively. Unless otherwise specified, A_{HX} and A_{HY} may be taken equal to $A_H/3$
- C_{FA} : Combination factor, to be taken equal to:
  - $C_{FA} = 0{,}7$ for load case "c"
  - $C_{FA} = 1{,}0$ for load case "d".

6 Scantlings

6.1 Net scantling

6.1.1 As specified in Ch 4, Sec 2, [1], all scantlings referred to in this Section are net, i.e. they do not include any margin for corrosion.

The net scantlings are obtained as specified in Ch 4, Sec 2, [1].

6.2 Plating

6.2.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$

  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.2]
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the garage loads, as defined in [5.3], if applicable

6.2.2 Plating subjected to sea pressure

The net thickness of an helicopter deck or platform subject to forces defined in [6.2.1] is to be not less than the values obtained according to Ch 7, Sec 1, [4.3], considering λ equal to 1,0 in the particular case of a platform.

The value of P_0 when used in the formula of Ch 7, Sec 1, [4.3] is to be taken as specified in [5.2] for the emergency load and [5.3] for the garage load

6.3 Ordinary stiffeners

6.3.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$
  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.2]
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$
  where F_s and $F_{w,z}$ are the forces corresponding to the garage loads, as defined in [5.3], if applicable
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$
  where F_s and $F_{w,z}$ are the forces corresponding to the loads due to ship accelerations and wind, as defined in [5.4]
- sea pressure loads as defined in [5.3.2].

6.3.2 Normal and shear stresses

Normal and shear stresses induced by loads and pressures in an ordinary stiffener are to be obtained according to:

- Ch 7, Sec 2, [3.4] for an ordinary stiffener subjected to sea pressure
- Ch 7, Sec 2, [3.5] for an ordinary stiffener subjected to loads transmitted by tyre prints.

6.3.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [6.3.2] fulfill the following conditions:

$$\sigma \le \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \le 0{,}5\frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance:

- γ_R = 1,02 for garage loads
- γ_R = 1,00 for emergency condition
- γ_R = 1,02 for loads dues to ship accelerations and wind.

6.4 Primary supporting members

6.4.1 Load model

The following forces P_0 are to be considered independently:

- $P_0 = F_{EL}$
  where F_{EL} is the force corresponding to the emergency landing load, as defined in [5.2]
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$
  where F_s and $F_{w,z}$ are the forces corresponding to the garage loads, as defined in [5.3], if applicable
- $P_0 = \gamma_{s2}\ F_s + \gamma_{w2}\ F_{w,z}$
  where F_s and $F_{w,z}$ are the forces corresponding to the loads due to ship accelerations and wind, as defined in [5.4]
- sea pressure loads as defined in [5.3.2].

6.4.2 Load model for landing area located on a platform

The following loads are to be considered independently:

- sea pressure, as defined in Ch 5, Sec 5, [3.2]
- loads transmitted by tyre prints:
  - emergency landing load, as defined in [5.2]
  - garage load, if any, as defined in [5.3]
- loads due to ship accelerations and wind, as defined in [5.4].

6.4.3 Normal and shear stresses

Normal and shear stresses induced by loads and pressures in a primary supporting member are to be obtained according to Ch 7, App 1, [5], considering:

- for analyses based on finite element models:
  $\sigma = \text{Max}\ (\sigma_1\ ;\ \sigma_2)$ and $\tau = \tau_{12}$
- for analyses based on beam models:
  $\sigma = \sigma_1$ and $\tau = \tau_{12}$

6.4.4 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [6.4.3] fulfill the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0{,}5\frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material to be taken equal to 1,02

γ_R : Partial safety factor covering uncertainties on the resistance:

- γ_R = 1,02 for garage loads
- γ_R = 1,00 for emergency condition
- γ_R = 1,02 for loads dues to ship accelerations and wind.

7 Lashing

7.1 General

7.1.1 Where lashing pots are fitted on helicopter deck, the strength of the structure in way of the lashing pots is to be assessed according to this Article.

7.1.2 As a rule, the fixed lashing devices are to be fitted in way of deck stiffening structural elements.

7.2 Documentation to be submitted

7.2.1 The following documentation is to be submitted to the Society for information:

- lashing arrangement showing clearly the lashing forces transmitted to the hull structures and pre-tensioning forces, if any
- Safe Working Load (SWL) and Breaking Load (BL) of the fixed and portable lashing devices
- details of welding between fixed lashing devices and deck structure

In the absence of information, the lashing force transmitted through one single lashing device may be taken equal to 50 kN acting at 45° with respect to the deck plan, in the most severe direction.

7.3 Design Load

7.3.1 The design load to be considered for the structural assessment of the deck structure in way of lashing devices is to be taken equal to 1,1 SWL.

7.4 Checking criteria

7.4.1 It is to be checked that the normal stress σ and the shear stress τ in way of all structure elements supporting lashing forces fulfill the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0{,}5\frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_r : Partial safety factor covering uncertainties on the resistance, to be taken as specified in Ch 7, Sec 3.

8 Recovery devices

8.1 Definition

8.1.1 A recovery device is a system used for free deck landing and to handle the helicopter to the hangar. It provides a means of securing the helicopter to the flight deck by aligning it with a deck-mounted track.

8.2 Documentation to be submitted

8.2.1 The following documentation is to be submitted to the Society for information:

- General arrangement showing the maximum reaction forces induced by the recovery device on the deck structure
- Drawing of the integration of the system within the ship structure, including scantling and welding details.

8.3 Checking criteria

8.3.1 It is to be checked that the normal stress σ and the shear stress τ in way of all structure elements supporting lashing forces fulfill the following conditions:

$$\sigma \leq \frac{R_y}{\gamma_R \gamma_m}$$

$$\tau \leq 0{,}5\frac{R_y}{\gamma_R \gamma_m}$$

where:

γ_m : Partial safety factor covering uncertainties on the material, to be taken equal to 1,02

γ_r : Partial safety factor covering uncertainties on the resistance, to be taken as specified in Ch 7, Sec 3.

CHAPTER 9
HULL OUTFITTING

Section 1	Rudders
Section 2	Bulwarks and Guard Rails
Section 3	Propeller Shaft Brackets
Section 4	Equipment
Section 5	Masts and Other Outfitting Components
Appendix 1	Criteria for Direct Calculation of Rudder Loads

Section 1 Rudders

Symbols

V_{AV} : Maximum ahead speed, in knots, with the ship on full load waterline; if V_{AV} is less than 10 knots, the maximum service speed is to be taken not less than the value obtained from the following formula:

$$V_{MIN} = \frac{V_{AV} + 20}{3}$$

V_{AD} : Maximum astern speed, in knots, to be taken not less than 0,5 V_{AV}. However, in case the maximum achievable astern speed indicated by the designer is less, the latest can be considered

A : Total area of the rudder blade, in m^2, bounded by the blade external contour, including the mainpiece and the part forward of the centreline of the rudder pintles, if any

k_1 : Material factor, defined in [1.4.1]

k : Material factor, defined in Ch 4, Sec 1, [2.3] (see also [1.4.5])

C_R : Rudder force, in N, acting on the rudder blade, defined in [2.1.1] and [2.2.1]

M_{TR} : Rudder torque, in N.m, acting on the rudder blade, defined in [2.1.2] and [2.2.2]

M_B : Bending moment, in N.m, in the rudder stock, defined in [4.1].

1 General

1.1 Application

1.1.1 Ordinary profile rudders

The requirements of this Section apply to ordinary profile rudders, without any special arrangement for increasing the rudder force, whose maximum orientation at maximum ship speed is limited to 35° on each side.

In general, an orientation greater than 35° is accepted for manoeuvres or navigation at very low speed.

When the maximum orientation at maximum speed is limited to angle smaller than 35° by physical or software devices, the Society may accept reductions, on a case-by-case basis.

1.1.2 High lift profiles

The requirements of this Section also apply to rudders fitted with flaps to increase rudder efficiency. For these rudder types, an orientation at maximum speed less than 35° may be accepted. In these cases, the rudder forces are to be calculated by the Designer for the most severe combinations between orientation angle and ship speed. These calculations are to be considered by the Society on a case-by-case basis.

The rudder scantlings are to be designed so as to be able to sustain possible failures of the orientation control system, or, alternatively, redundancy of the system itself may be required.

1.1.3 Steering nozzles

The requirements for steering nozzles are given in Article [10].

1.1.4 Special rudder types

Rudders others than those in [1.1.1], [1.1.2] and [1.1.3] will be considered by the Society on a case-by-case basis.

1.1.5 Materials

The requirements of the present section apply to rudders made of steel. Rudders made of other materials are to be considered on a case-by-case basis.

1.2 Gross scantlings

1.2.1 With reference to Ch 4, Sec 2, [1], all scantlings and dimensions referred to in this Section are gross, i.e. they include the margins for corrosion.

1.3 Arrangements

1.3.1 Effective means are to be provided for supporting the weight of the rudder without excessive bearing pressure, e.g. by means of a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

1.3.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

In addition, structural rudder stops of suitable strength are to be provided, except where the steering gear is provided with its own rudder stopping devices, as detailed in Pt C, Ch 1, Sec 12.

1.3.3 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

1.4 Materials

1.4.1 Rudder stocks, pintles, coupling bolts, keys and cast parts of rudders are to be made of rolled steel, steel forgings or steel castings according to the applicable requirements in NR216 Materials and Welding, Chapter 2.

1.4.2 The material used for rudder stocks, pintles, keys and bolts is to have a minimum yield stress not less than 200 N/mm².

1.4.3 The requirements relevant to the determination of scantlings contained in this Section apply to steels having a minimum yield stress equal to 235 N/mm².

Where the material used for rudder stocks, pintles, coupling bolts, keys and cast parts of rudders has a yield stress different from 235 N/mm², the scantlings calculated with the formulae contained in the requirements of this Section are to be modified, as indicated, depending on the material factor k_1, to be obtained from the following formula:

$$k_1 = \left(\frac{235}{R_{eH}}\right)^n$$

where:

R_{eH} : Yield stress, in N/mm², of the steel used, and not exceeding the lower of 0,7 R_m and 450 N/mm²

R_m : Minimum ultimate tensile strength, in N/mm² of the steel used,

n : Coefficient to be taken equal to:

- $n = 0{,}75$ for $R_{eH} > 235$ N/mm²
- $n = 1{,}00$ for $R_{eH} \leq 235$ N/mm².

1.4.4 Significant reductions in rudder stock diameter due to the application of steels with yield stresses greater than 235 N/mm² may be accepted by the Society subject to the results of a check calculation of the rudder stock deformations.

Large rudder stock deformations are to be avoided in order to avoid excessive edge pressures in way of bearings.

1.4.5 Welded parts of rudders are to be made of approved rolled hull materials. For these members, the material factor k defined in Ch 4, Sec 1, [2.3] is to be used.

2 Force and torque acting on the rudder

2.1 Rudder blade without cut-outs

2.1.1 Rudder blade description

A rudder blade without cut-outs may have trapezoidal or rectangular contour.

2.1.2 Rudder force

The rudder force C_R is to be obtained, in N, from the following formula:

$$C_R = 132\, n_R\, A\, V^2\, r_1\, r_2\, r_3$$

where:

n_R : Navigation coefficient, defined in Tab 1

V : V_{AV} or V_{AD}, depending on the condition under consideration (for high lift profiles, see [1.1.2])

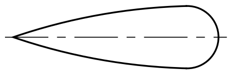
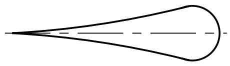
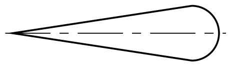
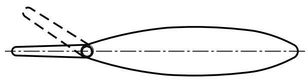
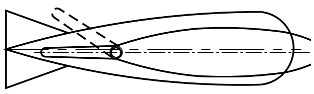
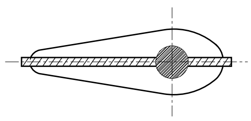
r_1 : Shape factor, to be taken equal to:

$$r_1 = \frac{\lambda + 2}{3}$$

Table 1 : Navigation coefficient n_R

Navigation notation	Navigation coefficient n_R
Unrestricted navigation	1,00
Coastal area	0,85
Sheltered area	0,75

Table 2 : Values of coefficient r_2

Rudder profile type	r_2 for ahead condition	r_2 for astern condition
NACA 00 - Goettingen 	1,10	0,80
Hollow 	1,35	0,90
Flat side 	1,10	0,90
High lift 	1,70	1,30
Fish tail 	1,40	0,80
Single plate 	1,00	1,00

λ : Coefficient, to be taken equal to:

$$\lambda = \frac{h^2}{A_T}$$

and not greater than 2,0

h : Mean height, in m, of the rudder area to be taken equal to (see Fig 1):

$$h = \frac{z_3 + z_4 - z_2}{2}$$

A_T : Area, in m², to be calculated by adding the rudder blade area A to the area of the rudder post or rudder horn, if any, up to the height h

r_2 : Coefficient to be obtained from Tab 2. For other profiles than those defined in Tab 2, the value of r_2 is defined by the Society on a case-by-case basis

r_3 : Coefficient to be taken equal to:

- r_3 = 0,8 for rudders outside the propeller jet (centre rudders on twin screw ships, or similar cases)
- r_3 = 1,15 for rudders behind a fixed propeller nozzle
- r_3 = 1,0 in other cases.

2.1.3 Rudder torque

The rudder torque M_{TR}, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = C_R\, r$

where:

r : Lever of force C_R, in m, equal to:

$$r = b\left(\alpha - \frac{A_F}{A}\right)$$

and to be taken not less than 0,1 b for the ahead condition b : Mean breadth, in m, of rudder area to be taken equal to (see Fig 1):

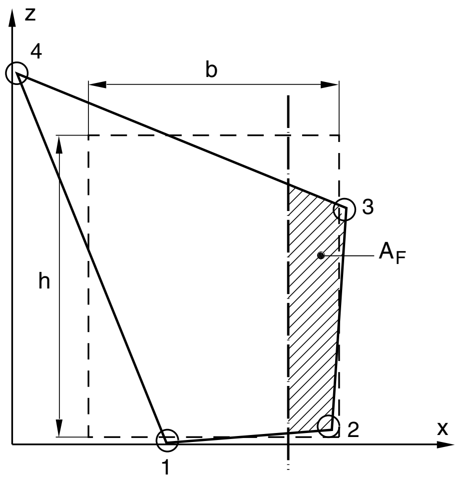
$$b = \frac{x_2 + x_3 - x_1}{2}$$

α : Coefficient to be taken equal to:

- α = 0,33 for ahead condition
- α = 0,66 for astern condition

A_F : Area, in m^2, of the rudder blade portion afore the centreline of rudder stock (see Fig 1).

Figure 1 : Geometry of rudder blade without cut-outs

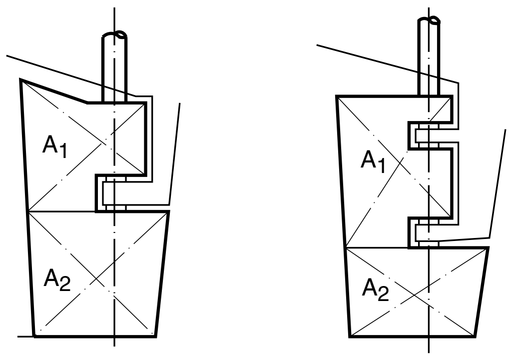


2.2 Rudder blade with cut-outs (semi-spade rudders)

2.2.1 Rudder blade description

A rudder blade with cut-outs may have trapezoidal or rectangular contour, as indicated in Fig 2.

Figure 2 : Rudder blades with cut-outs



2.2.2 Rudder force

The rudder force C_R, in N, acting on the blade is to be calculated in accordance with [2.1.2].

2.2.3 Rudder torque

The rudder torque M_{TR}, in N·m, is to be calculated in accordance with the following procedure.

The rudder blade area A is to be divided into two rectangular or trapezoidal parts having areas A_1 and A_2, defined in Fig 2, so that:

$A = A_1 + A_2$

The rudder forces C_{R1} and C_{R2}, acting on each part A_1 and A_2 of the rudder blade, respectively, are to be obtained, in N, from the following formulae:

$$C_{R1} = C_R \frac{A_1}{A}$$

$$C_{R2} = C_R \frac{A_2}{A}$$

The levers r_1 and r_2 of the forces C_{R1} and C_{R2}, respectively, are to be obtained, in m, from the following formulae:

$$r_1 = b_1\left(\alpha - \frac{A_{1F}}{A_1}\right)$$

$$r_2 = b_2\left(\alpha - \frac{A_{2F}}{A_2}\right)$$

where:

b_1, b_2 : Mean breadths of the rudder blade parts having areas A_1 and A_2, respectively, to be determined according to [2.1.3]

A_{1F}, A_{2F} : Areas, in m^2, of the rudder blade parts, defined in Fig 3

α : Coefficient to be taken equal to:

- $\alpha = 0,33$ for ahead condition
- $\alpha = 0,66$ for astern condition

For rudder parts located behind a fixed structure such as a rudder horn, α is to be taken equal to:

- $\alpha = 0,25$ for ahead condition
- $\alpha = 0,55$ for astern condition.

The torques M_{TR1} and M_{TR2}, relevant to the rudder blade parts A_1 and A_2 respectively, are to be obtained, in N.m, from the following formulae:

$M_{TR1} = C_{R1}\, r_1$

$M_{TR2} = C_{R2}\, r_2$

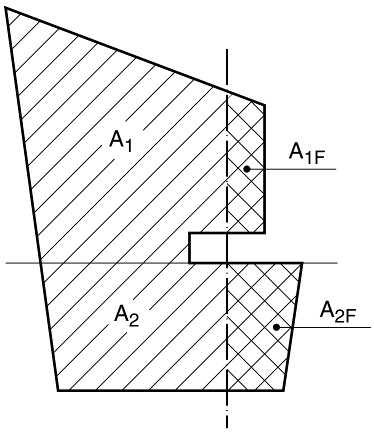
The total torque M_{TR} acting on the rudder stock, for both ahead and astern conditions, is to be obtained, in N.m, from the following formula:

$M_{TR} = M_{TR1} + M_{TR2}$

For the ahead condition only, M_{TR} is to be taken not less than the value obtained, in N.m, from the following formula:

$$M_{TR,MIN} = 0,1\, C_R \frac{A_1 b_1 + A_2 b_2}{A}$$

Figure 3 : Geometry of rudder blade with cut-outs



3 Loads acting on the rudder structure

3.1 General

3.1.1 Loads

The force and torque acting on the rudder, defined in Article [2], induce in the rudder structure the following loads:

- bending moment and torque in the rudder stock
- support forces
- bending moment, shear force and torque in the rudder body
- bending moment, shear force and torque in rudder horns and solepieces.

3.1.2 Direct load calculations

The bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body are to be determined through direct calculations to be performed in accordance to the static schemes and the load conditions specified in Ch 9, App 1.

For rudders with solepiece or rudder horns these structures are to be included in the calculation model in order to account for the elastic support of the rudder body.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and sole-pieces) are to be calculated as indicated in the relevant requirements of this Section.

3.1.3 Simplified methods for load calculation

For ordinary rudder types, the bending moment in the rudder stock, the support forces, and the bending moment and shear force in the rudder body may be determined through approximate methods specified in the relevant requirements of this Section.

The other loads (i.e. the torque in the rudder stock and in the rudder body and the loads in rudder horns and sole-pieces) are to be calculated as indicated in the relevant requirements of this Section.

4 Rudder stock scantlings

4.1 Bending moment

4.1.1 General

The bending moment M_B in the rudder stock is to be obtained as follows:

- for spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn:

  M_B is to be calculated according to:

  - [4.1.2] through a direct calculation, or
  - [4.1.3] through a simplified method

- for 3 bearing semi-spade rudders with rudder horn and for the rudder types shown in Fig 4:

  M_B may be taken equal to zero.

4.1.2 Bending moment calculated through a direct calculation

For spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is carried out, the bending moment in the rudder stock is to be obtained as specified in Ch 9, App 1.

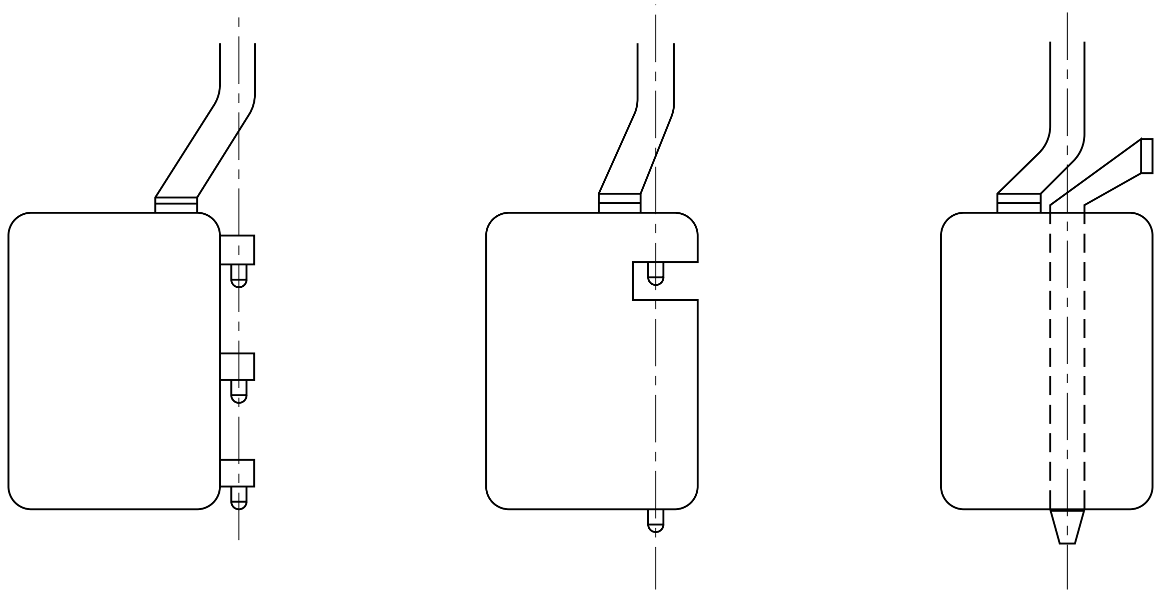
4.1.3 Bending moment calculated through a simplified method

For spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn, where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is not carried out, the bending moment M_B in the rudder stock is to be obtained, in N.m, from the following formula:

$$M_B = 0{,}866\frac{HC_R}{A}$$

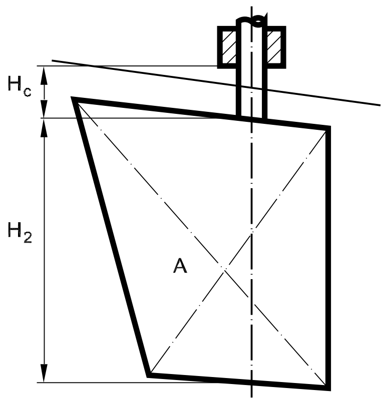
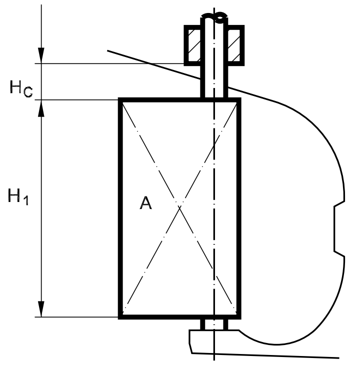
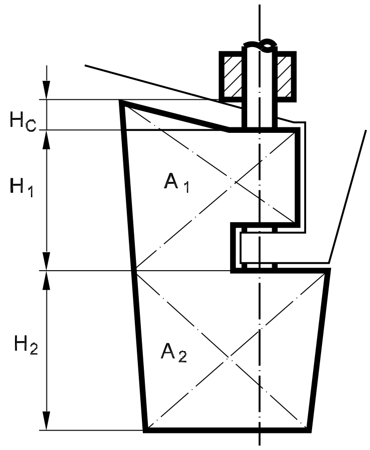
where H is defined, in m^3, in Tab 3.

Figure 4 : Rudder types



Hinged rudder with three bearings | Hinged rudder with three bearings | Simplex-type rudder

Table 3 : Factor H, in m^3

Spade rudders	2 bearing rudders with solepiece	2 bearing semi-spade rudders with rudder horn
		
$H = A\left(H_C + \frac{H_2}{2}\right)$	$H = A\ a_1\ u\ H_1$	$H = 0{,}83\ B$ **(1)**

(1) B is the greater of the absolute values obtained from the following formulae:
- $B = A_1\ u\ H_1 + A_2\ (v\ H_1 + w\ H_2)$
- $B = A_1\ a_2\ H_1 - A_2\ (a_3\ H_1 + 0{,}5\ H_2)$

where a_1 , a_2 , a_3 , u, v and w are defined in Tab 4.

Table 4 : Coefficients for calculating the bending moment in the rudder stock

Coefficient	Value
a_1	$2{,}55 - 1{,}75\ c$
a_2	$1{,}75\ c^2 - 3{,}9\ c + 2{,}35$
a_3	$2{,}65\ c^2 - 5{,}9\ c + 3{,}25$
u	$1{,}10\ c^2 - 2{,}05\ c + 1{,}175$
v	$1{,}15\ c^2 - 1{,}85\ c + 1{,}025$
w	$-3{,}05\ c^4 + 8{,}14\ c^3 - 8{,}15\ c^2 + 3{,}81\ c - 0{,}735$

Note 1:

$$c = \frac{H_1}{H_1 + H_C}$$

H_1 , H_C : As defined in Tab 3, as applicable.

4.2 Scantlings

4.2.1 Rudder stock subjected to torque only

For rudder stocks subjected to torque only (3 bearing semi-spade rudders with rudder horn in Fig 2 and the rudder types shown in Fig 4), it is to be checked that the torsional shear stress τ, in N/mm^2, induced by the torque M_{TR} is in compliance with the following formula:

$\tau \leq \tau_{ALL}$

where:

τ_{ALL} : Allowable torsional shear stress, in N/mm^2: $\tau_{ALL} = 68 / k_1$

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$d_T = 4{,}2\ (M_{TR}\ k_1)^{1/3}$

4.2.2 Rudder stock subjected to combined torque and bending

For rudder stocks subjected to combined torque and bending (spade rudders, 2 bearing rudders with solepiece and 2 bearing semi-spade rudders with rudder horn in Tab 3), it is to be checked that the equivalent stress σ_E induced by the bending moment M_B and the torque M_{TR} is in compliance with the following formula:

$\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau_T^2}$$

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = 10^3 \frac{10{,}2 M_B}{d_{TF}^3}$$

τ_T : Torsional stress to be obtained, in N/mm², from the following formula:

$$\tau_T = 10^3 \frac{5{,}1 M_{TR}}{d_{TF}^3}$$

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to:

$\sigma_{E,ALL} = 118/k_1$ N/mm²

For this purpose, the rudder stock diameter is to be not less than the value obtained, in mm, from the following formula:

$$d_{TF} = 4{,}2(M_{TR}k_1)^{1/3}\left[1 + \frac{4}{3}\left(\frac{M_B}{M_{TR}}\right)^2\right]^{1/6}$$

In general, the diameter of a rudder stock subjected to torque and bending may be gradually tapered above the lower stock bearing so as to reach, from the diameter d_{TF}, the value of d_T in way of the quadrant or the tiller.

5 Rudder stock couplings

5.1 Horizontal flange couplings

5.1.1 General

In general, the coupling flange and the rudder stock are to be forged from a solid piece. A shoulder radius as large as practicable is to be provided for between the rudder stock and the coupling flange. This radius is to be not less than 0,13 d_1, where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively.

Where the rudder stock diameter does not exceed 350 mm, the coupling flange may be welded onto the stock provided that its thickness is increased by 10%, and that the weld extends through the full thickness of the coupling flange and that the assembly obtained is subjected to heat treatment. This heat treatment is not required if the diameter of the rudder stock is less than 75 mm.

Where the coupling flange is welded, the grade of the steel used is to be of weldable quality, particularly with a carbon content not greater than 0,25% and the welding conditions (preparation before welding, choice of electrodes, pre and post heating, inspection after welding) are to be defined to the satisfaction of the Society. The throat weld at the top of the flange is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is to be not less than 0,13 d_1, where d_1 is defined above.

5.1.2 Bolts

Horizontal flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = 0{,}62\sqrt{\frac{d_1^3 k_{1B}}{n_B e_M k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.1.1]

k_{1S} : Material factor k_1 for the steel used for the rudder stock

k_{1B} : Material factor k_1 for the steel used for the bolts

e_M : Mean distance, in mm, from the bolt axes to the longitudinal axis through the coupling centre (i.e. the centre of the bolt system)

n_B : Total number of bolts, which is to be not less than 6.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of ($0{,}25d_T$ x $0{,}10d_T$) mm² and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B.

5.1.3 Coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_B\sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_B : Bolt diameter, in mm, calculated in accordance with [5.1.2], where the number of bolts n_B is to be taken not greater than 8

k_{1F} : Material factor k_1 for the steel used for the flange

k_{1B} : Material factor k_1 for the steel used for the bolts.

In any case, the thickness t_P is to be not less than 0,9 d_B.

5.1.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.2 Couplings between rudder stocks and tillers

5.2.1 Application

The requirements of this sub-Article apply in addition to those specified in Pt C, Ch 1, Sec 12.

The requirements specified in [5.2.3] and [5.2.4] apply to solid rudder stocks in steel and to tiller bosses, either in steel or in SG iron, with constant external diameter. Solid rudder stocks others than those above will be considered by the Society on a case-by-case basis, provided that the relevant calculations, to be based on the following criteria, are submitted to the Society:

- Young's modulus:
  - $E = 2{,}06.10^5$ N/mm^2 for steel
  - $E = 1{,}67.10^5$ N/mm^2 for SG iron
- Poisson's ratio:
  - $\nu = 0{,}30$ for steel
  - $\nu = 0{,}28$ for SG iron
- frictional coefficient:
  - $\mu = 0{,}15$ for contact steel/steel
  - $\mu = 0{,}13$ for contact steel/SG iron
- torque C_T transmissible through friction:

  $C_T \geq \eta\ M_{TR}$

  where η is defined in [5.2.3]
- combined stress in the boss:

  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T} \leq (0{,}5 + 0{,}2\ \eta)R_{eH}$$

  where σ_R and σ_T are, in N/mm^2, the radial compression stress and tangent tensile stress, respectively, induced by the grip pressure, considered as positive, and calculated at the bore surface ($\sigma_R = p_F$, where p_F is the grip pressure in the considered horizontal cross-section of the boss)
- where the rudder stock is hollow, the following strength criterion is to be complied with at any point of the rudder stock cross-section:

  $$\sqrt{\sigma_R^2 + \sigma_T^2 - \sigma_R\sigma_T + 3\tau^2} \leq 0{,}7\ R_{eH}$$

  where:

  σ_R, σ_T : Radial and tangent compressive stress, respectively, in N/mm^2, induced by the grip pressure, considered as positive

  τ : Shear stress, in N/mm^2, induced by the torque M_{TR}.

5.2.2 General

The entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

The right fit of the tapered bearing is to be checked before final fit up, to ascertain that the actual bearing is evenly distributed and at least equal to 80% of the theoretical bearing area; push-up length is measured from the relative positioning of the two parts corresponding to this case.

The required push-up length is to be checked after releasing of hydraulic pressures applied in the hydraulic nut and in the assembly.

5.2.3 Push up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the rudder stock tapered part into the tiller boss is in compliance with the following formula:

$\Delta_0 \leq \Delta_E \leq \Delta_1$

where:

$$\Delta_0 = 6,2\frac{M_{TR}\eta\gamma}{cd_M t_S \mu_A \beta}10^{-3}$$

$$\Delta_1 = \frac{2\eta + 5}{1,8}\cdot\frac{\gamma d_0 R_{eH}}{c}10^{-6}$$

η : Coefficient to be taken equal to:

- $\eta = 1$ for keyed connections
- $\eta = 2$ for keyless connections

c : Taper of conical coupling measured on diameter, to be obtained from the following formula:

$c = (d_U - d_0) / t_S$

t_S , d_U , d_0 : Geometrical parameters of the coupling, defined in Fig 5

β : Coefficient to be taken equal to:

$$\beta = 1 - \left(\frac{d_M}{d_E}\right)^2$$

d_M : Mean diameter, in mm, of the conical bore, to be obtained from the following formula:

$d_M = d_U - 0,5\ c\ t_S$

d_E : External boss diameter, in mm

μ_A : Coefficient to be taken equal to:

$$\mu_A = \sqrt{\mu^2 - 0,25c^2}$$

μ, γ : Coefficients to be taken equal to:

- for rudder stocks and bosses made of steel:

  $\mu = 0,15$

  $\gamma = 1,00$

- for rudder stocks made of steel and bosses made of SG iron:

  $\mu = 0,13$

  $\gamma = 1,24 - 0,1\ \beta$

R_{eH} : Defined in [1.4.3].

5.2.4 Boss of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

The scantlings of the boss are to comply with the following formula:

$$\frac{1,8}{2\eta + 5}\frac{\Delta_E c}{\gamma d_0}10^6 \le R_{eH}$$

where:

Δ_E : Push-up length adopted, in mm

c, η, γ : Defined in [5.2.3]

d_0 : Defined in Fig 5

R_{eH} : Defined in [1.4.3].

5.2.5 Cylindrical couplings by shrink fit

It is to be checked that the diametral shrinkage allowance δ_E is in compliance with the following formula:

$\delta_0 \le \delta_E \le \delta_1$

where:

$$\delta_0 = 6,2\frac{M_{TR}\eta\gamma}{d_U t_S \mu \beta_1}$$

$$\delta_1 = \frac{2\eta + 5}{1,8}\gamma d_U R_{eH} 10^{-6}$$

η, μ, γ, c: Defined in [5.2.3]

d_U : Defined in Fig 5

β_1 : Coefficient to be taken equal to:

$$\beta_1 = 1 - \left(\frac{d_U}{d_E}\right)^2$$

R_{eH} : Defined in [1.4.3].

5.2.6 Keyless couplings through special devices

The use of special devices for frictional connections, such as expansible rings, may be accepted by the Society on a case-by-case basis provided that the following conditions are complied with:

- evidence that the device is efficient (theoretical calculations and results of experimental tests, references of behaviour during service, etc.) are to be submitted to the Society
- the torque transmissible by friction is to be not less than 2 M_{TR}
- design conditions [5.2.1]
- instructions provided by the manufacturer are to be complied with, notably concerning the pre-stressing of the tightening screws.

5.3 Cone couplings between rudder stocks and rudder blades

5.3.1 Taper on diameter

The taper on diameter of the cone couplings is to be in compliance with the following formulae:

- for cone couplings without hydraulic arrangements for assembling and disassembling the coupling:

$$\frac{1}{12} \le \frac{d_U - d_0}{t_S} \le \frac{1}{8}$$

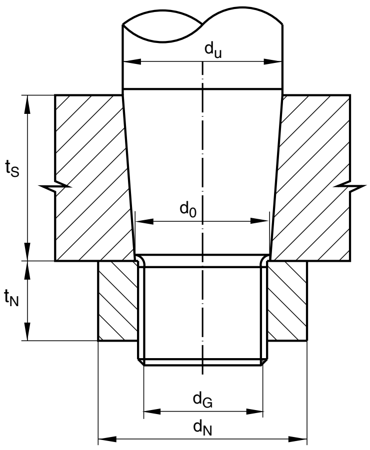
- for cone couplings with hydraulic arrangements for assembling and disassembling the coupling (assembling with oil injection and hydraulic nut):

$$\frac{1}{20} \le \frac{d_U - d_0}{t_S} \le \frac{1}{12}$$

where:

d_U , t_S , d_0 : Geometrical parameters of the coupling, defined in Fig 5.

Figure 5 : Geometry of cone coupling



5.3.2 Push up length of cone coupling with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the rudder stock tapered part into the boss is in compliance with the following formula:

$\Delta_0 \le \Delta_E \le \Delta_1$

where Δ_0 and Δ_1 are to be obtained from the formulae in Tab 5.

5.3.3 Slogging nut

The coupling is to be secured by a slugging nut, whose dimensions are to be in accordance with the following formulae:

$t_S \ge 1{,}5\ d_1$

$d_G \ge 0{,}65\ d_1$

$t_N \ge 0{,}60\ d_G$

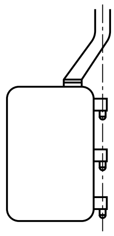
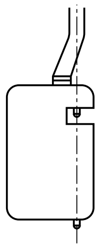
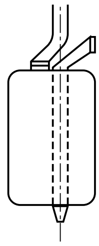
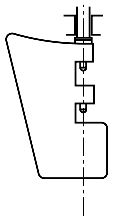
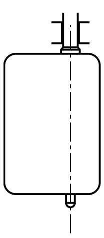
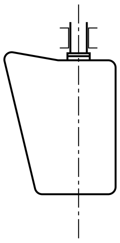
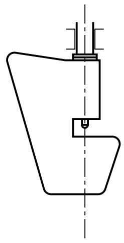
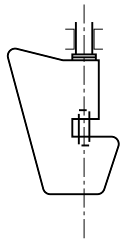
$d_N \ge 1{,}2\ d_0$ and, in any case, $d_N \ge 1{,}5\ d_G$

where:

t_S , d_G , t_N , d_N , d_1 , d_0 : Geometrical parameters of the coupling, defined in Fig 5.

The above minimum dimensions of the locking nut are only given for guidance, the determination of adequate scantlings being left to the Designer.

Table 5 : Push up length values

Rudder type	Δ_0	Δ_1
 Hinged rudder with three bearings  Hinged rudder with two bearings  Simplex - type  3 bearings semi-spade rudders with rudder horn	$6,2\dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$	$\dfrac{2\eta+5}{1,8}\dfrac{\gamma d_0 R_{eH}}{10^6 c}$
  Spade rudder  Simple pintle  Inserted pintle	the greater of: • $6,2\dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$ • $16\dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\dfrac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}}$	$\dfrac{2\eta+5}{1,8}\dfrac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$
High lift profile and special rudder types	the greater of: • $6,2\dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$ • $16\dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\dfrac{d_{1L}^6 - d_{1S}^6}{d_{1S}^6}}$ • $6,2\dfrac{M_T\eta\gamma}{c d_M t_S \mu_A \beta}$ • $18,4\dfrac{M_F\eta\gamma}{c t_S^2 \beta}$	the greater of: • $\dfrac{2\eta+5}{1,8}\dfrac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$ • $\dfrac{2\eta+5}{1,8}\dfrac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_2)}$

Note 1:

$$\rho_1 = \frac{80\sqrt{d_{1L}^6 - d_{1S}^6}}{R_{eH} d_M t_S^2\left[1-\left(\frac{d_0}{d_E}\right)^2\right]}$$

$$\rho_2 = \frac{7,4 M_F \cdot 10^6}{R_{eH} d_M t_S^2\left[1-\left(\frac{d_0}{d_E}\right)^2\right]}$$

R_{eH} : Defined in [1.4.3]

M_F, M_T : Bending moment and torsional moment, respectively, in kN.m, provided by the manufacturer

d_{1L} : The greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the lower part of the rudder stock (between the top of the rudder plate and the lower bearing of the rudder stock) in compliance with the requirements in [4.2.1] and [4.2.2], respectively, considering $k_1 = 1$

d_{1S} : The greater of the rudder stock diameters d_T and d_{TF}, in mm, calculated in way of the upper part of the rudder stock (at tiller level) in compliance with the requirements in [4.2.1] and [4.2.2], respectively, considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ : Defined in [5.2.3]

t_S, d_U, d_0 : Defined in Fig 5.

5.3.4 Washer

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, a washer is to be fitted between the nut and the rudder gudgeon, having a thickness not less than 0,13 d_G and an outer diameter not less than 0,13 d_0 or 1,6 d_G, whichever is the greater.

5.3.5 Key

For cone couplings without hydraulic arrangements for assembling and disassembling the coupling, a key is to be fitted having a section of ($0,25\ d_T \times 0,10\ d_T$) mm^2 and keyways in both the tapered part and the rudder gudgeon.

The key is to be machined and located on the fore or aft part of the rudder. The key is to be inserted at half-thickness into stock and into the solid part of the rudder.

For cone couplings with hydraulic arrangements for assembling and disassembling the coupling, the key may be omitted. In this case the designer is to submit to the Society shrinkage calculations supplying all data necessary for the relevant check.

5.3.6 Instructions

All necessary instructions for hydraulic assembly and disassembly of the nut, including indication of the values of all relevant parameters, are to be available on board.

5.4 Vertical flange couplings

5.4.1 Vertical flange couplings are to be connected by fitted bolts having a diameter not less than the value obtained, in mm, from the following formula:

$$d_B = \frac{0,81\, d_1}{\sqrt{n_B}}\sqrt{\frac{k_{1B}}{k_{1S}}}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.1.1]

k_{1S}, k_{1B} : Material factors, defined in [5.1.2]

n_B : Total number of bolts, which is to be not less than 8.

5.4.2 The first moment of area of the sectional area of bolts about the vertical axis through the centre of the coupling is to be not less than the value obtained, in cm^3, from the following formula:

$$M_S = 0,43\ d_1^3 \cdot 10^{-6}$$

where:

d_1 : Rudder stock diameter, in mm, defined in [5.1.1].

5.4.3 The thickness of the coupling flange, in mm, is to be not less than d_B , defined in [5.4.1].

5.4.4 The distance, in mm, from the bolt axes to the external edge of the coupling flange is to be not less than $1,2\ d_B$, where d_B is defined in [5.4.1].

5.4.5 A suitable locking device is to be provided to prevent the accidental loosening of nuts.

5.5 Couplings by continuous rudder stock welded to the rudder blade

5.5.1 When the rudder stock extends through the upper plate of the rudder blade and is welded to it, the thickness of this plate in the vicinity of the rudder stock is to be not less than $0,20\ d_1$, where d_1 is defined in [5.1.1].

5.5.2 The welding of the upper plate of the rudder blade with the rudder stock is to be made with a full penetration weld and is to be subjected to non-destructive inspection through dye penetrant or magnetic particle test and ultrasonic testing.

The throat weld at the top of the rudder upper plate is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is to be not less than $0,20\ d_1$, where d_1 is defined in [5.1.1].

5.6 Skeg connected with rudder trunk

5.6.1 In case of a rudder trunk connected with the bottom of a skeg, the throat weld is to be concave shaped to give a fillet shoulder radius as large as practicable. This radius is considered by the Society on a case-by-case basis.

6 Rudder stock and pintle bearings

6.1 Forces on rudder stock and pintle bearings

6.1.1 Where a direct calculation according to the static schemes and the load conditions specified in Ch 9, App 1 is carried out, the support forces are to be obtained as specified in Ch 9, App 1.

Where such a direct calculation is not carried out, the support forces F_{A1} and F_{A2} acting on the rudder stock bearing and on the pintle bearing, respectively, are to be obtained, in N, from the following formulae:

$$F_{A1} = \left(\frac{A_{G1}}{A} + 0,87\frac{h_0}{H_0}\right)C_R$$

$$F_{A2} = \frac{A_{G2}}{A}C_R$$

where:

A_{G1} , A_{G2} : Portions of the rudder blade area A, in m², supported by the rudder stock bearing and by the pintle bearing respectively, to be not less than the value obtained from Tab 6

h_0 : Coefficient defined in Tab 6

H_0 : Distance, in m, between the points at mid-height of the upper and lower rudder stock bearings.

6.2 Rudder stock bearing

6.2.1 The mean bearing pressure acting on the rudder stock bearing is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the rudder stock bearings, in N/mm², equal to:

$$p_F = \frac{F_{A1}}{d_m h_m}$$

F_{A1} : Force acting on the rudder stock bearing, in N, calculated as specified in [6.1.1]

d_m : Actual inner diameter, in mm, of the rudder stock bearings

h_m : Bearing length, in mm. For the purpose of this calculation, h_m is to be taken not greater than:

- 1,2 d_m for spade rudders
- d_m for rudder of other types

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society on the basis of specific tests.

6.2.2 An adequate lubrication of the bearing surface is to be ensured.

6.3 Pintle bearings

6.3.1 The mean bearing pressure acting on the gudgeons is to be in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeons, in N/mm², equal to:

$$p_F = \frac{F_{A2}}{d_A h_L}$$

F_{A2} : Force acting on the pintle, in N, calculated as specified in [6.1.1]

d_A : Actual diameter, in mm, of the rudder pintles

h_L : Bearing length, in mm (see [6.3.3])

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 7.

Values greater than those given in Tab 7 may be accepted by the Society on the basis of specific tests.

6.3.2 An adequate lubrication of the bearing surface is to be ensured.

6.3.3 The bearing length h_L , in mm, is to be not less than d_A, where d_A is defined in [6.4.1]. For the purpose of the calculation in [6.3.1], the bearing length is to be taken not greater than 1,2 d_A.

6.3.4 The manufacturing tolerance t_0 on the diameter of metallic supports is to be not less than the value obtained, in mm, from the following formula:

$$t_0 = \frac{d_A}{1000} + 1$$

In the case of non-metallic supports, the tolerances are to be carefully evaluated on the basis of the thermal and distortion properties of the materials employed.

In any case, the tolerance on support diameter is to be not less than 1,5 mm.

Table 6 : Areas A_{G1} , A_{G2} and h_0

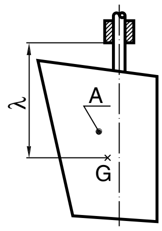
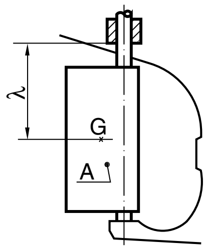
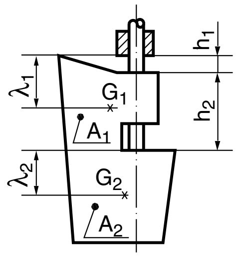
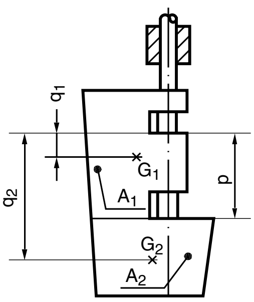
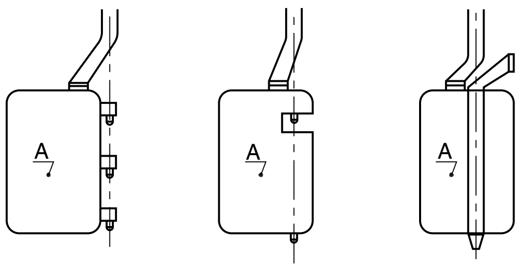
<table>
<tr><th>Rudder type</th><th>A_{G1} , in m²</th><th>A_{G2} , in m²</th><th>h_0 , in m</th></tr>
<tr><td>spade rudders

</td><td>A</td><td>0</td><td>1,15 λ</td></tr>
<tr><td>2 bearing rudders with solepiece

</td><td>Rudder blade area above a horizontal line equally spaced from the upper and the lower edges</td><td>Rudder blade area below a horizontal line equally spaced from the upper and the lower edges</td><td>0,30 λ</td></tr>
<tr><td>2 bearing semi-spade rudders with rudder horn

</td><td>$\frac{A_1\lambda_1 h_2^2}{(h_1+h_2)^3}$</td><td>the greater of:
• $\frac{\lambda A}{h_1+h_2}$
• A</td><td>the greater of:
• $0{,}19\frac{A_1\lambda_1}{A}$
• $\left\lvert 0{,}3\frac{A_1\lambda_1 - 2A_2\lambda_2}{A}\right\rvert$</td></tr>
<tr><td>3 bearing semi-spade rudders with rudder horn

</td><td>0</td><td>• Lower pintle:
$\frac{A_1q_1+A_2q_2}{p}$
• Upper pintle:
the greater of:
$A_1+A_2-\frac{A_1q_1+A_2q_2}{p}$
$0{,}5\frac{A_1q_1+A_2q_2}{p}$</td><td>0</td></tr>
<tr><td>Hinged rudders and Simplex type rudders

</td><td>0</td><td>$\frac{A}{n}$</td><td>0</td></tr>
<tr><td colspan="4">Note 1:
G, G_1, G_2 : Centres of gravity of area A, A_1 and A_2 respectively
$\lambda = \frac{(\lambda_2+h_2+h_1)A_2+\lambda_1A_1}{A}$
n : Number of pintles.</td></tr>
</table>

Table 7 : Allowable bearing pressure $p_{F,ALL}$

Bearing material	$p_{F,ALL}$, in N/mm²
Lignum vitae	2,5
White metal, oil lubricated	4,5
Synthetic material with hardness between 60 and 70 Shore D**(1)**	5,5
Steel, bronze and hot-pressed bronze-graphite materials**(2)**	7,0
(1) Indentation hardness test at 23°C and with 50% moisture to be performed according to a recognised standard. Type of synthetic bearing materials is to be approved by the Society. **(2)** Stainless and wear-resistant steel in combination with stock liner approved by the Society.	

6.4 Pintles

6.4.1 Rudder pintles are to have a diameter not less than the value obtained, in mm, from the following formula:

$$d_A = \frac{0,38V_{AV}}{V_{AV}+3}\sqrt{F_{A2}k_1}+f_C$$

where:

F_{A2} : Force, in N, acting on the pintle, calculated as specified in [6.1.1]

f_C : Coefficient depending on corrosion, whose value may generally be obtained from the following formula:

$$f_C = 30\sqrt{k_1}$$

The Society may accept lower values of f_C , considering the ship dimensions and satisfactory service experience of corrosion control systems adopted.

6.4.2 Provision is to be made for a suitable locking device to prevent the accidental loosening of pintles.

6.4.3 The pintles are to have a conical coupling with a taper on diameter in accordance with [5.3.1].

The conical coupling is to be secured by a nut, whose dimensions are to be in accordance with [5.3.3].

6.4.4 The length of the pintle housing in the gudgeon is to be not less than the value obtained, in mm, from the following formula:

$$h_L = 0,35\sqrt{F_{A2}k_1}$$

where:

F_{A2} : Force, in N, acting on the pintle, calculated as specified in [6.1.1].

The thickness of pintle housing in the gudgeon, in mm, is to be not less than 0,25 d_A, where d_A is defined in [6.4.1].

7 Rudder blade scantlings

7.1 General

7.1.1 Application

The requirements in [7.1] to [7.6] apply to streamlined rudders and, when applicable, to rudder blades of single plate rudders.

7.1.2 Rudder blade structure

The structure of the rudder blade is to be such that stresses are correctly transmitted to the rudder stock and pintles. To this end, horizontal and vertical web plates are to be provided.

Horizontal and vertical webs acting as main bending girders of the rudder blade are to be suitably reinforced.

7.1.3 Access openings

Streamlined rudders, including those filled with pitch, cork or foam, are to be fitted with plug-holes and the necessary devices to allow their mounting and dismounting.

Access openings to the pintles are to be provided. If necessary, the rudder blade plating is to be strengthened in way of these openings.

The corners of openings intended for the passage of the rudder horn heel and for the dismantling of pintle or stock nuts are to be rounded off with a radius as large as practicable.

Where the access to the rudder stock nut is closed with a welded plate, a full penetration weld is to be provided.

7.1.4 Connection of the rudder blade to the trailing edge for rudder blade area greater than 6 m²

Where the rudder blade area is greater than 6 m², the connection of the rudder blade plating to the trailing edge is, in general, to be made by means of a forged or cast steel fashion piece, a flat or a round bar.

Other arrangements proposed by the shipyard may be accepted by the Society, on a case-by-case basis.

7.2 Strength checks

7.2.1 Bending stresses

For the generic horizontal section of the rudder blade, it is to be checked that the bending stress σ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$\sigma \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable bending stress, in N/mm², specified in Tab 8.

Table 8 : Allowable stresses for rudder blade scantlings

Type of rudder blade	Allowable bending stress σ_{ALL} in N/mm²	Allowable shear stress τ_{ALL} in N/mm²	Allowable equivalent stress $\sigma_{E,ALL}$ in N/mm²
Without cut-outs	110/k	50/k	120/k
With cut-outs (see Fig 2)	75/k	50/k	100/k

7.2.2 Shear stresses

For the generic horizontal section of the rudder blade it is to be checked that the shear stress τ, in N/mm², induced by the loads defined in [3.1], is in compliance with the following formula:

$\tau \leq \tau_{ALL}$

where:

τ_{ALL} : Allowable shear stress, in N/mm², specified in Tab 8.

7.2.3 Combined bending and shear stresses

For the generic horizontal section of the rudder blade, it is to be checked that the equivalent stress σ_E is in compliance with the following formula:

$\sigma_E \leq \sigma_{E,ALL}$

where:

σ_E : Equivalent stress induced by the loads defined in [3.1], to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma^2 + 3\tau^2}$$

Where unusual rudder blade geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress σ_E is to be obtained by means of direct calculations aiming at assessing the rudder blade areas where the maximum stresses, induced by the loads defined in [3.1], occur

σ : Bending stress, in N/mm²

τ : Shear stress, in N/mm²

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², specified in Tab 8.

7.3 Rudder blade plating

7.3.1 Plate thickness

The thickness of each rudder blade plate panel is to be not less than the value obtained, in mm, from the following formula:

$$t_F = \left(5{,}5 s\beta\sqrt{T + \frac{C_R 10^{-4}}{A}} + 2{,}5\right)\sqrt{k}$$

where:

β : Coefficient equal to:

$$\beta = \sqrt{1{,}1 - 0{,}5\left(\frac{s}{b_L}\right)^2}$$

to be taken not greater than 1,0 if $b_L/s > 2{,}5$

s : Length, in m, of the shorter side of the plate panel

b_L : Length, in m, of the longer side of the plate panel.

7.3.2 Thickness of the top and bottom plates of the rudder blade

The thickness of the top and bottom plates of the rudder blade is to be not less than the thickness t_F defined in [7.3.1] for the attached side plating.

Where the rudder is connected to the rudder stock with a coupling flange, the thickness of the top plate which is welded in extension of the rudder flange is to be not less than 1,1 times the thickness calculated above.

7.3.3 Web spacing

The spacing between horizontal web plates is to be not greater than 1,20 m.

Vertical webs are to have spacing not greater than twice that of horizontal webs.

7.3.4 Web thickness

Web thickness is to be at least 70% of that required for rudder plating and in no case is it to be less than 8 mm, except for the upper and lower horizontal webs, for which the requirements in [7.3.2] apply.

When the design of the rudder does not incorporate a mainpiece, this is to be replaced by two vertical webs closely spaced, having thickness not less than that obtained from Tab 9. In rudders having area less than 6 m^2, one vertical web only may be accepted provided its thickness is at least twice that of normal webs.

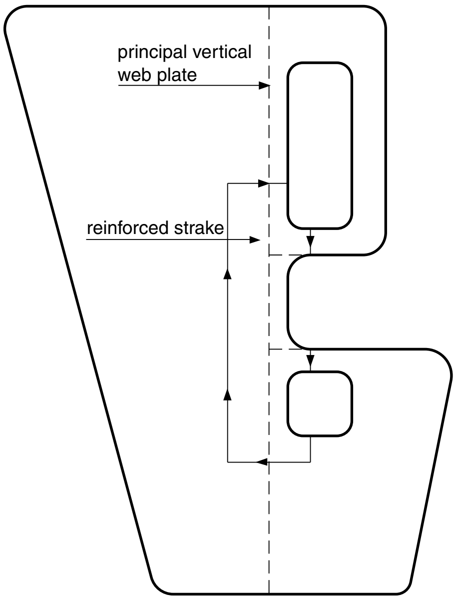
7.3.5 Thickness of side plating and vertical web plates welded to solid part or to rudder flange

The thickness, in mm, of the vertical web plates welded to the solid part where the rudder stock is housed, or welded to the rudder flange, as well as the thickness of the rudder side plating under this solid part, or under the rudder coupling flange, is to be not less than the value obtained, in mm, from Tab 9.

7.3.6 Reinforced strake of semi-spade rudders

A reinforced strake is to be provided in the lower pintle zone of semi-spade rudders. Its thickness is to be not less than 1,6 t_F , where t_F is defined in [7.3.1]. This strake is to be extended forward of the main vertical web plate (see Fig 6).

Figure 6 : Reinforced strake extension for semi-spade rudders



7.3.7 Main vertical webs of semi-spade rudders

The thickness of the main vertical web plate in the area between the rudder blade upper part and the pintle housing of semi-spade rudders is to be not less than 2,6 t_F , where t_F is defined in [7.3.1].

Under the pintle housing, the thickness of this web is to be not less than the value obtained from Tab 9.

Where two main vertical webs are fitted, the thicknesses of these webs are to be not less than the values obtained from Tab 9 depending on whether the web is fitted in a rudder blade area without opening or if the web is along the recess cut in the rudder for the passage of the rudder horn heel.

7.3.8 Welding

The welded connections of blade plating to vertical and horizontal webs are to be in compliance with the applicable requirements of NR216 Materials and Welding.

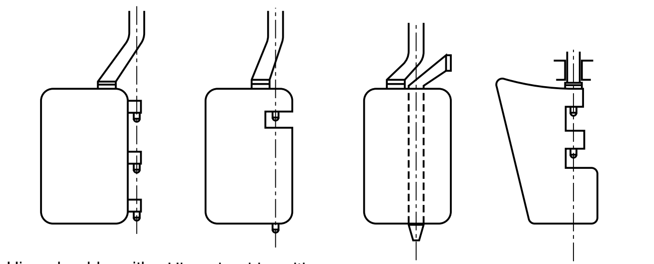
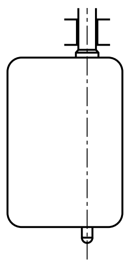
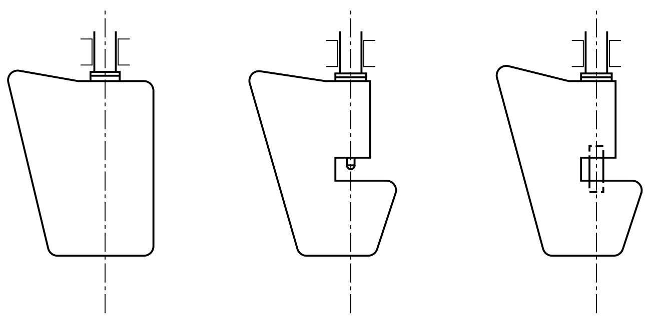
Where the welds of the rudder blade are accessible only from outside of the rudder, slots on a flat bar welded to the webs are to be provided to support the weld root, to be cut on one side of the rudder only.

7.3.9 Rudder nose plate thickness

Rudder nose plates are to have a thickness not less than 1,25 t_F , where t_F is defined in [7.3.1].

In general this thickness need not exceed 22 mm, unless otherwise required in special cases to be considered individually by the Society.

Table 9 : Thickness of the vertical webs and rudder side plating welded to solid part or to rudder flange

Type of rudder	Thickness of vertical web plates, in mm		Thickness of rudder plating, in mm	
	Rudder blade without opening	At opening boundary	Rudder blade without opening	Area with opening
Hinged rudders, Simplex type rudders and semi-spade with three bearings rudders  	t_F	1,3 t_F	t_F	1,2 t_F
Rudder without intermediate pintles 	1,2 t_F	1,6 t_F	1,2 t_F	1,4 t_F
Spade and one bearing rudders  	1,4 t_F	2,0 t_F	1,3 t_F	1,6 t_F
Note 1: t_F : Defined in [7.3.1].				

7.4 Connections of rudder blade structure with solid parts in forged or cast steel

7.4.1 General

Solid parts in forged or cast steel which ensure the housing of the rudder stock or of the pintle are in general to be connected to the rudder structure by means of two horizontal web plates and two vertical web plates.

7.4.2 Minimum section modulus of the connection with the rudder stock housing

The section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed, which is made by vertical web plates and rudder plating, is to be not less than that obtained, in cm³, from the following formula:

$$w_S = c_S d_1^3 \left(\frac{H_E - H_X}{H_E}\right)^2 \frac{k}{k_1} 10^{-4}$$

where:

c_S : Coefficient, to be taken equal to:
- c_S = 1,0 if there is no opening in the rudder plating
- c_S = 1,5 if there is an opening in the considered cross-section of the rudder

d_1 : Rudder stock diameter, in mm, defined in [5.1.1]

H_E : Vertical distance, in m, between the lower edge of the rudder blade and the upper edge of the solid part

H_X : Vertical distance, in m, between the considered cross-section and the upper edge of the solid part

k, k_1 : Material factors, defined in [1.4], for the rudder blade plating and the rudder stock, respectively.

7.4.3 Calculation of the actual section modulus of the connection with the rudder stock housing

The actual section modulus of the cross-section of the structure of the rudder blade which is connected with the solid part where the rudder stock is housed is to be calculated with respect to the symmetrical axis of the rudder.

The breadth of the rudder plating to be considered for the calculation of this actual section modulus is to be not greater than that obtained, in m, from the following formula:

$$b = s_V + 2\frac{H_X}{m}$$

where:

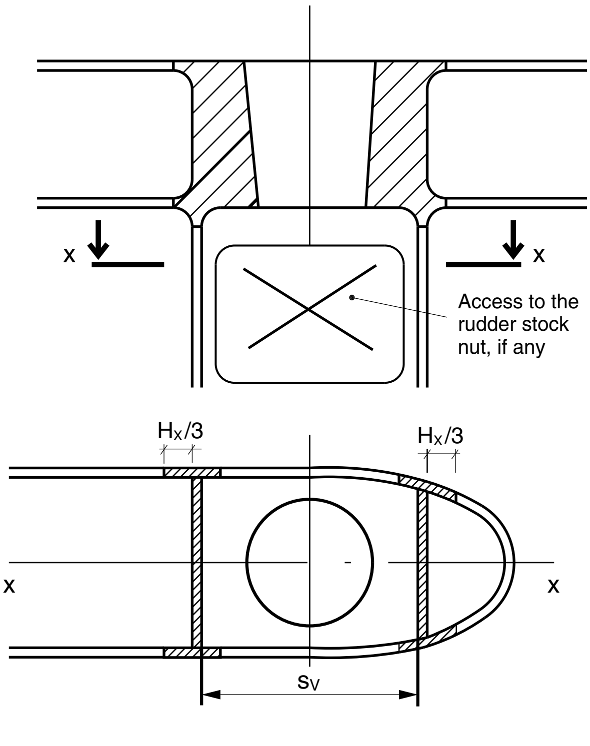
s_V : Spacing, in m, between the two vertical webs (see Fig 7)

H_X : Distance defined in [7.4.2]

m : Coefficient to be taken, in general, equal to 3.

Where openings for access to the rudder stock nut are not closed by a full penetration welded plate according to [7.1.3], they are to be deducted (see Fig 7).

Figure 7 : Cross-section of the connection between rudder blade structure and rudder stock housing



7.4.4 Thickness of horizontal web plates

In the vicinity of the solid parts, the thickness of the horizontal web plates, as well as that of the rudder blade plating between these webs, is to be not less than the greater of the values obtained, in mm, from the following formulae:

$$t_H = 1{,}2\ t_F$$

$$t_H = 0{,}045\frac{d_S^2}{s_H}$$

where:

t_F : Defined in [7.3.1]

d_S : Diameter, in mm, to be taken equal to:

- d_1 for the solid part connected to the rudder stock
- d_A for the solid part connected to the pintle

d_1 : Rudder stock diameter, in mm, defined in [5.1.1]

d_A : Pintle diameter, in mm, defined in [6.4.1]

s_H : Spacing, in mm, between the two horizontal web plates.

Different thickness may be accepted when justified on the basis of direct calculations submitted to the Society for approval.

7.4.5 Thickness of side plating and vertical web plates welded to the solid part

The thickness of the vertical web plates welded to the solid part where the rudder stock is housed as well as the thickness of the rudder side plating under this solid part is to be not less than the values obtained, in mm, from Tab 9.

7.4.6 Solid part protrusions

The solid parts are to be provided with protrusions. Vertical and horizontal web plates of the rudder are to be butt welded to these protrusions.

These protrusions are not required when the web plate thickness is less than:

- 10 mm for web plates welded to the solid part on which the lower pintle of a semi-spade rudder is housed and for vertical web plates welded to the solid part of the rudder stock coupling of spade rudders
- 20 mm for the other web plates.

If no protrusions are provided, vertical and horizontal webs are to be welded by full penetration welds. Particular precautions are to be taken for these welds. The Society may request full Non Destructive Testing to be carried out on the concerned welds, and machining of welds if necessary.

7.5 Connection of the rudder blade with the rudder stock by means of horizontal flanges

7.5.1 Minimum section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange, which is made by vertical web plates and rudder blade plating, is to be not less than the value obtained, in cm^3, from the following formula:

$w_S = 1,3\ d_1^3\ 10^{-4}$

where d_1 is the greater of the rudder stock diameters d_T and d_{TF}, in mm, to be calculated in compliance with the requirements in [4.2.1] and [4.2.2], respectively, taken k_1 equal to 1.

7.5.2 Actual section modulus of the connection

The section modulus of the cross-section of the structure of the rudder blade which is directly connected with the flange is to be calculated with respect to the symmetrical axis of the rudder.

For the calculation of this actual section modulus, the length of the rudder cross-section equal to the length of the rudder flange is to be considered.

Where the rudder plating is provided with an opening under the rudder flange, the actual section modulus of the rudder blade is to be calculated in compliance with [7.4.3].

7.5.3 Welding of the rudder blade structure to the rudder blade flange

The welds between the rudder blade structure and the rudder blade flange are to be full penetrated (or of equivalent strength) and are to be 100% inspected by means of non-destructive tests.

Where the full penetration welds of the rudder blade are accessible only from outside of the rudder, a backing flat bar is to be provided to support the weld root.

The external fillet welds between the rudder blade plating and the rudder flange are to be of concave shape and their throat thickness is to be at least equal to 0,5 times the rudder blade thickness.

Moreover, the rudder flange is to be checked before welding by non-destructive inspection for lamination and inclusion detection in order to reduce the risk of lamellar tearing.

7.5.4 Thickness of side plating and vertical web plates welded to the rudder flange

The thickness of the vertical web plates directly welded to the rudder flange as well as the plating thickness of the rudder blade upper strake in the area of the connection with the rudder flange is to be not less than the values obtained, in mm, from Tab 9.

7.6 Single plate rudders

7.6.1 Mainpiece diameter

The mainpiece diameter is to be obtained from the formulae in [4.2].

In any case, the mainpiece diameter is to be not less than the stock diameter.

For spade rudders the lower third may taper down to 0,75 times the stock diameter.

7.6.2 Blade thickness

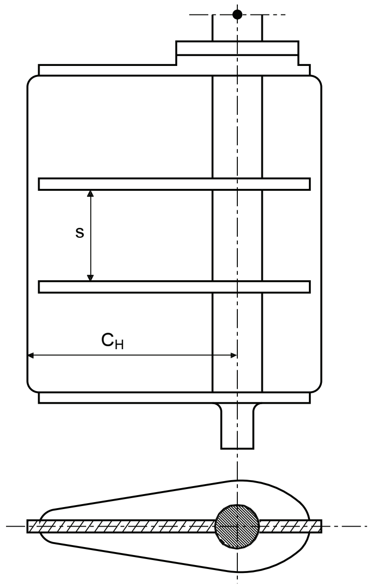
The blade thickness is to be not less than the value obtained, in mm, from the following formula:

$$t_B = (1{,}5sV_{AV} + 2{,}5)\sqrt{k}$$

where:

s : Spacing of stiffening arms, in m, to be taken not greater than 1 m (see Fig 8).

Figure 8 : Single plate rudder



7.6.3 Arms

The thickness of the arms is to be not less than the blade thickness.

The section modulus of the generic section is to be not less than the value obtained, in cm^3, from the following formula:

$$Z_A = 0{,}5\ s\ C_H^2\ V_{AV}^2\ k$$

where (see Fig 8):

C_H : Horizontal distance, in m, from the aft edge of the rudder to the centreline of the rudder stock

s : Defined in [7.6.2].

8 Rudder horn and solepiece scantlings

8.1 General

8.1.1 The weight of the rudder is normally supported by a carrier bearing inside the rudder trunk.

In the case of unbalanced rudders having more than one pintle, the weight of the rudder may be supported by a suitable disc fitted in the solepiece gudgeon.

Robust and effective structural rudder stops are to be fitted, except where adequate positive stopping arrangements are provided in the steering gear, in compliance with the applicable requirements of Pt C, Ch 1, Sec 12.

8.2 Rudder horn

8.2.1 General

When the connection between the rudder horn and the hull structure is designed as a curved transition into the hull plating, special consideration is to be paid to the effectiveness of the rudder horn plate in bending and to the stresses in the transverse web plates.

8.2.2 Loads

The following loads acting on the generic section of the rudder horn are to be considered:

- bending moment
- shear force
- torque.

The requirements in [8.2.3], [8.2.4] and [8.2.5] apply for calculating the above loads in the case of 2 bearing semi-spade rudders.

In the case of 3 bearing semi-spade rudders, these loads are to be calculated on the basis of the support forces at the lower and upper pintles, obtained according to [6.1].

8.2.3 Bending moment

For 2 bearing semi-spade rudders, the bending moment acting on the generic section of the rudder horn is to be obtained, in N·m, from the following formula:

$M_H = F_{A1}\ z$

where:

F_{A1} : Support force, in N, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in Ch 9, App 1. As an alternative, it may to be obtained from the following formula:

$$F_{A1} = C_R \frac{b}{\ell_{20} + \ell_{30}}$$

b, ℓ_{20}, ℓ_{30} : Distances, in m, defined in Fig 9

z : Distance, in m, defined in Fig 10, in any case to be taken less than the distance d, in m, defined in the same figure.

Figure 9 : Geometrical parameters for the calculation of the bending moment in rudder horn

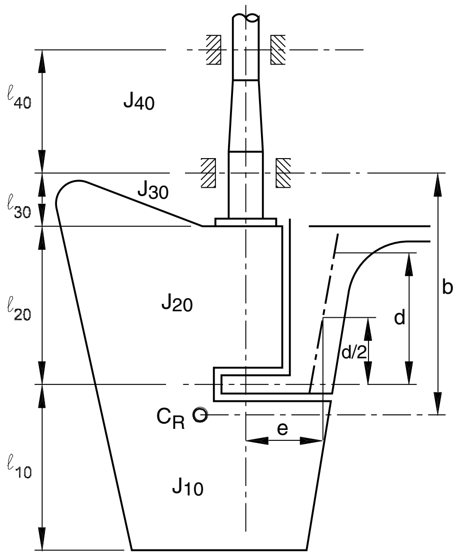
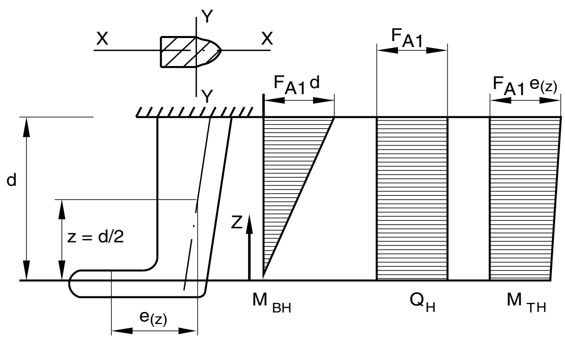


Figure 10 : Rudder horn geometry



8.2.4 Shear force

The shear force Q_H acting on the generic section of the rudder horn is to be obtained, in N, from the following formula:

$Q_H = F_{A1}$

where:

F_{A1} : Force, in N, defined in [8.2.3].

8.2.5 Torque

The torque acting on the generic section of the rudder horn is to be obtained, in N.m, from the following formula:

$M_T = F_{A1}\ e$

where:

F_{A1} : Force, in N, defined in [8.2.3]

e : Distance, in m, defined in Fig 10.

8.2.6 Shear stress check

For the generic section of the rudder horn it is to be checked that:

$\tau_S + \tau_T \leq \tau_{ALL}$

where:

τ_S : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau_S = \frac{F_{A1}}{A_H}$$

F_{A1} : Force, in N, defined in [8.2.3]

A_H : Shear sectional area of the rudder horn in Y direction, in mm²

τ_T : Torsional stress to be obtained for hollow rudder horn, in N/mm², from the following formula:

$$\tau_T = \frac{M_T 10^3}{2 A_T t_H}$$

For solid rudder horn, τ_T is to be considered by the Society on a case-by-case basis

M_T : Torque, in N·m, defined in [8.2.5]

A_T : Area of the horizontal section enclosed by the rudder horn, in mm²

t_H : Plate thickness of rudder horn, in mm

τ_{ALL} : Allowable torsional shear stress, in N/mm²:

$\tau_{ALL} = 48 / k_1$

8.2.7 Combined stress strength check

For the generic section of the rudder horn within the length d, defined in Fig 10, it is to be checked that:

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3(\tau_S^2 + \tau_T^2)}$$

Where unusual rudder horn geometries make it practically impossible to adopt ample corner radiuses or generous tapering between the various structural elements, the equivalent stress s_E is to be obtained by means of direct calculations aiming at assessing the rudder horn areas where the maximum stresses, induced by the loads defined in [3.1], occur

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_H}{W_X}$$

M_H : Bending moment at the section considered, in N·m, defined in [8.2.3]

W_X : Section modulus, in cm³, around the horizontal axis X (see Fig 10)

τ_S , τ_T : Shear and torsional stresses, in N/mm², defined in [8.2.6]

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to: $\sigma_{E,ALL} = 120/k_1$ N/mm²

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to: $\sigma_{B,ALL} = 67/k_1$ N/mm².

8.3 Solepieces

8.3.1 Bending moment

The bending moment acting on the generic section of the solepiece is to be obtained, in N·m, from the following formula:

$M_S = F_{A1}\, x$

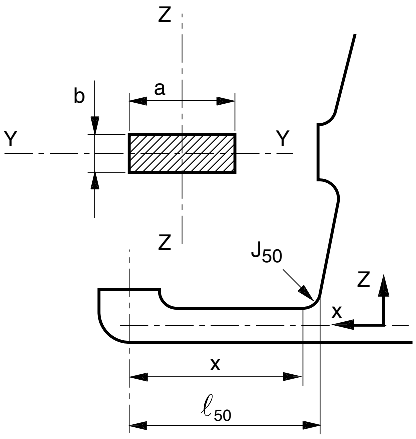
where:

F_{A1} : Supporting force, in N, in the pintle bearing, to be determined through a direct calculation to be performed in accordance with the static schemes and the load conditions specified in Ch 9, App 1; where such a direct calculation is not carried out, this force may be taken equal to:

$$F_{A1} = \frac{C_R}{2}$$

x : Distance, in m, defined in Fig 11.

Figure 11 : Solepiece geometry



8.3.2 Strength checks

For the generic section of the solepiece within the length ℓ_{50}, defined in Fig 11, it is to be checked that

$\sigma_E \leq \sigma_{E,ALL}$

$\sigma_B \leq \sigma_{B,ALL}$

$\tau \leq \tau_{ALL}$

where:

σ_E : Equivalent stress to be obtained, in N/mm², from the following formula:

$$\sigma_E = \sqrt{\sigma_B^2 + 3\tau^2}$$

σ_B : Bending stress to be obtained, in N/mm², from the following formula:

$$\sigma_B = \frac{M_S}{W_Z}$$

τ : Shear stress to be obtained, in N/mm², from the following formula:

$$\tau = \frac{F_{A1}}{A_S}$$

M_S : Bending moment at the section considered, in N·m, defined in [8.3.1]

F_{A1} : Force, in N, defined in [8.3.1]

W_Z : Section modulus, in cm³, around the vertical axis Z (see Fig 11)

A_S : Shear sectional area in Y direction, in mm²

$\sigma_{E,ALL}$: Allowable equivalent stress, in N/mm², equal to: $\sigma_{E,ALL} = 115/k_1$ N/mm²

$\sigma_{B,ALL}$: Allowable bending stress, in N/mm², equal to: $\sigma_{B,ALL} = 80/k_1$ N/mm²

τ_{ALL} : Allowable shear stress, in N/mm², equal to: $\tau_{ALL} = 48/k_1$ N/mm².

8.3.3 Minimum section modulus around the horizontal axis

The section modulus around the horizontal axis Y (see Fig 11) is to be not less than the value obtained, in cm³, from the following formula:

$W_Y = 0,5\ W_Z$

where:

W_Z : Section modulus, in cm³, around the vertical axis Z (see Fig 11).

9 Simplex rudder shaft

9.1 Scantlings

9.1.1 Diameter of the rudder shaft

The rudder shaft diameter is to be not less than the value obtained, in mm, from the following formula:

$$d = 17{,}9\left(\frac{\alpha A(V_{AV} + 2)^2}{\ell}\right)^{1/3}$$

where:

α : Coefficient equal to:

- $\alpha = b\,(\ell - b + a)$ if $a \le b$
- $\alpha = a\,(\ell - a + b)$ if $a > b$

a, b, ℓ : Geometrical parameters, in m, defined in Fig 12.

9.1.2 Sectional area of rudder shaft

The overall sectional area of the rudder shaft is to be not less than the greater of the following values:

- 70% of the sectional area for the propeller post defined in Ch 8, Sec 2, [6.3]
- value of the sectional area of the pintle supporting half the rudder blade, whose diameter is to be calculated from the formula in [6.4.1].

If the latter value is the greater, it is to be applied only where the rudder bears on the rudder shaft; in such case, it is recommended that an overthickness or a bush is provided in way of the bearing areas.

9.1.3 Bearings

The bearing length of the rudder shaft is to be not less than 1,2 d, where d is the shaft diameter defined in [9.1.1].

The mean pressure acting on the bearings is not to exceed the relevant allowable values, defined in Tab 7.

9.2 Connections

9.2.1 Connection with the hull

The shaft is to be connected with the hull by means of a vertical coupling flange having thickness at least equal to d/4, where d is the shaft diameter, obtained from the formula in [9.1.1] (see Fig 12).

The coupling flange is to be secured by means of six fitted bolts. The shank diameter of the bolts is to be not less than the coupling flange thickness defined above.

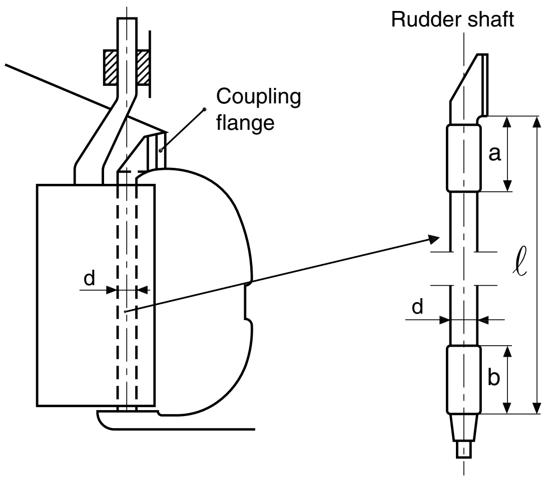
The distance from the bolt centre lines to the coupling flange edge is to be not less than 1,17 times the bolt diameter defined above.

9.2.2 Connection with the solepiece

The rudder shaft is to be connected with the solepiece by means of a cone coupling, having a taper on the radius equal to about 1/10 and housing length not less than 1,1 d, where d is obtained from the formula in [9.1.1] (See Fig 12).

The mean pressure exerted by the rudder shaft on the bearing is to be not greater than the relevant allowable bearing pressure, defined in Tab 6 assuming a rudder with two pintles.

Figure 12 : Simplex rudder shaft geometry



10 Steering nozzles

10.1 General

10.1.1 The requirements of this Article apply to scantling steering nozzles for which the power transmitted to the propeller is less than the value obtained, in kW, from the following formula:

$$P = \frac{16900}{d_M}$$

where:

d_M : Inner diameter of the nozzle, in m.

Nozzles for which the power transmitted is greater than the value obtained from the above formula are considered on a case-by-case basis.

The following requirements may apply also to fixed nozzle scantlings.

10.1.2 Nozzles normally consist of a double skin cylindrical structure stiffened by ring webs and other longitudinal webs placed perpendicular to the nozzle.

At least two ring webs are to be fitted, one of which, of greater thickness, is to be placed in way of the axis of rotation of the nozzle.

For nozzles with an inner diameter d_M exceeding 3 m, the number of ring webs is to be suitably increased.

10.1.3 Care is to be taken in the manufacture of the nozzle to ensure the welded connection between plating and webs.

10.1.4 The internal part of the nozzle is to be adequately protected against corrosion.

10.2 Nozzle plating and internal diaphragms

10.2.1 The thickness of the inner plating of the nozzle is to be not less than the value obtained, in mm, from the following formulae:

$$t_F = (0{,}085\sqrt{Pd_M} + 9{,}65)\sqrt{k} \qquad \text{for} \quad P \le \frac{6100}{d_M}$$

$$t_F = (0{,}085\sqrt{Pd_M} + 11{,}65)\sqrt{k} \qquad \text{for} \quad P > \frac{6100}{d_M}$$

where:

P, d_M : Defined in [10.1.1].

The thickness t_F is to be extended to a length, across the transverse section containing the propeller blade tips, equal to one third of the total nozzle length.

Outside this length, the thickness of the inner plating is to be not less than (t_F – 7) mm and, in any case, not less than 7 mm.

10.2.2 The thickness of the outer plating of the nozzle is to be not less than (t_F – 9) mm, where t_F is defined in [10.2.1] and, in any case, not less than 7 mm.

10.2.3 The thicknesses of ring webs and longitudinal webs are to be not less than (t_F – 7) mm, where t_F is defined in [10.2.1], and, in any case, not less than 7 mm.

However, the thickness of the ring web, in way of the headbox and pintle support structure, is to be not less than t_F.

The Society may consider reduced thicknesses where an approved stainless steel is used, in relation to its type.

10.3 Nozzle stock

10.3.1 The diameter of the nozzle stock is to be not less than the value obtained, in mm, from the following formula:

$d_{NTF} = 64{,}2\ (M_T\ k_1)^{1/3}$

where:

M_T : Torque, to be taken as the greater of those obtained, in N·m, from the following formulae:

- $M_{TAV} = 0{,}3\ S_{AV}\ a$
- $M_{TAD} = S_{AD}\ b$

S_{AV} : Force, in N, equal to: $S_{AV} = 150\ V^2_{AV}\ A_N$

S_{AD} : Force, in N, equal to: $S_{AD} = 200\ V^2_{AD}\ A_N$

A_N : Area, in m², equal to: $A_N = 1{,}35\ A_{1N} + A_{2N}$

A_{1N} : Area, in m², equal to: $A_{1N} = L_M\ d_M$

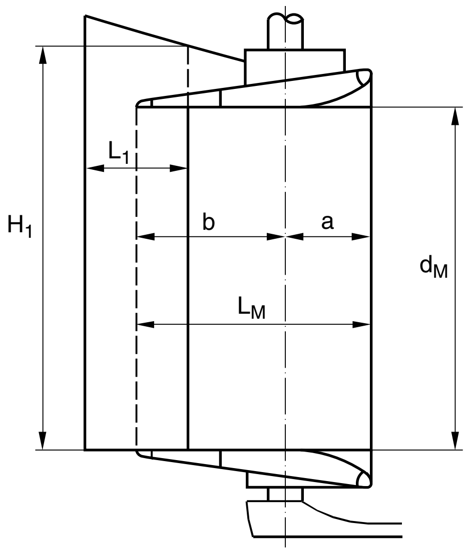
A_{2N} : Area, in m², equal to: $A_{2N} = L_1\ H_1$

a, b, L_M, d_M, L_1, H_1 : Geometrical parameters of the nozzle, in m, defined in Fig 13.

The diameter of the nozzle stock may be gradually tapered above the upper stock bearing so as to reach, in way of the tiller or quadrant, the value obtained, in mm, from the following formula:

$d_{NT} = 0{,}75\ d_{NTF}$

Figure 13 : Geometrical parameters of the nozzle



10.4 Pintles

10.4.1 The diameter of the pintles is to be not less than the value obtained, in mm, from the following formula:

$$d_A = \left(\frac{11 V_{AV}}{V_{AV}+3}\sqrt{S_{AV}} + 30\right)\sqrt{k_1}$$

where:

S_{AV} : Defined in [10.3.1].

10.4.2 The net pintle length h_A, in mm, is to be not less than 1,2 d_A , where d_A is defined in [10.4.1].

Smaller values of h_A may be accepted provided that the pressure on the gudgeon bearing p_F is in compliance with the following formula:

$p_F \leq p_{F,ALL}$

where:

p_F : Mean bearing pressure acting on the gudgeon, to be obtained in N/mm², from the following formula:

$$p_F = 10^3 \frac{0,6S'}{d'_A h'_A}$$

S' : The greater of the values S_{AV} and S_{AD} , in kN, defined in [10.3.1]

d'_A : Actual pintle diameter, in mm

h'_A : Actual bearing length of pintle, in mm

$p_{F,ALL}$: Allowable bearing pressure, in N/mm², defined in Tab 7.

In any case, h_A is to be not less than d_A .

10.5 Nozzle coupling

10.5.1 Diameter of coupling bolts

The diameter of the coupling bolts is to be not less than the value obtained, in mm, from the following formula:

$$d_B = 0,23 d_{NTF}\sqrt{\frac{k_{1B}}{k_{1A}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1A} : Material factor k_1 for the steel used for the stock

k_{1B} : Material factor k_1 for the steel used for the bolts.

Non-fitted bolts may be used provided that, in way of the mating plane of the coupling flanges, a key is fitted having a section of (0,25 d_{NT} x 0,10 d_{NT}) mm², where d_{NT} is defined in [10.3.1], and keyways in both the coupling flanges, and provided that at least two of the coupling bolts are fitted bolts.

The distance from the bolt axes to the external edge of the coupling flange is to be not less than 1,2 d_B .

10.5.2 Thickness of coupling flange

The thickness of the coupling flange is to be not less than the value obtained, in mm, from the following formula:

$$t_P = d_{NTF}\sqrt{\frac{k_{1F}}{k_{1B}}}$$

where:

d_{NTF} : Diameter of the nozzle stock, in mm, defined in [10.3.1]

k_{1B}, : Material factor k_1 for the steel used for the bolts

k_{1F} : Material factor k_1 for the steel used for the coupling flange.

10.5.3 Push up length of cone couplings with hydraulic arrangements for assembling and disassembling the coupling

It is to be checked that the push up length Δ_E of the nozzle stock tapered part into the boss is in compliance with the following formula:

$\Delta_0 \le \Delta_E \le \Delta_1$

where:

Δ_0 : The greater of:

- $6,2\dfrac{M_{TR}\eta\gamma}{c d_M t_S \mu_A \beta}$
- $16\dfrac{M_{TR}\eta\gamma}{c t_S^2 \beta}\sqrt{\dfrac{d_{NTF}^6 - d_{NT}^6}{d_{NT}^6}}$

$$\Delta_1 = \frac{2\eta + 5}{1,8}\,\frac{\gamma d_0 R_{eH}}{10^6 c(1+\rho_1)}$$

$$\rho_1 = \frac{80\sqrt{d_{NTF}^6 - d_{NT}^6}}{R_{eH} d_M t_S^2\left[1 - \left(\dfrac{d_0}{d_{NTF}}\right)^2\right]}$$

d_{NTF} : Nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering $k_1 = 1$

d_{NT} : Nozzle stock diameter, in mm, to be obtained from the formula in [10.3.1], considering $k_1 = 1$

η, c, β, d_M, d_E, μ_A, μ, γ : Defined in [5.2.3]

t_S, d_U, d_0 : Defined in Fig 5

R_{eH} : Defined in [1.4.3].

10.5.4 Locking device

A suitable locking device is to be provided to prevent the accidental loosening of nuts.

11 Azimuth propulsion system

11.1 General

11.1.1 Arrangement

The azimuth propulsion system is constituted by the following sub-systems (see Fig 14):

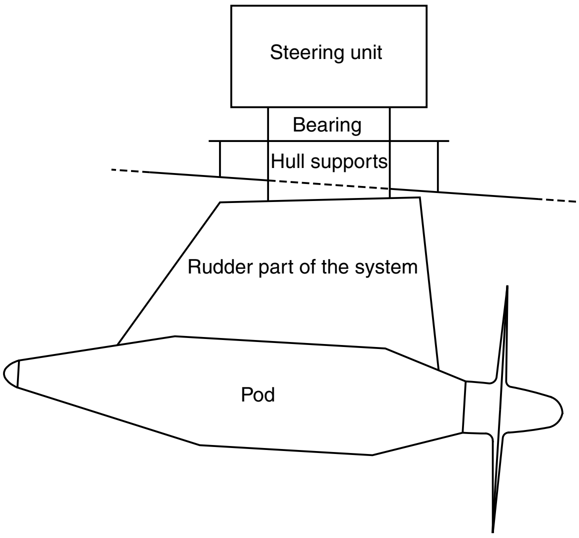
- the steering unit
- the bearing
- the hull supports
- the rudder part of the system
- the pod, which contains the electric motor in the case of a podded propulsion system.

11.1.2 Application

The requirements of this Article apply to the scantlings of the hull supports, the rudder part and the pod.

The steering unit and the bearing are to comply with the requirements in Pt C, Ch 1, Sec 12 and Pt C, Ch 1, Sec 13, respectively.

Figure 14 : Azimuth propulsion system



11.1.3 Operating conditions

The maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed is to be specified by the Designer. Such maximum angle is generally to be less than 35° on each side.

In general, orientations greater than this maximum angle may be considered by the Society for azimuth propulsion systems during manoeuvres, provided that the orientation values together with the relevant speed values are submitted to the Society for approval.

11.2 Arrangement

11.2.1 Plans to be submitted

In addition to the plans showing the structural arrangement of the pod and the rudder part of the system, the plans showing the arrangement of the azimuth propulsion system supports are to be submitted to the Society for approval. The scantlings of the supports and the maximum loads which acts on the supports are to be specified in these drawings.

11.2.2 Locking device

The azimuth propulsion system is to be mechanically lockable in a fixed position, in order to avoid rotations of the system and propulsion in undesirable directions in the event of damage.

11.3 Design loads

11.3.1 The lateral pressure to be considered for scantling of plating and ordinary stiffeners of the azimuth propulsion system is to be determined for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed.

The total force which acts on the azimuth propulsion system is to be obtained by integrating the lateral pressure on the external surface of the system.

The calculations of lateral pressure and total force are to be submitted to the Society for information.

11.4 Plating

11.4.1 Plating of the rudder part of the azimuth propulsion system

The thickness of plating of the rudder part of the azimuth propulsion system is to be not less than that obtained, in mm, from the formulae in [7.3.1], in which the term C_R/A is to be replaced by the lateral pressure calculated according to [11.3].

11.4.2 Plating of the pod

The thickness of plating of the pod is to be not less than that obtained, in mm, from the formulae in Ch 7, Sec 1, where the lateral pressure is to be calculated according to [11.3].

11.4.3 Webs

The thickness of webs of the rudder part of the azimuth propulsion system is to be determined according to [7.3.4], where the lateral pressure is to be calculated according to [11.3].

11.5 Ordinary stiffeners

11.5.1 Ordinary stiffeners of the pod

The scantlings of ordinary stiffeners of the pod are to be not less than those obtained from the formulae in Ch 7, Sec 2, where the lateral pressure is to be calculated according to [11.3].

11.6 Primary supporting members

11.6.1 Analysis criteria

The scantlings of primary supporting members of the azimuth propulsion system are to be obtained through direct calculations, to be carried out according to the following requirements:

- the structural model is to include the pod, the rudder part of the azimuth propulsion system, the bearing and the hull supports
- the boundary conditions are to represent the connections of the azimuth propulsion system to the hull structures
- the loads to be applied are those defined in [11.6.2].

The direct calculation analyses (structural model, load and stress calculation, strength checks) carried out by the Designer are to be submitted to the Society for information.

11.6.2 Loads

The following loads are to be considered in the direct calculation of the primary supporting members of the azimuth propulsion system:

- gravity loads
- buoyancy
- maximum loads calculated for an orientation of the system equal to the maximum angle at which the azimuth propulsion system can be oriented on each side when the ship navigates at its maximum speed
- maximum loads calculated for the possible orientations of the system greater than the maximum angle at the relevant speed (see [11.1.3])
- maximum loads calculated for the crash stop of the ship obtained through inversion of the propeller rotation
- maximum loads calculated for the crash stop of the ship obtained through a 180° rotation of the pod.

11.6.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in primary supporting members, calculated, in N/mm², for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², to be taken equal to the lesser of the following values:
- $0,275\ R_m$
- $0,55\ R_{eH}$

R_m : Tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2].

11.7 Hull supports of the azimuth propulsion system

11.7.1 Analysis criteria

The scantlings of hull supports of the azimuth propulsion system are to be obtained through direct calculations, to be carried out in accordance with the requirements in [11.6.1].

11.7.2 Loads

The loads to be considered in the direct calculation of the hull supports of the azimuth propulsion system are those specified in [11.6.2].

11.7.3 Strength check

It is to be checked that the Von Mises equivalent stress σ_E in hull supports, in N/mm², calculated for the load cases defined in [11.6.2], is in compliance with the following formula:

$\sigma_E \leq \sigma_{ALL}$

where:

σ_{ALL} : Allowable stress, in N/mm², equal to:

$\sigma_{ALL} = 65/k$ N/mm²

k : Material factor, defined in Ch 4, Sec 1, [2.3].

Values of σ_E greater than σ_{ALL} may be accepted by the Society on a case-by-case basis, depending on the localization of σ_E and on the type of direct calculation analysis.

Section 2 Bulwarks and Guard Rails

1 General

1.1 Introduction

1.1.1 The requirements of this Section apply to the arrangement of bulwarks and guard rails provided at boundaries of the main watertight deck, superstructure decks and tops of the first tier of deckhouses located on the main watertight deck.

1.2 General

1.2.1 Efficient bulwarks or guard rails are to be fitted at the boundaries of all exposed parts of the main watertight deck and superstructure decks directly attached to the main watertight deck, as well as the first tier of deckhouses fitted on the main watertight deck and the superstructure ends.

1.2.2 The height of the bulwarks or guard rails is to be at least 1 m from the deck. However, where their height would interfere with the normal operation of the ship, a lesser height may be accepted, if adequate protection is provided.

1.2.3 Where superstructures are connected by trunks, open rails are to be fitted for the whole length of the exposed parts of the main watertight deck.

1.2.4 In case a freeboard calculation is undertaken, in type A and B-100 ships, open rails on the weather parts of the main watertight deck for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 8, Sec 9, [5] are to be fitted.

1.2.5 In ships with bulwarks and trunks of breadth not less than 0,6 B, which are included in the stability calculation, open rails on the weather parts of the main watertight deck in way of the trunk for at least half the length of the exposed parts are to be fitted.

Alternatively, freeing ports complying with Ch 8, Sec 9, [4.3.1] are to be fitted.

1.2.6 In ships having superstructures which are open at either or both ends, adequate provision for freeing the space within such superstructures is to be provided.

1.2.7 The freeing port area in the lower part of the bulwarks is to be in compliance with the applicable requirements of Ch 8, Sec 9, [5].

2 Bulwarks

2.1 General

2.1.1 The requirement of this Article apply to bulwarks made of steel. Bulwarks made of other material are to be examined on a case-by-case basis.

2.1.2 As a rule, plate bulwarks are to be stiffened at the upper edge by a suitable bar and supported either by stays or plate brackets spaced not more than 2,0 m apart.

Bulwarks are to be aligned with the beams located below or are to be connected to them by means of local transverse stiffeners.

As an alternative, the lower end of the stay may be supported by a longitudinal stiffener.

2.1.3 In type A, B-60 and B-100 ships, the spacing forward of 0,07 L from the fore end of brackets and stays is to be not greater than 1,2 m.

2.1.4 Where bulwarks are cut completely, the scantlings of stays or brackets are to be increased with respect to those given in [2.2].

2.1.5 As a rule, bulwarks are not to be connected either to the upper edge of the sheerstrake plate or to the stringer plate.

Failing this, the detail of the connection will be examined by the Society on a case-by-case basis.

2.2 Scantlings

2.2.1 The thickness of bulwarks on the main watertight deck not exceeding 1100 mm in height is to be not less than:

- 5,5 mm for $L \leq 30$ m
- 6,0 mm for $30 < L \leq 120$ m
- 6,5 mm for $120 < L \leq 150$ m
- 7,0 mm for $L > 150$ m.

Where the height of the bulwark is equal to or greater than 1800 mm, its thickness is to be equal to that calculated for the side of a superstructure situated in the same location as the bulwark.

For bulwarks between 1100 mm and 1800 mm in height, their thickness is to be calculated by linear interpolation.

The thickness of bulwarks not located on the main watertight deck is to be determined as for the side of a superstructure considered in the same location as the bulwark.

2.2.2 Bulwark plating and stays are to be adequately strengthened in way of eyeplates used for shrouds or other tackles in use for cargo gear operation, as well as in way of hawserholes or fairleads provided for mooring or towing.

2.2.3 At the ends of partial superstructures and for the distance over which their side plating is tapered into the bulwark, the latter is to have the same thickness as the side plating; where openings are cut in the bulwark at these positions, adequate compensation is to be provided either by increasing the thickness of the plating or by other suitable means.

2.2.4 The section modulus of stays in way of the lower part of the bulwark is to be not less than the value obtained, in cm^3, from the following formula:

$$Z = 40\, s\, (1 + 0{,}01\, L)\, h_B^2$$

where:

L : Length of ship, in m, to be assumed not greater than 100 m

s : Spacing of stays, in m

h_B : Height of bulwark, in m, measured between its upper edge and the deck.

The actual section of the connection between stays and deck structures is to be taken into account when calculating the above section modulus.

To this end, the bulb or face plate of the stay may be taken into account only where welded to the deck; in this case the beam located below is to be connected by double continuous welding.

For stays with strengthening members not connected to the deck, the calculation of the required minimum section modulus is considered by the Society on a case-by-case basis.

At the ends of the ship, where the bulwark is connected to the sheerstrake, an attached plating having width not exceeding 600 mm may also be included in the calculation of the actual section modulus of stays.

2.2.5 Openings in bulwarks are to be arranged so that the protection of the crew is to be at least equivalent to that provided by the horizontal courses in [3.1.2].

For this purpose, vertical rails or bars spaced approximately 230 mm apart may be accepted in lieu of rails or bars arranged horizontally.

2.2.6 In the case of ships intended for the carriage of timber deck cargoes, the specific provisions of the main watertight regulations are to be complied with.

2.2.7 Bulwarks located in the bow flare area as defined in Ch 8, Sec 1, [4.1.2] are to be reinforced according to Ch 8, Sec 1, [4], considering the stays as cantilever primary supporting members.

3 Guard rails

3.1

3.1.1 Where guard rails are provided, the upper edge of sheerstrake is to be kept as low as possible.

3.1.2 The opening below the lowest course is to be not more than 230 mm. The other courses are to be not more than 380 mm apart.

3.1.3 In the case of ships with rounded gunwales or sheerstrake, the stanchions are to be placed on the flat part of the deck.

3.1.4 Fixed, removable or hinged stanchions are to be fitted about 1,5 m apart. At least every third stanchion is to be supported by a bracket or stay. However, other arrangement may be considered on a case-by-case basis (e.g. stanchions directly screwed in exposed decks), when strength is deemed equivalent.

Removable or hinged stanchions are to be capable of being locked in the upright position.

3.1.5 Wire ropes may only be accepted in lieu of guard rails in special circumstances and then only in limited lengths. Wires are to be made taut by means of turnbuckles.

3.1.6 Chains may only be accepted in short lengths in lieu of guard rails if they are fitted between two fixed stanchions and/or bulwarks.

Section 3 Propeller Shaft Brackets

Symbols

θ : Angle defined in Fig 1 and Fig 2

D_e : Propeller diameter, in m

L : Bracket length, in m (see Fig 1 and Fig 2)

A : Bracket cross-sectional area, in m²

$$K_6 = \frac{2 - \frac{\ell}{L_1} - \frac{\ell}{L_1^2}}{4\left(1 + \frac{\ell}{L_1} + \frac{\ell}{L_1^2}\right)}$$

L_1 : Length, in m, of the bracket between the hull and the intersection point with the propeller bossing, obtained as follows:

$L_1 = L - \ell$

ℓ : Distance, in m, from the above intersection point to the intersection between the barycentre axes of the brackets (see Fig 1 and Fig 2).

1 General

1.1 Bracket configuration

1.1.1 Propeller shafting is generally supported by two brackets, a main one connected to the propeller bossing and an intermediate one between the main one and the ship hull.

The main bracket is to be of double arm type, while the intermediate one may be of single arm type.

2 Double arm brackets of propeller shaft

2.1 General

2.1.1 Double arm brackets of propeller shaft are generally to be radial or tangential, as schematically shown in, respectively, Fig 1 and Fig 2. Other arrangements proposed by the shipyard may be accepted by the Society, on a case-by-case basis.

Usually, the vertical plane passing through the base chord of the bracket is parallel to the ship symmetry plane. When this is not the case, the brackets are said to be twisted and the twist angle is to be identified.

The brackets should be in a lateral plane. However, when more space is needed between the brackets and the propeller, or when brackets normal to the hull are considered, the bracket inclination angle is to be toward the aft.

Figure 1 : Radial type double arm bracket

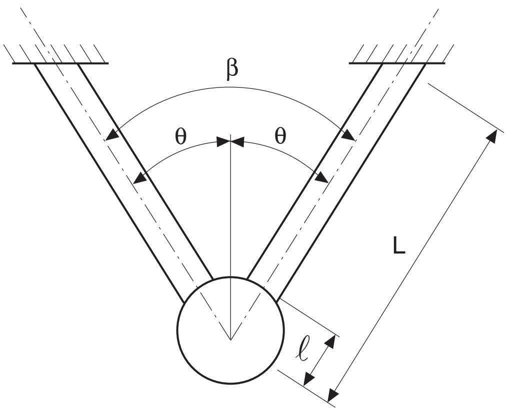
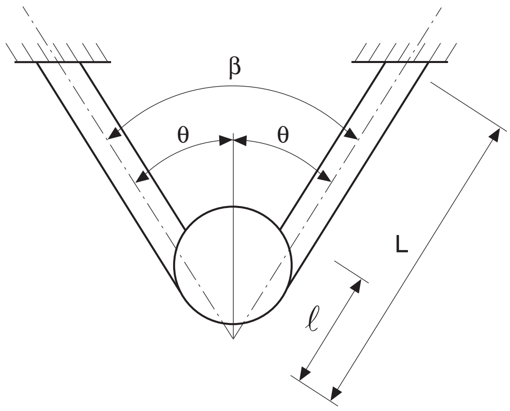


Figure 2 : Tangential type double arm bracket



2.1.2 The hull structure in the zone where the propeller brackets are attached to the hull is to be capable of completely absorbing the forces induced by the brackets; in particular, the connection with the primary longitudinal structural members is important. The connections brackets-hull and brackets-propeller bossing are to be rounded. Alternative designs of connections between internal hull structure and propeller bossing avoiding excessive stress concentration may be accepted, subject to special examination.

2.1.3 The lowest natural frequency of the brackets should exceed the blade frequency with not less than 20%.

In cases where this is not possible, the above requirement should be fulfilled for the second resonance frequency and, furthermore, the blade frequency should be at least twice the lowest natural frequency.

2.2 Limit state verification - Loss of blade

2.2.1 General

In the case of loss of a propeller blade, it is to be verified that the maximum global stress σ_{TOT} induced in the propeller brackets do not exceed the permissible stress σ_P :

$\sigma_{TOT} \le \sigma_P$

where:

$\sigma_P = 0{,}48\ \sigma_y$

with:

σ_y : Yield stress of the material.

2.2.2 Maximum global stress

The maximum global stress acting on the propeller shaft bracket is to be determined as the sum of the maximum bending induced stress and the compressive stress at that instant:

$\sigma_{TOT} = \sigma_x + \sigma_c$

where:

$\sigma_x = \text{Max}\ (\sigma_A\ ;\ \sigma_B)$, with σ_A and σ_B defined in [2.2.3]

σ_c : Compressive stress when the bending stress is maximized, defined in [2.2.4].

2.2.3 Acting bending stresses

As the brackets are subjected to combined bending (longitudinal and transverse) the stress can achieve its greatest values at two locations, A and B (see Fig 3).

The stress is therefore to be determined at both locations and the acting stress σ_x is then taken equal to the greater value.

The stress in point A is determined as follows:

$$\sigma_A = \frac{M_{L,\,max}}{W_{zz}}$$

where:

$M_{L,\,max}$: Maximum longitudinal bending moment in the bracket, defined in [2.2.5]

W_{zz} : Section modulus around z axis.

The stress in point B is determined as follows:

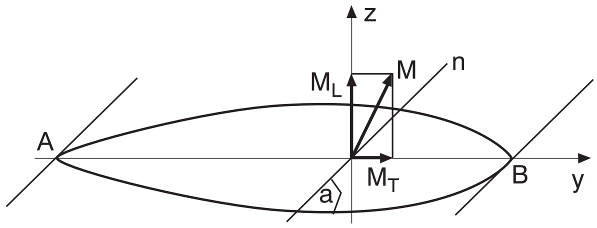
$$\sigma_B = \frac{M_{T\varphi}}{I_{yy}} Z_B + \frac{M_{L,\,max}}{I_{zz}} Y_B$$

where:

$M_{T\varphi}$: Transverse moment in the bracket when the longitudinal moment is maximum, as defined in [2.2.6]

I_{yy} : Sectional moment of inertia around y axis
I_{zz} : Sectional moment of inertia around z axis
Z_B : Distance from point B to the neutral axis for transverse bending
Y_B : Distance from point B to the neutral axis for longitudinal bending.

Figure 3 : Locations of maximum stress under combined bending



2.2.4 Compressive stress

The compressive stress, acting in the brackets when the longitudinal bending moment is maximized, is to be determined as follows:

$$\sigma_c = \frac{P}{2A}\left(\frac{\sin\varphi}{\sin\theta} + \frac{\cos\varphi}{\cos\theta}\right)$$

where:

P : Centrifugal force of the lost blade, in N, to be taken equal to (see Fig 4):
$P = m\,\omega^2\,\rho$
with:
m : Weight of the blade, in kg
ω : Angular velocity, in rad/s, equal to: $\omega = 2\,\pi\,RPM / 60$, with:
RPM : Maximum number of revolutions per minute of the propeller
ρ : Distance from the centre of gravity of the blade to the propeller axis

φ : Phase angle for which the bending stress in the bracket is maximized.
The phase angle maximizing the bending induced stress is to be determined from:

$$\tan\varphi = \frac{2K_6}{\tan\theta}$$

2.2.5 Maximum longitudinal moment in bracket

The maximum longitudinal bending moment, in N·m, acting in the brackets is defined as follows:

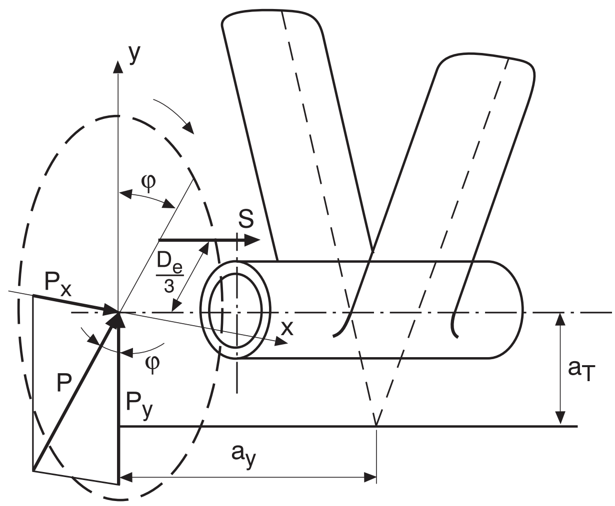
$$M_{L,\,max} = \frac{4K_6^2\cos\theta + \sin\theta\tan\theta}{2\sin\theta\cos\theta\sqrt{4K_6^2 + \tan^2\theta}}\left(Pa_y + \frac{SD_e}{3}\right)$$

where:

S : Thrust of the lost blade (see Fig 4), in N, to be obtained as the total thrust of the propeller divided by the number of propeller blades

a_y : Distance from the propeller to the brackets, in m (see Fig 4).

Figure 4 : Definition of forces, directions and distances



2.2.6 Maximum transverse moment in bracket

The maximum transverse bending moment, in N·m, acting in the brackets is defined as follows:

$$M_{T\varphi} = K_6 P a_T \frac{2K_6}{\sqrt{4K_6^2 + \tan^2\theta}}$$

where:

P : Defined in [2.2.4]

a_T : Defined in Fig 4, in m.

2.2.7 Resonance

In case of loss of a propeller blade, it is to be verified that the bracket lowest natural frequency f_1 is at least 20% larger than the exciting frequency of the damaged propeller f_{dam}:

$f_1 \geq 1,2\ f_{dam}$

where:

f_1 : Determined as described in [2.3.2]

f_{dam} = RPM / 60, in Hz, with:

RPM : Maximum number of revolutions per minute of the propeller.

2.3 Other verifications

2.3.1 Stability under compression

The maximum compressive stress σ_{max} acting on the brackets is defined as follows:

$$\sigma_{max} = \frac{P}{2A}\left(\frac{1}{\sin\theta\sqrt{1+\tan^2\theta}} + \frac{\tan\theta}{\cos\theta\sqrt{1+\tan^2\theta}}\right)$$

It is to be verified that σ_{max} does not exceed the critical instability stress σ_{cr}, in N/m², defined as follows:

$$\sigma_{cr} = \pi^2 \frac{EI_{min}}{0,64AL^2}$$

where:

E : Young's modulus, equal to $2,06\cdot10^{11}$ N/m² for steel

I_{min} : Minimum moment of inertia of the bracket cross-section, in m⁴.

2.3.2 Resonance

In general, it is to be verified that either:

a) the bracket lowest natural frequency f_1 exceeds with at least 20% the blade frequency f_{bl}, or

b) the blade frequency f_{bl} is at least twice as large as the bracket lowest natural frequency f_1 and 20% smaller than the second natural frequency f_2,

which can be expressed by:

- $f_1 > 1,20\ f_{bl}$
- $0,8\ f_2 > f_{bl} > 2\ f_1$

where:

f_{bl} : Blade frequency, in Hz, equal to:

$f_{bl} = n \cdot$ RPM / 60, with:

n : Number of blades

RPM : Maximum number of revolutions per minute of the propeller

$$f_i = \frac{\lambda_i^2}{2\pi L^2}\sqrt{\frac{EI_{min}}{w + w_e}}$$

with:

λ_1 : Factor equal to:

- 1,875 in case of a single arm bracket
- 3,927 in case of double arm brackets

λ_2 : Factor equal to:

- 4,694 in case of a single arm bracket
- 7,069 in case of double arm brackets

E, I_{min} : Defined in [2.3.1]

w : Mass of the bracket per unit length, in kg/m

w_e : Added mass of water per unit length, in kg/m.

The added mass of water is to be determined as, unless otherwise agreed with the Society:

$w_e = \rho\ (A_{cir} - A)$

where:

ρ : Density of sea water, equal to 1025 kg/m^3

A_{cir} : Area of the circle circumscribing the bracket profile, in m^2.

Section 4 Equipment

Symbols

EN : Equipment Number defined in [2.1]

σ_{ALL} : Allowable stress, in N/mm², used for the yielding check, to be taken as follows:

σ_{ALL} = Min (0,67 R_{eH} ; 0,40 R_m)

R_{eH} : Minimum yield stress, in N/mm², of the material, defined in Ch 4, Sec 1, [2]

R_m : Tensile strength, in N/mm², of the material, defined in Ch 4, Sec 1, [2].

1 General

1.1 General

1.1.1 The minimum requirements in Articles [2] to [4] apply to temporary mooring of a ship within or near harbour, or in a sheltered area, when the ship is awaiting a berth, the tide, etc.

Therefore, the equipment complying with the requirements in Articles [2] to [4] is not intended for holding a ship off fully exposed coasts in rough weather or for stopping a ship which is moving or drifting.

The requirements in Articles [2] and [4] are based on a wind speed of 25 m/s, a current speed of 2,5 m/s and a water depth of 50 m.

For a water depth greater than 50 m, a length of chain cable greater than the one obtained from Tab 1 may be accepted by the Society, on the basis of justificative calculation submitted by the shipyard.

1.1.2 The equipment complying with the requirements in Articles [2] to [4] is intended for holding a ship in good holding ground, where the conditions are such as to avoid dragging of the anchor. In poor holding ground the holding power of the anchors is to be significantly reduced.

1.1.3 It is assumed that under normal circumstances a ship will use one anchor only.

2 Equipment number

2.1 Equipment number

2.1.1 General

All ships are to be provided with equipment in anchors and chain cables (or ropes according to [3.2.5]), to be obtained from Tab 1, based on their Equipment Number EN.

In general, stockless anchors are to be adopted.

For ships with EN greater than 16000, the determination of the equipment will be considered by the Society on a case-by-case basis.

For ships of special design or ships engaged in special services or on special voyages, the Society may consider equipment other than that given in Tab 1.

Table 1 : Equipment

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N **(1)**	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
50	70	2	240	220,0	16,0	14,0	
70	90	2	300	247,5	17,5	16,0	
90	110	2	360	247,5	19,0	17,5	
110	130	2	420	275,0	20,5	17,5	
130	150	2	480	275,0	22,0	19,0	
150	175	2	570	302,5	24,0	20,5	
175	205	3	660	302,5	26,0	22,0	20,5
205	240	3	780	330,0	28,0	24,0	22,0

(1) See [3.1.4].

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N **(1)**	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
240	280	3	900	357,5	30,0	26,0	24,0
280	320	3	1020	357,5	32,0	28,0	24,0
320	360	3	1140	385,0	34,0	30,0	26,0
360	400	3	1290	385,0	36,0	32,0	28,0
400	450	3	1440	412,5	38,0	34,0	30,0
450	500	3	1590	412,5	40,0	34,0	30,0
500	550	3	1740	440,0	42,0	36,0	32,0
550	600	3	1920	440,0	44,0	38,0	34,0
600	660	3	2100	440,0	46,0	40,0	36,0
660	720	3	2280	467,5	48,0	42,0	36,0
720	780	3	2460	467,5	50,0	44,0	38,0
780	840	3	2640	467,5	52,0	46,0	40,0
840	910	3	2850	495,0	54,0	48,0	42,0
910	980	3	3060	495,0	56,0	50,0	44,0
980	1060	3	3300	495,0	58,0	50,0	46,0
1060	1140	3	3540	522,5	60,0	52,0	46,0
1140	1220	3	3780	522,5	62,0	54,0	48,0
1220	1300	3	4050	522,5	64,0	56,0	50,0
1300	1390	3	4320	550,0	66,0	58,0	50,0
1390	1480	3	4590	550,0	68,0	60,0	52,0
1480	1570	3	4890	550,0	70,0	62,0	54,0
1570	1670	3	5250	577,5	73,0	64,0	56,0
1670	1790	3	5610	577,5	76,0	66,0	58,0
1790	1930	3	6000	577,5	78,0	68,0	60,0
1930	2080	3	6450	605,0	81,0	70,0	62,0
2080	2230	3	6900	605,0	84,0	73,0	64,0
2230	2380	3	7350	605,0	87,0	76,0	66,0
2380	2530	3	7800	632,5	90,0	78,0	68,0
2530	2700	3	8300	632,5	92,0	81,0	70,0
2700	2870	3	8700	632,5	95,0	84,0	73,0
2870	3040	3	9300	660,0	97,0	84,0	76,0
3040	3210	3	9900	660,0	100,0	87,0	78,0
3210	3400	3	10500	660,0	102,0	90,0	78,0
3400	3600	3	11100	687,5	105,0	92,0	81,0
3600	3800	3	11700	687,5	107,0	95,0	84,0
3800	4000	3	12300	687,5	111,0	97,0	87,0
4000	4200	3	12900	715,0	114,0	100,0	87,0
4200	4400	3	13500	715,0	117,0	102,0	90,0
4400	4600	3	14100	715,0	120,0	105,0	92,0
4600	4800	3	14700	742,5	122,0	107,0	95,0
4800	5000	3	15400	742,5	124,0	111,0	97,0
5000	5200	3	16100	742,5	127,0	111,0	97,0
5200	5500	3	16900	742,5	130,0	114,0	100,0
5500	5800	3	17800	742,5	132,0	117,0	102,0
5800	6100	3	18800	742,5		120,0	107,0
6100	6500	3	20000	770,0		124,0	111,0
6500	6900	3	21500	770,0		127,0	114,0
6900	7400	3	23000	770,0		132,0	117,0
7400	7900	3	24500	770,0		137,0	122,0
7900	8400	3	26000	770,0		142,0	127,0

(1) See [3.1.4].

Equipment number EN A < EN ≤ B		Stockless anchors		Stud link chain cables for anchors			
		N (1)	Mass per anchor, in kg	Total length, in m	Diameter, in mm		
A	B				Q1	Q2	Q3
8400	8900	3	27500	770,0		147,0	132,0
8900	9400	3	29000	770,0		152,0	132,0
9400	10000	3	31000	770,0			137,0
10000	10700	3	33000	770,0			142,0
10700	11500	3	35500	770,0			147,0
11500	12400	3	38500	770,0			152,0
12400	13400	3	42000	770,0			157,0
13400	14600	3	46000	770,0			162,0
(1) See [3.1.4].							

2.1.2 Equipment number for ships with perpendicular superstructure front bulkhead

The equipment number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\ h\ B + 0{,}1\ A$

where:

Δ : Moulded displacement of the ship, in t, to the full load waterline "end of life"

h : Effective height, in m, from the full load waterline to the top of the uppermost house, to be obtained in accordance with the following formula:

$h = a + \Sigma h_n$

when calculating h, sheer and trim are to be disregarded

a : Distance amidships between the full load waterline and the exposed deck, in m

h_n : Height, in m, at the centreline of tier "n" of superstructures or deckhouses having a breadth greater than B/4. Where a house having a breadth greater than B/4 is above a house with a breadth of B/4 or less, the upper house is to be included and the lower ignored

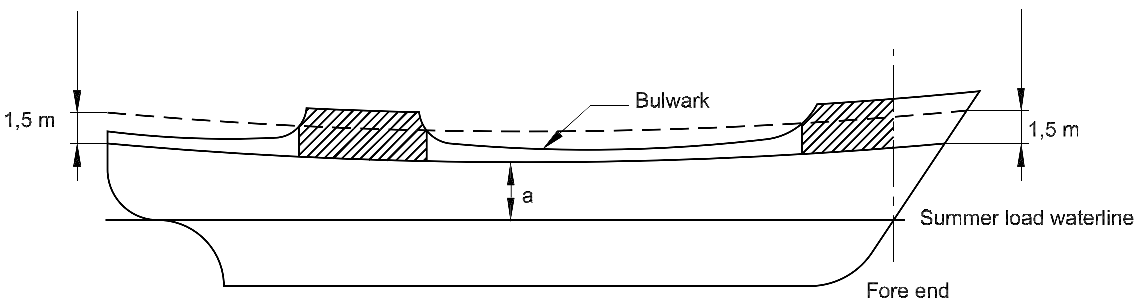
A : Area, in m², in profile view, of the parts of the hull, superstructures and houses above the full load waterline which are within the length L_E and also have a breadth greater than B/4

L_E : Equipment length, in m, equal to L without being taken neither less than 96% nor greater than 97% of the total length of the full load waterline.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 1 is to be included.

The height of hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

Figure 1 : Ships with perpendicular front bulkhead
Effective area of bulwarks or fixed screen to be included in the equipment number



2.1.3 Equipment number for ships with inclined superstructure front bulkhead

For ships having superstructures with the front bulkhead with an angle of inclination aft, the equipment number EN is to be obtained from the following formula:

$EN = \Delta^{2/3} + 2\ (a\ B + \Sigma\ b_N\ h_N \sin\theta_N) + 0{,}1\ A$

where:

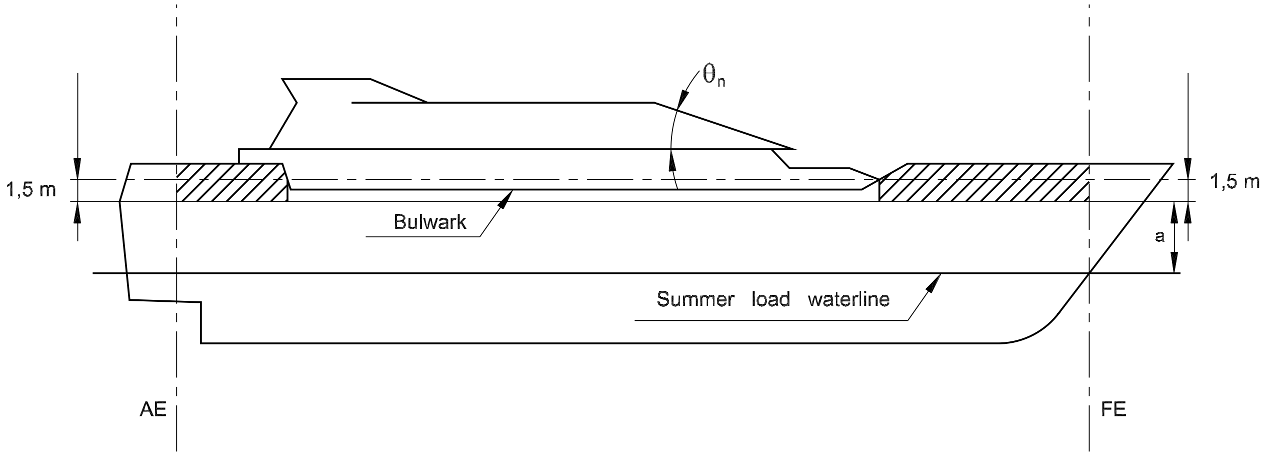
Δ, a, h_N , A: Defined in [2.1.2]

θ_N : Angle of inclination aft of each front bulkhead, shown in Fig 2

b_N : Greatest breadth, in m, of each tier n of superstructures or deckhouses having a breadth greater than B/4.

Fixed screens or bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A. In particular, the hatched area shown in Fig 2 is to be included.

Figure 2 : Ships with inclined front bulkhead
Effective area of bulwarks or fixed screen to be included in the equipment number



3 Equipment

3.1 Anchors

3.1.1 General

The scantlings of anchors are to be in compliance with the following requirements.

Anchors are to be constructed and tested in compliance with approved plans.

3.1.2 Ordinary anchors

The required mass for each anchor is to be obtained from Tab 1.

The individual mass of a main anchor may differ by ± 7% from the mass required for each anchor, provided that the total mass of anchors is not less than the total mass required in Tab 1.

The mass of the head of an ordinary stockless anchor, including pins and accessories, is to be not less than 60% of the total mass of the anchor.

Where a stock anchor is provided, the mass of the anchor, excluding the stock, is to be not less than 80% of the mass required in Tab 1 for a stockless anchor. The mass of the stock is to be not less than 25% of the mass of the anchor without the stock but including the connecting shackle.

3.1.3 High and very high holding power anchors

High holding power (HHP) and very high holding power (VHHP) anchors, i.e. anchors for which a holding power higher than that of ordinary anchors has been proved according to NR216 Materials and Welding, Ch 4, Sec 1, [1], do not require prior adjustment or special placement on the sea bottom.

Where HHP or VHHP anchors are used as bower anchors, the mass of each anchor is to be not less than 75% or 50%, respectively, of that required for ordinary stockless anchors in Tab 1.

The mass of VHHP anchors is to be, in general, less than or equal to 1500 kg.

3.1.4 Third anchor

Where three anchors are provided, two are to be connected to their own chain cables and positioned on board always ready for anchoring.

The third anchor is intended as a spare and is not required for the purpose of classification.

3.1.5 Test for high holding power anchors approval

For approval and/or acceptance as a HHP anchor, comparative tests are to be performed on various types of sea bottom. Such tests are to show that the holding power of the HHP anchor is at least twice the holding power of an ordinary stockless anchor of the same mass.

For approval and/or acceptance as a HHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least two anchors of different sizes are to be tested. The mass of the maximum size to be approved is to be not greater than 10 times the maximum size tested. The mass of the smallest is to be not less than 0,1 times the minimum size tested.

3.1.6 Test for very high holding power anchors approval

For approval and/or acceptance as a VHHP anchor, comparative tests are to be performed at least on three types of sea bottom: soft mud or silt, sand or gravel and hard clay or similar compounded material. Such tests are to show that the holding power of the VHHP anchor is to be at least four times the holding power of an ordinary stockless anchor of the same mass or at least twice the holding power of a previously approved HHP anchor of the same mass.

The holding power test load is to be less than or equal to the proof load of the anchor, specified in NR216 Materials and Welding, Ch 4, Sec 1, [1.6].

For approval and/or acceptance as a VHHP anchor of a whole range of mass, such tests are to be carried out on anchors whose sizes are, as far as possible, representative of the full range of masses proposed. In this case, at least three anchors of different sizes are to be tested. relevant to the bottom, middle and top of the mass range.

3.1.7 Specification for test on high holding power and very high holding power anchors

Tests are generally to be carried out from a tug. Shore based tests may be accepted by the Society on a case-by-case basis.

Alternatively, sea trials by comparison with a previous approved anchor of the same type (HHP or VHHP) of the one to be tested may be accepted by the Society on a case-by-case basis.

For each series of sizes, the two anchors selected for testing (ordinary stockless and HHP anchors for testing HHP anchors, ordinary stockless and VHHP anchors or, when ordinary stockless anchors are not available, HHP and VHHP anchors for testing VHHP anchors) are to have the same mass.

The length of chain cable connected to each anchor, having a diameter appropriate to its mass, is to be such that the pull on the shank remains practically horizontal. For this purpose a value of the ratio between the length of the chain cable paid out and the water depth equal to 10 is considered normal. A lower value of this ratio may be accepted by the Society on a case-by-case basis.

Three tests are to be carried out for each anchor and type of sea bottom.

The pull is to be measured by dynamometer; measurements based on the RPM/bollard pull curve of tug may, however, be accepted instead of dynamometer readings.

Note is to be taken where possible of the stability of the anchor and its ease of breaking out.

3.2 Chain cables for anchors

3.2.1 Material

The chain cables are classified as grade Q1, Q2 or Q3 depending on the type of steel used and its manufacture.

The characteristics of the steel used and the method of manufacture of chain cables are to be approved by the Society for each manufacturer. The material from which chain cables are manufactured and the completed chain cables themselves are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Ch 4, Sec 1.

Chain cables made of grade Q1 may not be used with high holding power and very high holding power anchors.

3.2.2 Stud link chain cables

The mass and geometry of stud link chain cables, including the links, are to be in compliance with the requirements in NR216 Materials and Welding, Ch 4, Sec 1.

The diameter of stud link chain cables is to be not less than the values given in Tab 1.

3.2.3 Studless link chain cables

For ships with EN less than 90, studless short link chain cables may be accepted by the Society as an alternative to stud link chain cables, provided that the equivalence in strength is based on proof load, defined in NR216 Materials and Welding, Ch 4, Sec 1, [3], and that the steel grade of the studless chain is equivalent to the steel grade of the stud chains it replaces, as defined in [3.2.1].

3.2.4 Chain cable arrangement

Chain cables are to be made by lengths of 27,5 m each, joined together by Dee or lugless shackles.

The total length of chain cable, required in Tab 1, is to be divided in approximately equal parts between the two anchors ready for use.

Where different arrangements are provided, they are considered by the Society on a case-by-case basis. In particular, different lengths of chain cable for each anchor may be accepted, provided each mooring line is appropriate for 50m water depth.

Where the ship may anchor in areas with current speed greater than 2,5 m/s, the Society may require a length of heavier chain cable to be fitted between the anchor and the rest of the chain in order to enhance anchor bedding.

3.2.5 Wire ropes

As an alternative to the stud link or short link chain cables mentioned, wire ropes may be used in the following cases:

- wire ropes for both the anchors, for ship length less than 30 m
- wire rope for one of the two anchors, for ship length between 30 m and 40 m.

The wire ropes above are to have a total length equal to 1,5 times the corresponding required length of stud link chain cables, obtained from Tab 1, and a minimum breaking load equal to that given for the corresponding stud link chain cable (see [3.2.2]).

A short length of chain cable is to be fitted between the wire rope and the anchor, having a length equal to 12,5 m or the distance from the anchor in the stowed position to the winch, whichever is the lesser.

3.3 Attachment pieces

3.3.1 General

Where the lengths of chain cable are joined to each other by means of shackles of the ordinary Dee type, the anchor may be attached directly to the end link of the first length of chain cable by a Dee type end shackle.

A detachable open link in two parts riveted together may be used in lieu of the ordinary Dee type end shackle; in such case the open end link with increased diameter, defined in [3.3.2], is to be omitted.

Where the various lengths of chain cable are joined by means of lugless shackles and therefore no special end and increased diameter links are provided, the anchor may be attached to the first length of chain cable by a special pear-shaped lugless end shackle or by fitting an attachment piece.

3.3.2 Scantlings

The diameters of the attachment pieces, in mm, are to be not less than the values indicated in Tab 2.

Attachment pieces may incorporate the following items between the increased diameter stud link and the open end link:

- swivel, having diameter equal to 1,2 d
- increased stud link, having diameter equal to 1,1 d.

Where different compositions are provided, they will be considered by the Society on a case-by-case basis.

Table 2 : Diameters of attachment pieces

Attachment piece	Diameter, in mm
End shackle	1,4 d
Open end link	1,2 d
Increased stud link	1,1 d
Common stud link	d
Lugless shackle	d
Note 1: d : Diameter, in mm, of the common link	

3.3.3 Material

Attachment pieces, joining shackles and end shackles are to be of such material and design as to provide strength equivalent to that of the attached chain cable, and are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Ch 4, Sec 1.

3.4 Towlines

3.4.1 General

The towlines are given as a guidance, but are not required as a condition of classification.

The towlines having the characteristics defined in Tab 3 are intended as those belonging to the ship to be towed by a tug or another ship.

3.4.2 Materials

Towlines may be of wire, natural or synthetic fibre or a mixture of wire and fibre.

The breaking loads defined in Tab 3 refer to steel wires or natural fibre ropes.

Steel wires and fibre ropes are to be tested in accordance with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1.

3.4.3 Steel wires

Steel wires are to be made of flexible galvanized steel and are to be of types defined in Tab 4.

3.4.4 Synthetic fibre ropes

Where synthetic fibre ropes are adopted, their size is to be determined taking into account the type of material used and the manufacturing characteristics of the rope, as well as the different properties of such ropes in comparison with natural fibre ropes.

The breaking load of synthetic fibre ropes B_{LS} is to be not less than that obtained, in kN, from the following formula:

$B_{LS} = K\, B_{L0}$

where:

B_{L0} : Breaking load, in kN, for the towline, defined in Tab 3,

K : Coefficient to be taken equal to:

K = 1,3 for polypropylene towlines

K = 1,2 for towlines made in other synthetic material.

Fibre rope diameters are to be not less than 20 mm.

3.4.5 Equivalence between the breaking loads of synthetic and natural fibre ropes

Generally, fibre ropes are to be made of polyamide or other equivalent synthetic fibres.

The equivalence between the breaking loads of synthetic fibre ropes B_{LS} and of natural fibre ropes B_{LN} is to be obtained, in kN, from the following formula:

$B_{LS} = 7{,}4\ \delta\ B_{LN}^{8/9}$

where:

δ : Elongation to breaking of the synthetic fibre rope, to be assumed not less than 30%.

Table 3 : Towlines and mooring lines

Equipment number EN A< EN ≤ B		Towlines		Equipment number EN A< EN ≤ B		Towlines	
A	B	Minimum length, in m	Breaking load, in kN	A	B	Minimum length, in m	Breaking load, in kN
50	70	180	98,1	1390	1480	200	836
70	90	180	98,1	1480	1570	220	889
90	110	180	98,1	1570	1670	220	942
110	130	180	98,1	1670	1790	220	1024
130	150	180	98,1	1790	1930	220	1109
150	175	180	98,1	1930	2080	220	1168
175	205	180	112	2080	2230	240	1259
205	240	180	129	2230	2380	240	1356
240	280	180	150	2380	2530	240	1453
280	320	180	174	2530	2700	260	1471
320	360	180	207	2700	2870	260	1471
360	400	180	224	2870	3040	260	1471
400	450	180	250	3040	3210	280	1471
450	500	180	277	3210	3400	280	1471
500	550	190	306	3400	3600	280	1471
550	600	190	338	3600	3800	300	1471
600	660	190	371	3800	4000	300	1471
660	720	190	406	4000	4200	300	1471
720	780	190	441	4200	4400	300	1471
780	840	190	480	4400	4600	300	1471
840	910	190	518	4600	4800	300	1471
910	980	190	550	4800	5000	300	1471
980	1060	200	603	5000	5200	300	1471
1060	1140	200	647	5200	5500	300	1471
1140	1220	200	692	5500	5800	300	1471
1220	1300	200	739	5800	6100	300	1471
1300	1390	200	786				

Table 4 : Steel wire composition

Breaking load B_L ,in kN	Steel wire components		
	Number of threads	Ultimate tensile strength of threads, in N/mm²	Composition of wire
$B_L < 216$	72	1420 ÷ 1570	6 strands with 7-fibre core
$216 < B_L < 490$	144	1570 ÷ 1770	6 strands with 7-fibre core
$B_L > 490$	216 or 222	1770 ÷ 1960	6 strands with 1-fibre core

3.5 Hawse pipes

3.5.1 Hawse pipes are to be built according to sound marine practice.

Their position and slope are to be so arranged as to create an easy lead for the chain cables and efficient housing for the anchors, where the latter are of the retractable type, avoiding damage to the hull during these operations.

For this purpose chafing lips of suitable form with ample lay-up and radius adequate to the size of the chain cable are to be provided at the shell and deck. The shell plating in way of the hawse pipes is to be reinforced as necessary.

3.5.2 All mooring units and accessories, such as timbler, riding and trip stoppers are to be securely fastened, to the Surveyor's satisfaction.

3.6 Windlass

3.6.1 General

The Rule Note NR626 "Anchor Windlass and Chain Stoppers" is to be applied, considering the windlass brake capacity defined in [3.6.2].

The deck in way of the windlass is to be suitably reinforced. The windlass, its frame and the stoppers are to be efficiently bedded to the deck.

3.6.2 Brake capacity

Based on mooring line arrangements with brakes engaged and cable lifter disengaged, the capacity HL (Holding Load), in kN, of the windlass brake is to be sufficient to withstand the following design loads without any permanent deformation of the stressed parts and without brake slip:

- 0,8 times the breaking load BL of the chain, if not combined with a chain stopper
- 0,45 times the breaking load BL of the chain, if combined with a chain stopper.

3.7 Chain stoppers

3.7.1 A chain stopper is generally to be fitted between the windlass and the hawse pipe in order to relieve the windlass of the pull of the chain cable when the ship is at anchor. The chain stopper is to comply with applicable requirements given in the Rule Note NR626 "Anchor Windlass and Chain Stoppers".

For the same purpose, a piece of chain cable may be used with a rigging screw capable of supporting the weight of the anchor when housed in the hawse pipe or a chain tensioner. Such arrangements are not to be considered as chain stoppers.

3.7.2 Where the windlass is at a distance from the hawse pipes and no chain stoppers are fitted, suitable arrangements are to be provided to lead the chain cables to the windlass.

3.8 Chain locker

3.8.1 The capacity of the chain locker is to be adequate to stow all chain cable equipment and provide an easy direct lead to the windlass.

3.8.2 Where two chains are used, the chain lockers are to be divided into two compartments, each capable of housing the full length of one line.

3.8.3 The inboard ends of chain cables are to be secured to suitably reinforced attachments in the structure by means of end shackles, whether or not associated with attachment pieces.

Generally, such attachments are to be able to withstand a force not less than 15% of the breaking load of the chain cable.

In an emergency, the attachments are to be easily released from outside the chain locker.

3.8.4 Where the chain locker is arranged aft of the collision bulkhead, its boundary bulkheads are to be watertight and a drainage system is to be provided.

4 Mooring arrangement

4.1 General

4.1.1 The mooring lines and the hawser for mooring to a buoy are to be in accordance with the following sub-articles. The other mooring equipment are outside the scope of classification.

4.2 Mooring lines

4.2.1 Minimum breaking load

The minimum breaking load BL, in KN, of the mooring lines is given by:

BL = FS / N

with:

FS : Static force, in kN, induced by wind on the ship in the transverse direction given by the following formula:
$FS = 2,382\ A\ (h + 18) / (h + 60)$

h : Mean height, in m, above waterline to be taken as:
$h = 2\ A / 3\ L_E$

A : Area, in m^2, as given in [2.1.2]

L_E : Length, in m, as given in [2.1.2]

N : Number of breast lines.

4.2.2 Number

As a rule, two breast lines are to be fitted on board. However, for large ships, the number of breast lines may be increased in order to ensure that the diameter of the lines will be less than 72 mm, which is considered to be the maximum permissible diameter for handiness.

All the mooring lines are to be made of the same material and have the same diameter. However, when this diameter is greater than 63 mm, the head and stern lines will be replaced by four ones with lower diameter.

As a minimum, eight mooring lines are to be fitted on board:

- one head line and one stern line
- one forward spring and one after spring
- one forward breast line and one after breast line
- two spare lines (one breast line and one spring).

4.2.3 Length

As a rule, the length of the breast lines and the springs is to be between 0,7 L_E and L_E.

The length of head and stern lines is to be equal to 1,5 times the length of the other mooring lines.

4.2.4 Material

Mooring lines may be of natural or synthetic fibre or a mixture of wire and fibre.

4.3 Hawser for mooring to a buoy

4.3.1 Material

Each ship is to have a special hawser for mooring to a buoy. As a rule, this hawser is to be made of steel wire made of six strands with 7-fibre core.

4.3.2 Minimum breaking load

The minimum breaking load R, in daN, of the hawser is given by the relation:

$$(R \cdot 10^{-3})^{0,5} > 0,17\ \Delta^{1/3} + 2$$

where Delta

Δ : Displacement, in t, as given in [2.1.2].

Section 5 Masts and Other Outfitting Components

1 Masts

1.1 Application

1.1.1 The requirements of this Article apply to the arrangement of masts fitted on weather deck or on superstructure decks for supporting lights or other important fittings having significant mass with respect to the one of the mast structure.

The requirements in [1.2] apply for static analysis of masts subjected to still water, inertial and wind loads.

The requirements in [1.3] apply for the dynamic analysis of masts.

1.2 Static analysis of masts

1.2.1 General

In general, the inertial loads acting on the mast structures are to be obtained from a complete analysis of the ship motion and accelerations in irregular waves, whose results are to be submitted to the Society for approval. These loads are to be obtained as those that can be reached with a probability of 10^{-5} per cycle.

Extreme wind values are to be considered in association with these inertial loads.

However, when deemed acceptable by the Society, the design loads in [1.2.2] may be used for the structural analysis of masts.

1.2.2 Design loads

The design loads are constituted by still water, inertial and wind loads. The structural weight of the mast and the weight of the mast fittings and devices are to be taken into account when calculating the still water force F_S and the inertial force F_W, as indicated in Tab 1.

The wind force F_{Wind}, to be considered as being perpendicular to the surface of the mast exposed to the wind, is to be obtained, in N, from the following formula:

$F_{Wind} = 0,613\ C_S\ V^2\ A$

where:

C_S : Shape coefficient, to be taken equal to:
- C_S = 1,6 for lattice and flat-sided masts
- C_S = 0,9 for masts with circular cross-sections
- C_S = 1,2 for mast fittings

V : Wind speed, in m/s, to be taken, in general, not less than 63 m/s

A : Projected area, in m², of all the mast surfaces exposed to wind.

1.2.3 Structural analysis

In general, the structural analysis of masts is to be based on direct calculations performed through three-dimensional models. Direct calculations are to be carried out according to the following requirements:

- the structural modelling is to comply with the requirements from Ch 7, App 1, [2] to Ch 7, App 1, [4]
- the loads to be applied on the model are to comply with [1.2.1]
- the stress calculation is to comply with the requirements in Ch 7, App 1, [5].

However, structural analysis of masts based on isolate beam models, performed according to the requirements in Ch 7, Sec 3, [2], may be carried out when deemed acceptable by the Society depending on the structural typology and arrangement adopted for the mast.

When three-dimensional direct calculations are carried out, the structural model of the mast is to include a suitable portion of the hull structure supporting the mast, in order to avoid that the unavoidable inaccuracy in the modelling of the boundary conditions affect the results in the area to be analysed.

1.2.4 Strength check criteria of mast structures

The following strength checks of mast structures are to be carried out:

- yielding check, to be carried out according to Ch 7, Sec 3
- local buckling check of plate panels, to be carried out according to Ch 7, Sec 1, [5]
- column buckling check, to be carried out according to Ch 7, Sec 3, [5.2] and Ch 7, Sec 3, [5.3].

1.3 Dynamic analysis of masts

1.3.1 General

The dynamic analysis of masts is to be based on direct calculations performed through three-dimensional models.

The criteria adopted for structural modelling are to comply with the requirements specified in Ch 7, App 1.

In any case, the mesh accuracy is to be such that the stiffness and the mass distribution of the model elements of the mast, of the mast foundation and of the surrounding hull structure properly represent those of the actual structure.

1.3.2 Normal mode analysis

It is to be checked that each normal mode frequency f_{Ni} , in Hz, of the mast is in compliance with one of the following formulae:

$f_{Ni} < 0,8\ f_{E,MIN}$

$f_{Ni} > 1,2\ f_{E,MAX}$

where:

$f_{E,MIN}$, $f_{E,MAX}$: The lesser and the greater values, in Hz, respectively, among the possible excitations frequencies due to the ship motions or the propulsion system, to be calculated for the ship at the following speeds:

- cruise speed
- maximum continuous rate speed
- patrol speed.

The normal mode calculation method and the number of normal modes to be taken into account are considered by the Society on a case-by-case basis.

When at least one of the mast normal mode frequencies does not comply with the above formulae, a dynamic analysis is to be carried out according to the requirements in [1.3.2].

1.3.3 Dynamic analysis

It is to be checked that the dynamic effects induced in the mast by the ship's motions or propulsion system excitations are within the allowable limits, when this is required according to [1.3.2].

The dynamic effects are to be calculated by means of a dynamic analysis aiming at evaluating the response of the mast in the frequency domain.

When the dynamic analysis is based on normal models, their number is, in general, to be such that the modal effective mass is not less than 95% of the mass of the system constituted by the mast and its supporting structure.

The modal effective mass is defined as:

$$\sum_{i=1}^{N} \gamma_i^2$$

where γ_i is the i^{th} modal participation factor and N is the number of the considered normal modes.

The dynamic analysis criteria and the relevant allowable limits are considered by the Society on a case-by-case basis.

Where requested by the interested parties, the allowable limits may also take into account the serviceability limits of the mast fittings, i.e. the limits at which the efficiency of the mast fitting is impaired (e.g. because of excessive vibration level).

2 Outfitting components subjected to weapon firing loads

2.1 General

2.1.1 These requirements apply to the outfitting components that, because of their relative location with respect to a weapon, could be subjected to the weapon firing loads, but have not been designed to sustain them. Such components are to be completely enclosed within a protecting structure whose strength with respect to the weapon firing loads is to be checked by means of the applicable formulae in Part B, Chapter 7, where the loads are to be calculated according to Ch 5, Sec 6, [9].

If necessary, the protecting structure is to be provided with openings and closing devices. The strength of the closing devices is to be checked against the weapon firing loads as the protecting structure.

Table 1 : Still water force F_S and inertial force F_W

Ship condition	Load case	Forces F_S and F_W, in kN	
Still water condition		$F_{S,X} = 0,035\ g\ \Sigma_i\ W_i$ $F_{S,Y} = 0,087\ g\ \Sigma_i\ W_i$ $F_{S,Z} = g\ \Sigma_i\ W_i$	in x direction **(1)** in y direction **(2)** in z direction
Upright condition	"a"	No inertial force	
	"b"	$F_{W,X} = \Sigma_i\ a_{X1,i}\ W_i$ $F_{W,Z} = \Sigma_i\ a_{Z1,i}\ W_i$	in x direction in z direction
Inclined condition	"c"	$F_{W,Y} = C_{FA}\ \Sigma_i\ a_{Y2,i}\ W_i$	in y direction
	"d"	$F_{W,Z} = C_{FA}\ \Sigma_i\ a_{Z2,i}\ W_i$	in z direction

(1) Still water force corresponding to a ship trim angle equal to 2°. Other trim angle values may be accepted if adequate documentation is provided to the Society

(2) Still water force corresponding to a ship heel angle equal to 5°. Other heel angle values may be accepted if adequate documentation is provided to the Society.

Note 1:

W_i : Mass, in t, of each one of the N mast components considered (i = 1 to N). It includes also the mass of mast structure and the mass of mast fittings and devices

$a_{X1,i}$, $a_{Z1,i}$: Reference values of the accelerations a_{X1}, a_{Z1} in the upright ship condition, defined in Ch 5, Sec 3, 3.4, calculated in way of the centre of gravity of each one of the N mast components considered (i = 1 to N)

$a_{Y2,i}$, $a_{Z2,i}$: Reference values of the accelerations a_{Y2}, a_{Z2} in the inclined ship condition, defined in Ch 5, Sec 3, 3.4, calculated in way of the centre of gravity of each one of the N mast components considered (i = 1 to N)

C_{FA} : Combination factor, to be taken equal to:

- C_{FA} = 0,7 for load case "c"
- C_{FA} = 1,0 for load case "d".

Appendix 1 Criteria for Direct Calculation of Rudder Loads

Symbols

ℓ_{10} , ℓ_{20} , ℓ_{30} , ℓ_{40} : Lengths, in m, of the individual girders of the rudder system (see Fig 1, Fig 2 and Fig 3)

ℓ_{50} : Length, in m, of the solepiece (see Fig 2 and Fig 4)

J_{10} , J_{20} , J_{30} , J_{40} : Moments of inertia about the x axis, in cm^4, of the individual girders of the rudder system having lengths ℓ_{10}, ℓ_{20}, ℓ_{30}, ℓ_{40} (see Fig 1, Fig 2 and Fig 3). For rudders supported by a solepiece only, J_{20} indicates the moment of inertia of the pintle in the sole piece

J_{50} : Moment of inertia about the z axis, in cm^4, of the solepiece (see Fig 2 and Fig 4)

C_R : Rudder force, in N, acting on the rudder blade, defined in Ch 9, Sec 1, [2.1.1]

C_{R1} , C_{R2} : Rudder forces, in N, defined in Ch 9, Sec 1, [2.2.3].

1 Criteria for direct calculation of the loads acting on the rudder structure

1.1 General

1.1.1 Application

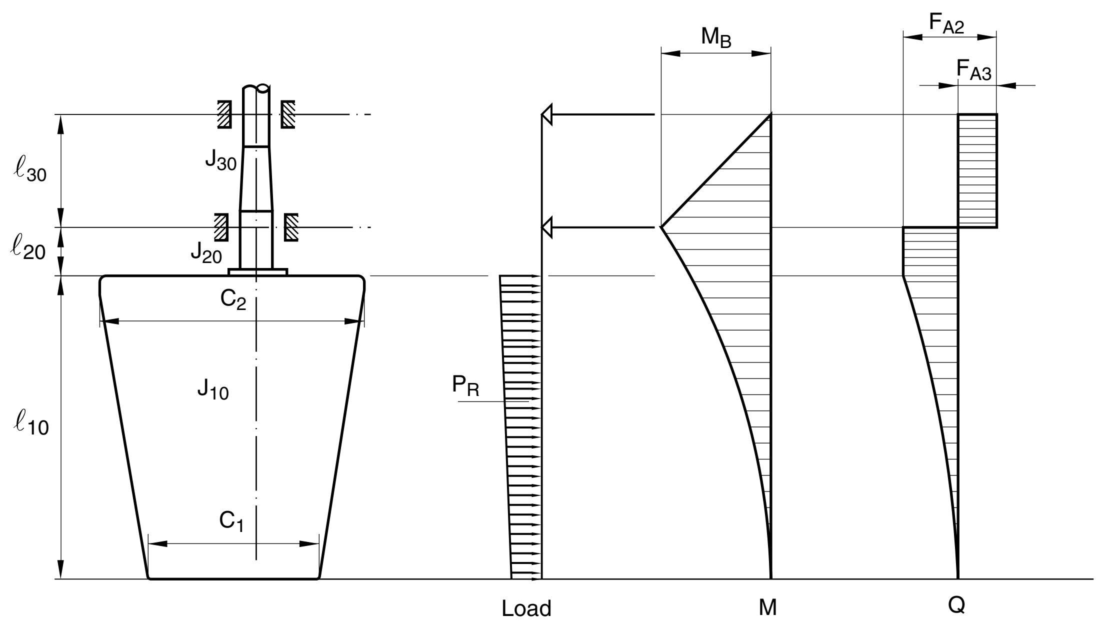
The requirements of this Appendix apply to the following types of rudders:

- spade rudders (see Fig 1)
- 2 bearing rudders with solepiece (see Fig 2)
- 2 bearing semi-spade rudders with rudder horn (see Fig 3).

The requirements of this Appendix provide the criteria for calculating the following loads:

- bending moment M_B in the rudder stock
- support forces F_A
- bending moment M_R and shear force Q_R in the rudder body.

Figure 1 : Spade rudders



1.1.2 Load calculation

The loads in [1.1.1] are to be calculated through direct calculations based on the model specified in Fig 1, Fig 2 and Fig 3, depending on the type of rudder.

They are to be used for the stress analysis required in:

- Ch 9, Sec 1, [4], for the rudder stock
- Ch 9, Sec 1, [6], for the rudder pintles and the pintle bearings
- Ch 9, Sec 1, [7] for the rudder blade
- Ch 9, Sec 1, [8] for the rudder horn and the solepiece.

Figure 2 : 2 bearing rudders with solepiece

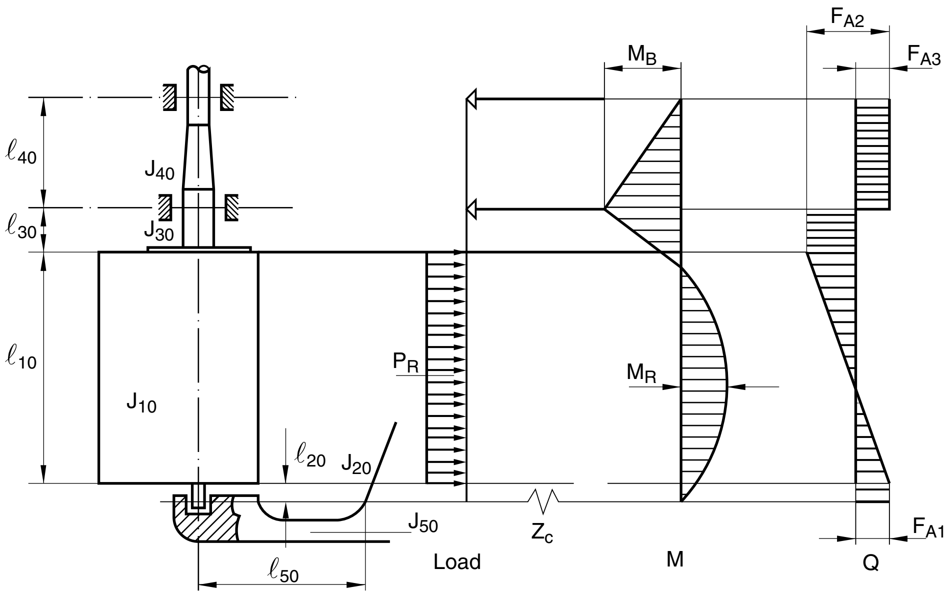


Figure 3 : 2 bearing semi-spade rudders with rudder horn

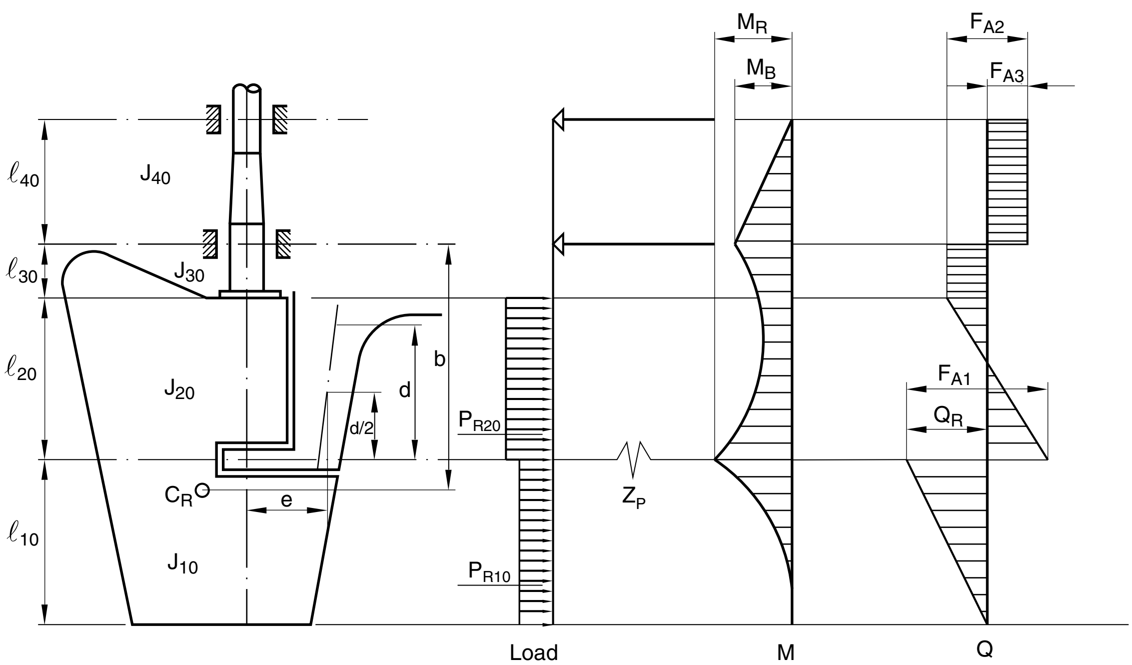
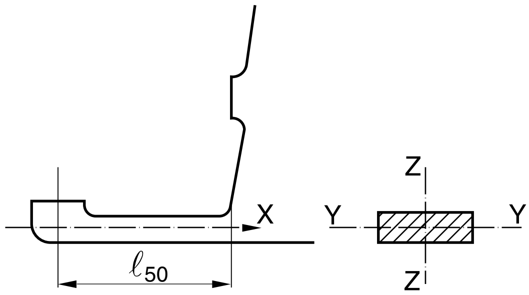


Figure 4 : Solepiece geometry



1.1.3 Specific case of spade rudders

For spade rudders, the results of direct calculations carried out in accordance with [1.1.2] may be expressed in an analytical form. The loads in [1.1.1] may therefore be obtained from the following formulae:

- maximum bending moment in the rudder stock, in N·m:

$$M_B = C_R\left(\ell_{20} + \frac{\ell_{10}(2C_1 + C_2)}{3(C_1 + C_2)}\right)$$

  where C_1 and C_2 are the lengths, in m, defined in Fig 1

- support forces, in N:

$$F_{A3} = \frac{M_B}{\ell_{30}}$$

  $F_{A2} = C_R + F_{A3}$

- maximum shear force in the rudder body, in N:

  $Q_R = C_R$

1.2 Data for the direct calculation

1.2.1 Forces per unit length

The following forces per unit length are to be calculated, in N/m, according to [1.3]:

- p_R for spade rudders and rudders with solepiece (see Fig 1 and Fig 2, respectively)
- p_{R10} and p_{R20} for semi-spade rudders with rudder horn (see Fig 3).

1.2.2 Spring constant

The following support spring constants are to be calculated, in N/m, according to [1.4]:

- Z_C for rudders with solepiece (see Fig 2)
- Z_P for semi-spade rudders with rudder horn (see Fig 3).

1.3 Force per unit length on the rudder body

1.3.1 Spade rudders and 2 bearing rudders with solepiece

The force per unit length p_R (see Fig 1 and Fig 2) acting on the rudder body is to be obtained, in N/m, from the following formula:

$$p_R = \frac{C_R}{\ell_{10}}$$

1.3.2 2 bearing semi-spade rudders with rudder horn

The forces per unit length p_{R10} and p_{R20} (see Fig 1) acting on the rudder body are to be obtained, in N/m, from the following formulae:

$$p_{R10} = \frac{C_{R2}}{\ell_{10}}$$

$$p_{R20} = \frac{C_{R1}}{\ell_{20}}$$

1.4 Support spring constant

1.4.1 Sole piece

The spring constant Z_C for the support in the solepiece (see Fig 2) is to be obtained, in N/m, from the following formula:

$$Z_C = \frac{6180 J_{50}}{\ell_{50}^3}$$

1.4.2 Rudder horn

The spring constant Z_P for the support in the rudder horn (see Fig 3) is to be obtained, in N/m, from the following formula:

$$Z_P = \frac{1}{f_B + f_T}$$

where:

f_B : Unit displacement of rudder horn due to a unit force of 1 N acting in the centroid of the rudder horn, to be obtained, in m/N, from the following formula:

$$f_B = 1{,}3\frac{d^3}{6180 J_N}$$

d : Height, in m, of the rudder horn, defined in Fig 3

J_N : Moment of inertia of rudder horn about the x axis, in cm^4 (see Fig 5)

f_T : Unit displacement due to torsion to be obtained, in m/N, from the following formula:

$$f_T = 10^{-8}\frac{de^2}{3140 F_T^2}\sum_i \frac{u_i}{t_i}$$

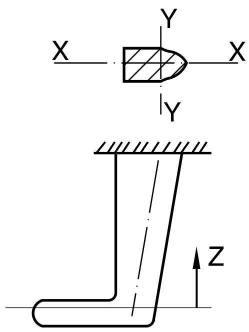
d, e : Lengths, in m, defined in Fig 3

F_T : Mean sectional area of rudder horn, in m^2

u_i : Length, in mm, of the individual plates forming the mean horn sectional area

t_i : Thickness of the individual plates mentioned above, in mm.

Figure 5 : Rudder horn geometry



CHAPTER 10
CORROSION PROTECTION AND LOADING INFORMATION

Section 1 Protection of Hull Metallic Structures
Section 2 Loading Manual and Loading Instruments

Section 1 Protection of Hull Metallic Structures

1 Protection by coating

1.1 General

1.1.1 It is the responsibility of the Shipbuilder and the Owner to choose the coating and have it applied in accordance with the manufacturer's requirements.

1.2 Structures to be protected

1.2.1 All salt water ballast spaces with boundaries formed by the hull envelope are to have a corrosion protective coating, epoxy or equivalent, applied in accordance with the manufacturer's requirements.

1.2.2 Corrosion protection of spaces other than ballast spaces is not a Class requirement.

1.2.3 Narrow spaces are generally to be filled by an efficient protective product, particularly at the ends of the ship where inspections and maintenance are not easily practicable due to their inaccessibility. Other equivalent dispositions may be accepted, such as demonstrated air watertightness without painting.

2 Cathodic protection

2.1 General

2.1.1 Internal structures in spaces intended to carry liquids may be provided with cathodic protection.

Cathodic protection may be fitted in addition to the required corrosion protective coating, if any.

2.1.2 Details concerning the type of anodes used and their location and attachment to the structure are to be submitted to the Society for approval.

2.2 Anodes

2.2.1 Magnesium or magnesium alloy anodes are not permitted in oil cargo tanks.

2.2.2 Aluminium anodes are only permitted in cargo tanks of tankers in locations where the potential energy does not exceed 28 kg·m. The height of the anode is to be measured from the bottom of the tank to the centre of the anode, and its weight is to be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from this surface.

Aluminium anodes are not to be located under tank hatches or Butterworth openings, unless protected by the adjacent structure.

2.2.3 There is no restriction on the positioning of zinc anodes.

2.2.4 Anodes are to have steel cores and are to be declared by the Manufacturer as being sufficiently rigid to avoid resonance in the anode support and designed so that they retain the anode even when it is wasted.

2.2.5 The steel inserts are to be attached to the structure by means of a continuous weld. Alternatively, they may be attached to separate supports by bolting, provided a minimum of two bolts with lock nuts are used. However, other mechanical means of clamping may be accepted.

2.2.6 The supports at each end of an anode may not be attached to separate items which are likely to move independently.

2.2.7 Where anode inserts or supports are welded to the structure, they are to be arranged by the Shipyard so that the welds are clear of stress peaks.

2.3 Impressed current systems

2.3.1 Impressed current systems are not permitted in oil cargo tanks.

3 Protection against galvanic corrosion

3.1 General

3.1.1 Non-stainless steel is to be electrically insulated from stainless steel or from aluminium alloys.

3.1.2 Where stainless steel or aluminium alloys are fitted in the same tank as non-stainless steel, a protective coating is to cover both materials.

4 Protection of bottom by ceiling

4.1 General

4.1.1 In double bottom ships, ceiling is to be laid over the inner bottom and lateral bilges, if any.

Ceiling on the inner bottom is not required where the thickness of the inner bottom is increased in accordance with Ch 7, Sec 1, [2.3.1].

4.2 Arrangement

4.2.1 Planks forming ceiling over the bilges and on the inner bottom are to be easily removable to permit access for maintenance.

4.2.2 Where the double bottom is intended to carry fuel oil, ceiling on the inner bottom is to be separated from the plating by means of battens 30 mm high, in order to facilitate the drainage of oil leakages to the bilges.

4.2.3 Where the double bottom is intended to carry water, ceiling on the inner bottom may lie next to the plating, provided a suitable protective composition is applied beforehand.

4.2.4 The Shipyard is to take care that the attachment of ceiling does not affect the tightness of the inner bottom.

4.2.5 In single bottom ships, ceiling is to be fastened to the reversed frames by galvanized steel bolts or any other equivalent detachable connection.

A similar connection is to be adopted for ceiling over the lateral bilges in double bottom ships.

4.3 Scantlings

4.3.1 The thickness of ceiling boards, when made of pine, is to be not less than 60 mm. Under cargo hatchways, the thickness of ceiling is to be increased by 15 mm.

Where the floor spacing is large, the thicknesses may be considered by the Society on a case-by-case basis.

5 Protection of decks by wood sheathing

5.1 General

5.1.1 Where decks are intended to carry specific loads, such as caterpillar trucks and unusual vehicles, the Society may require such decks wood sheathed.

5.2 Arrangement

5.2.1 Wood sheathing is to be fixed to the plating by welded studs or bolts of at least 12 mm in diameter, every second frame.

5.2.2 Before fitting the wood sheathing, deck plates are to be provided with protective coating declared to be suitable by the Shipyard.

Caulking is the Shipyard's responsibility.

5.3 Scantlings

5.3.1 The thickness of wood sheathing of decks is to be not less than:

- 65 mm for wood sheathing made of pine
- 50 mm for wood sheathing made of hardwood, such as teak.

The width of planks is not to exceed twice their thickness.

Section 2 Loading Manual and Loading Instruments

1 Definitions

1.1 Perpendiculars

1.1.1 Forward perpendicular

The forward perpendicular is the perpendicular to the waterline at the forward side of the stem on the full load waterline.

1.1.2 After perpendicular

The after perpendicular is the perpendicular to the waterline at the after side of the rudder post on the full load waterline. For ships without rudder post, the after perpendicular is the perpendicular to the waterline at the centre of the rudder stock on the full load waterline.

1.1.3 Midship perpendicular

The midship perpendicular is the perpendicular to the waterline at half the distance between forward and after perpendiculars.

2 Loading manual and loading instrument requirement criteria

2.1 General

2.1.1 The loading instrument is ship specific onboard equipment and the results of the calculations are only applicable to the ship for which it has been approved.

An approved loading instrument may not replace an approved loading manual.

3 Loading manual

3.1 Definitions

3.1.1 A loading manual is a document which describes:

- the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force
- the results of the calculations of still water bending moments, shear forces and, where applicable, limitations due to torsional and lateral loads
- the allowable local loading for the structure (hatch covers, decks, double bottom, etc.).

3.2 Conditions of approval

3.2.1 The approved loading manual is to be based on the final data of the ship. The manual is to include the design (full load and operational) loading conditions, subdivided into departure and arrival conditions as appropriate, upon which the approval of the hull scantlings is based, defined in Ch 5, Sec 2, [2.1.2].

In the case of modifications resulting in changes to the main data of the ship, a new approved loading manual is to be issued.

3.2.2 Language

The loading manual is to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4 Loading instrument

4.1 Definitions

4.1.1 A loading instrument is an instrument which is either analog or digital and by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces and still water torsional moments and lateral loads, where applicable, in any load or ballast condition, do not exceed the specified permissible values.

An operational manual is always to be provided for the loading instrument.

Single point loading instruments are not acceptable.

4.2 Conditions of approval

4.2.1 The loading instrument is subject to approval, which is to include:

- verification of type approval, if any
- verification that the final data of the ship have been used
- acceptance of number and position of all read-out points
- acceptance of relevant limits for read-out points
- checking of proper installation and operation of the instrument on board, under agreed test conditions, and that a copy of the operation manual is available.

4.2.2 In the case of modifications implying changes in the main data of the ship, the loading instrument is to be modified accordingly and approved.

4.2.3 The operation manual and the instrument output are to be prepared in a language understood by the users. If this is not English, a translation into English is to be included.

4.2.4 The operation of the loading instrument is to be verified upon installation under the agreed test conditions. It is to be checked that the agreed test conditions and the operation manual for the instrument are available on board.

4.2.5 When the loading instrument also performs stability calculations, it is to be approved for stability purposes in accordance with the procedures indicated in [4.5] and [4.6], as applicable.

4.3 Approval procedure

4.3.1 General

The loading instrument approval process includes the following procedures for each ship:

- data verification which results in endorsed test conditions
- approval of computer hardware, where necessary, as specified in Pt C, Ch 3, Sec 6, [2.4]
- installation testing which results in an Installation Test Report.

4.3.2 Data verification approval - Endorsed test conditions

The Society is to verify the results and actual ship data used by the calculation program for the particular ship on which the program will be installed.

Upon application for data verification, the Society is to advise the applicant of a minimum of four loading conditions, taken from the ship approved loading manual, which are to be used as the test conditions. Within the range of these test conditions, each compartment is to be loaded at least once. The test conditions normally cover the range of load draughts from the deepest envisaged loaded condition to the light ballast condition. In addition, the lightship test condition is to be submitted.

When the loading instrument also performs stability calculations, the test conditions are to be taken from the ship approved trim and stability booklet.

The data indicated in [4.3.3] and contained in the loading program are to be consistent with the data specified in the approved loading manual. Particular attention is drawn to the final lightship weight and centres of gravity derived from the inclining experiment or lightweight check.

The approval of the computer application software is based on the acceptance of the results of the test conditions according to [4.4], [4.5] and [4.6] as applicable.

When the requested information has been submitted and the results of the test conditions are considered satisfactory, the Society endorses the test conditions, a copy of which is to be available on board.

4.3.3 Data to be submitted

The following data, submitted by the applicant, are to be consistent with the as-built ship:

- identification of the calculation program including the version number
- main dimensions, hydrostatic particulars and, if applicable, ship profile
- position of the forward and after perpendiculars and, if appropriate, the calculation method to derive the forward and after draughts at the actual position of the ship draught marks
- ship lightweight and lightweight distribution along the ship length
- lines plans and/or offset tables
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate
- deadweight definitions for each loading condition.

4.3.4 Installation testing

During the installation test, one of the ship senior officers is to operate the loading instrument and calculate the test conditions. This operation is to be witnessed by a Surveyor of the Society. The results obtained from the loading instrument are to be identical to those stated in the endorsed test conditions. If the numerical output from the loading instrument is different from the endorsed test conditions, no approval will be confirmed.

An installation test is also to be carried out on the second nominated computer, when applicable as indicated in Pt C, Ch 3, Sec 6, [2.4], which would be used in the event of failure of the first computer. Where the installation test is carried out on a type approved computer, a second nominated computer and test are not required.

Subject to the satisfactory completion of installation tests, the Society's Surveyor endorses the test conditions, adding details of the place and the date of the installation test survey, as well as the Society stamp and the Surveyor's signature.

4.3.5 Operational manual

A uniquely identified ship specific operational manual is to be submitted to the Society for documentation.

The operational manual is to be written in a concise and unambiguous manner. The use of illustrations and flowcharts is recommended.

The operational manual is to contain:

- a general description of the program denoting identification of the program and its stated version number
- details of the hardware specification needed to run the loading program
- a description of error messages and warnings likely to be encountered, and unambiguous instructions for subsequent actions to be taken by the user in each case
- where applicable, the shear force correction factors
- where applicable, the local permissible limits for single and two adjacent hold loadings as a function of the appropriate draught and the maximum weight for each hold
- where applicable, the Society's restrictions (maximum allowable load on double bottom, maximum specific gravity allowed in liquid cargo tanks, maximum filling level or percentage in liquid cargo tanks)
- example of a calculation procedure supported by illustrations and sample computer output
- example computer output of each screen display, complete with explanatory text.

4.3.6 Calculation program specifications

The software is to be written so as to ensure that the user cannot alter the critical ship data files containing the following information:

- lightship weight and lightship weight distribution and associated centres of gravity
- the Society's structural limitations or restrictions
- geometric hull form data
- hydrostatic data and cross curves, where applicable
- compartment definitions, including frame spacing and centre of volumes, together with capacity tables (sounding/ullage tables), if appropriate.

Any changes in the software are to be made by the manufacturer or his appointed representative and the Society is to be informed immediately of such changes. Failure to advise of any modifications to the calculation program may invalidate the approval issued. In cases where the approval is considered invalid by the Society, the modified calculation program is to be re-assessed in accordance with the approval procedure.

4.3.7 Functional specification

The calculation program is to be user-friendly and designed such that it limits possible input errors by the user.

The forward, midship and after draughts, at the respective perpendiculars, are to be calculated and presented to the user on screen and hardcopy output in a clear and unambiguous manner.

It is recommended that the forward, midship and after draughts, at the actual position of the ship draught marks are calculated and presented to the user on screen and hard copy output in a clear and unambiguous manner.

The displacement is to be calculated for the specified loading condition and corresponding draught readings and presented to the user on screen and hardcopy output.

The loading instrument is to be capable of producing print-outs of the results in both numerical and graphical forms. The numerical values are to be given in both forms, as absolute values and as the percentage of the permissible values. This print-out is to include a description of the corresponding loading condition.

All screen and hardcopy output data is to be presented in a clear and unambiguous manner with an identification of the calculation program (the version number is to be stated).

4.4 Hull girder forces and moments

4.4.1 General

The loading program is to be capable of calculating the following hull girder forces and moments in accordance with Ch 5, Sec 2, [2]:

- still water shear force (SWSF) including the shear force correction, where applicable
- still water bending moment (SWBM).

Table 1 : Data to be provided to (or accepted by) the Society

Calculation	Data
Still water shear force (SWSF)	• The read-out points (frame locations) for the SWSF calculations. These points are normally selected at the position of the transverse bulkhead or other obvious boundaries. Additional read-out points may be specified between the bulkheads of long holds or tanks or between container stacks • Shear force correction factors and method of application • The permissible seagoing and harbour SWSF limits at the read-out points. Where appropriate, additional sets of permissible SWSF values may be specified
Still water bending moment (SWBM)	• The read-out points (frame locations) for the SWBM calculations. These points are normally selected at the position of the transverse bulkhead, mid-hold or other obvious boundaries • The permissible seagoing and harbour SWBM limits at the read-out points. Where appropriate, additional sets of permissible SWBM values may be specified

The data which are to be provided to, or accepted by, the Society are specified in Tab 1.

Read-out points are usually to be selected at the position of the transverse bulkheads or other obvious boundaries.

The calculated forces and moments are to be displayed in both graphical and tabular formats, including the percentage of permissible values. The screen and hardcopy output is to display the calculated forces or moments, and the corresponding permissible limits, at each specified read-out point. Alternative limits may be considered by the Society on a case-by-case basis.

4.4.2 Acceptable tolerances

The accuracy of the calculation program is to be within the acceptable tolerance band, specified in Tab 2, of the results at each read-out point obtained by the Society, using an independent program or the approved loading manual with identical input.

Table 2 : Tolerance band for the comparison of computational accuracy

Computation	Tolerance (percentage of the permissible values)
Still water shear force	± 5%
Still water bending moment	± 5%

4.4.3 Permissible limits and restrictions

The user is to be able to view the following Society structural limitations in a clear and unambiguous manner:

- all permissible still water shear forces and still water bending moments
- cargo hold weight
- ballast tank/hold capacities
- filling restrictions.

It is to be readily apparent to the user when any of the structural limits has been exceeded.

4.5 Intact stability

4.5.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs stability calculations, as stated in [4.2.5].

4.5.2 Data verification approval - Endorsed test conditions

The requirements in [4.3.2] apply. In addition, at least one of the four loading conditions required is to show the compartments, intended for liquid loads in which the free surface effect is considerable, filled in order to have the maximum free surface moment.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.5.3].

In order to obtain the approval of the loading instrument, all the intact stability requirements (and relevant criteria) applicable to the ship, reported in Ch 3, Sec 2 as well as in [4.5.2], are to be available in the computer output; the lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.5.3 Additional data to be submitted

In addition to the data required in [4.3.3], the following are to be submitted:

- cross curves of stability calculated on a free trimming basis, for the ranges of displacement and trim anticipated in normal operating conditions, with indication of the volumes which have been considered in the computation of these curves
- capacity tables indicating, for each compartment or space, the values of the co-ordinates X_G, Y_G and Z_G of the centre of gravity, as well as the inertia, corresponding to an adequate number of filling percentages
- list of all the openings (location, tightness, means of closure), pipes or other sources which may lead to progressive flooding
- deadweight definitions for each loading condition in which, for any load taken into account, the following information is to be specified:
  - weight and centre of gravity co-ordinates
  - percentage of filling (if liquid load)
  - free surface moment (if liquid load)
- information on loading restrictions (maximum filling level or percentage in liquid cargo tanks, maximum KG or minimum GM curve or table which can be used to determine compliance with the applicable intact and damage stability criteria), when applicable
- all the intact stability criteria applicable to the ship concerned.

4.6 Damage stability

4.6.1 Application

The loading instrument approval for stability purposes is required when a loading instrument to be installed on board a ship performs damage stability calculations, as stated in [4.2.5].

In such case, the loading instrument is also to perform intact stability calculations, and therefore the approval is to be based on the requirements specified in [4.5].

Additional requirements relevant to damage stability are given in [4.6.2] and [4.6.3].

4.6.2 Data verification approval - Endorsed test conditions

The requirements specified in [4.5.2] apply.

The additional data necessary for the approval of the loading instrument for stability purposes are specified in [4.6.3].

The approval of damage stability calculations performed by a loading instrument is limited to those relevant to deterministic damage stability rules specified in Part D. In order to obtain the approval of the loading instrument, all the damage stability requirements (and relevant criteria) applicable to the ship are to be available in the computer output. The lack of any one of them is sufficient to prevent the endorsement of the test conditions.

4.6.3 Additional data to be submitted

In addition to the data required in [4.5.3], the following are to be submitted:

- list of all the damage cases which are to be considered in accordance with the relevant deterministic damage stability rules

  Each damage case is to clearly indicate all the compartments or spaces taken into account, as well as the permeability associated with each compartment or space.

  This information is to be taken from the approved damage stability documentation, and the source details are to be clearly indicated; in the case of unavailability of such documentation, the above-mentioned information may be requested from the Society.
- all the damage stability criteria applicable to the ship concerned.

Part B
Hull and Stability

CHAPTER 11
CONSTRUCTION AND TESTING

Section 1	Welding and Weld Connections
Section 2	Special Structural Details
Section 3	Testing
Appendix 1	Welding Details
Appendix 2	Reference Sheets for Special Structural Details

Section 1 Welding and Weld Connections

1 General

1.1 Application

1.1.1 The requirements of this Section apply for the preparation, execution and inspection of welded connections in hull structures.

They are to be complemented by the criteria given in Ch 11, App 1, to which reference is made. These criteria being given as recommendations, minor departures may be accepted by the Society, on a case-by-case basis.

The general requirements relevant to fabrication by welding and qualification of welding procedures are given in NR216 Materials and Welding, Chapter 5.

1.1.2 Weld connections are to be executed according to the approved plans. Any detail not specifically represented in the plans is, if any, to comply with the applicable requirements.

1.1.3 It is understood that welding of the various types of steel is to be carried out by means of welding procedures approved for the purpose, even though an explicit indication to this effect may not appear on the approved plans.

1.1.4 The quality standard adopted by the shipyard is to be submitted to the Society and applies to all constructions unless otherwise specified on a case-by-case basis.

1.2 Base material

1.2.1 The requirements of this Section apply for the welding of hull structural steels or aluminium alloys of the types considered in NR216 Materials and Welding, or other types accepted as equivalent by the Society.

1.2.2 The service temperature is intended to be the ambient temperature, unless otherwise stated.

1.3 Welding consumables and procedures

1.3.1 Approval of welding consumables and procedures

Welding consumables and welding procedures adopted are to be approved by the Society.

The requirements for the approval of welding consumables are given in NR216 Materials and Welding, Chapter 11.

The requirements for the approval of welding procedures are given in NR216 Materials and Welding, Chapter 12.

1.3.2 Consumables

For welding of hull structural steels, the minimum consumable grades to be adopted are specified in Tab 1 depending on the steel grade.

Consumables used for manual or semi-automatic welding (covered electrodes, flux-cored and flux-coated wires) of higher strength hull structural steels are to be at least of hydrogen-controlled grade H15 (H). Where the carbon equivalent C_{eq} is not more than 0,41% and the thickness is below 30 mm, any type of approved higher strength consumables may be used at the discretion of the Society.

Especially, welding consumables with hydrogen-controlled grade H15 (H) and H10 (HH) shall be used for welding hull steel forgings and castings of respectively ordinary strength level and higher strength level.

1.4 Personnel and equipment

1.4.1 Welders

Manual and semi-automatic welding is to be performed by welders certified by the Society as specified in the Rule Note NR476 Approval Testing of Welders. The welders are to be employed within the limits of their respective approval.

1.4.2 Automatic welding operators

Personnel manning automatic welding machines and equipment are to be competent and sufficiently trained.

1.4.3 Organisation

The internal organization of the shipyard is to be such as to ensure compliance in full with the requirements in [1.4.1] and [1.4.2] and to provide for assistance and inspection of welding personnel, as necessary, by means of a suitable number of competent supervisors.

Table 1 : Consumable grades

Steel grade	Consumable minimum grade	
	Butt welding, partial and full T penetration welding	Fillet welding
A	1	1
B - D	2	
E	3	
AH32 - AH36 DH32 - DH36	2Y	2Y
EH32 - EH36	3Y	
FH32 - FH36	4Y	
AH40	2Y40	2Y40
DH40 - EH40	3Y40	
FH40	4Y40	
Note 1: Welding consumables approved for welding higher strength steels (Y) may be used in lieu of those approved for welding normal strength steels having the same or a lower grade; welding consumables approved in grade Y40 may be used in lieu of those approved in grade Y having the same or a lower grade. **Note 2:** In the case of welded connections between two hull structural steels of different grades, as regards strength or notch toughness, welding consumables appropriate to one or the other steel are to be adopted.		

1.4.4 NDE operators

Non-destructive tests are to be carried out by qualified personnel, certified by the Society, or by recognized bodies in compliance with appropriate standards.

The qualifications are to be appropriate to the specific applications.

1.4.5 Technical equipment and facilities

The welding equipment is to be appropriate to the adopted welding procedures, of adequate output power and such as to provide for stability of the arc in the different welding positions.

In particular, the welding equipment for special welding procedures is to be provided with adequate and duly calibrated measuring instruments, enabling easy and accurate reading, and adequate devices for easy regulation and regular feed.

Manual electrodes, wires and fluxes are to be stored in suitable locations so as to ensuring their preservation in proper condition. Especially, where consumables with hydrogen-controlled grade are to be used, proper precautions are to be taken to ensure that manufacturer's instructions are followed to obtain (drying) and maintain (storage, maximum time exposed, re-backing, ...) hydrogen-controlled grade.

1.5 Documentation to be submitted

1.5.1 The structural plans to be submitted for approval, according to Ch 1, Sec 3, are to contain the necessary data relevant to the fabrication by welding of the structures and items represented as far as class is concerned.

For important structures, the main sequences of prefabrication, assembly and welding and non-destructive examination planned are also to be represented in the plans.

1.5.2 A plan showing the location of the various steel types is to be submitted at least for outer shell, deck and bulkhead structures.

1.6 Design

1.6.1 General

For the various structural details typical of welded construction in shipbuilding and not dealt with in this Section, the rules of good practice, recognized standards and past experience are to apply as agreed by the Society.

1.6.2 Plate orientation

The plates of the shell and strength deck are generally to be arranged with their length in the fore-aft direction. Possible exceptions to the above will be considered by the Society on a case-by-case basis; tests as deemed necessary (for example, transverse impact tests) may be required by the Society.

1.6.3 Overall arrangement

Particular consideration is to be given to the overall arrangement and structural details of highly stressed parts of the hull.

Drawings relevant to the special details specified in Ch 11, Sec 2 are to be submitted.

1.6.4 Prefabrication sequences

Prefabrication sequences are to be arranged so as to facilitate positioning and assembling as far as possible.

The amount of welding to be performed on board is to be limited to a minimum and restricted to easily accessible connections.

1.6.5 Distance between welds

Welds located too close to one another are to be avoided. The minimum distance between two adjacent welds is considered on a case-by-case basis, taking into account the level of stresses acting on the connected elements.

In general, the distance between two adjacent butts in the same strake of shell or deck plating is to be greater than two frame spaces.

2 Type of connections and preparation

2.1 General

2.1.1 The type of connection and the edge preparation are to be appropriate to the welding procedure adopted, the structural elements to be connected and the stresses to which they are subjected.

2.2 Butt welding

2.2.1 General

In general, butt connections of plating are to be full penetration, welded on both sides except where special procedures or specific techniques, considered equivalent by the Society, are adopted.

Connections different from the above may be accepted by the Society on a case-by-case basis; in such cases, the relevant detail and workmanship specifications are to be approved.

2.2.2 Welding of plates with different thicknesses

In the case of welding of plates with a difference in gross thickness equal to, or greater than:

- 3 mm, if the thinner plate has a gross thickness equal to, or less than, 10 mm
- 4 mm, if the thinner plate has a gross thickness greater than 10 mm,

a taper having a length of not less than 4 times the difference in gross thickness is to be adopted for connections of plating perpendicular to the direction of main stresses. For connections of plating parallel to the direction of main stresses, the taper length may be reduced to 3 times the difference in gross thickness.

When the difference in thickness is less than the above values, it may be accommodated in the weld transition between plates.

For large thicknesses (e.g. 25mm), other criteria may be considered on a case-by-case basis, when deemed equivalent.

2.2.3 Edge preparation, root gap

Typical edge preparations and gaps are indicated in Ch 11, App 1.

The acceptable root gap is to be in accordance with the adopted welding procedure and relevant bevel preparation.

2.2.4 Butt welding on permanent backing

Butt welding on permanent backing, i.e. butt welding assembly of two plates backed by the flange or the face plate of a stiffener, may be accepted where back welding is not feasible or in specific cases deemed acceptable by the Society.

The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the weld on its backing and an adequate connection to the stiffener as required.

2.2.5 Section, bulbs and flat bars

When lengths of longitudinals of the shell plating and strength deck within 0,6 L amidships, or elements in general subject to high stresses, are to be connected together by butt joints, these are to be full penetration. Other solutions may be adopted if deemed acceptable by the Society on a case-by-case basis.

The work is to be done in accordance with an approved procedure; in particular, this requirement applies to work done on board or in conditions of difficult access to the welded connection. Special measures may be required by the Society.

2.3 Fillet welding

2.3.1 General

In general, ordinary fillet welding (without bevel) may be adopted for T connections of the various simple and composite structural elements.

Where stress level is high or where there is a possibility of local laminations, partial or full T penetration welding according to [2.4] may be requested by the Society.

2.3.2 Fillet welding types

Fillet welding may be of the following types:

- continuous fillet welding, where the weld is constituted by a continuous fillet on each side of the abutting plate (see [2.3.3])
- intermittent fillet welding, which may be subdivided (see [2.3.4]) into:
  - chain welding
  - scallop welding
  - staggered welding.

2.3.3 Continuous fillet welding

Continuous fillet welding is to be adopted:

- for watertight connections
- for connections of brackets, lugs and scallops
- at the ends of connections for a length of at least 75 mm
- where intermittent welding is not allowed, according to [2.3.4].

Continuous fillet welding may also be adopted in lieu of intermittent welding wherever deemed suitable, and it is recommended where the spacing p, calculated according to [2.3.4], is low.

2.3.4 Intermittent welding

The spacing p and the length d, in mm, of an intermittent weld, shown in:

- Fig 1 for chain welding
- Fig 2 for scallop welding
- Fig 3 for staggered welding,

are to be such that:

$$\frac{p}{d} \leq \varphi$$

where the coefficient φ is defined in Tab 1 and Tab 2 for the different types of intermittent welding, depending on the type and location of the connection.

In general, staggered welding is not allowed for connections subjected to high alternate stresses.

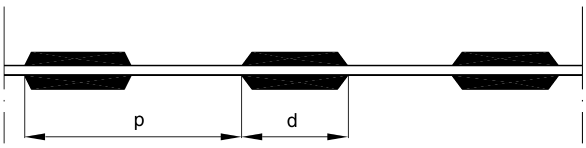
In addition, the following limitations are to be complied with:

- chain welding (see Fig 1):

  $d \geq 75$ mm

  $p - d \leq 200$ mm

Figure 1 : Intermittent chain welding



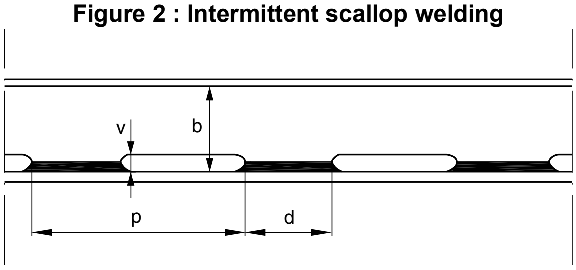
- scallop welding (see Fig 2):

  $d \geq 75$ mm

  $p - d \leq 150$ mm

  $v \leq 0,25\ b$, without being greater than 75 mm

Figure 2 : Intermittent scallop welding



- staggered welding (see Fig 3):

  $d \geq 75$ mm

  $p - 2d \leq 300$ mm

  $p \leq 2d$ for connections subjected to high alternate stresses.

Figure 3 : Intermittent staggered welding

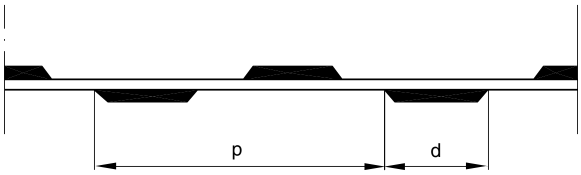


Table 2 : Welding factor w_F and coefficient φ for the various hull structural connections

Hull area	Connection			w_F **(1)**	φ**(2)(3)**			p_1, in mm (see [2.3.6])**(3)**
	of	to			CH	SC	ST	
General, unless otherwise specified in the table	watertight plates	boundaries		0,35				
	webs of ordinary stiffeners	plating		0,13	3,5	3,0	4,6	ST 260
		face plate of fabricated stiffeners	at ends**(4)**	0,13				
			elsewhere	0,13	3,5	3,0	4,6	ST 260
Bottom and double bottom	longitudinal ordinary stiffeners	bottom and inner bottom plating		0,13	3,5	3,0	4,6	ST 260
	centre girder	keel		0,25	1,8	1,8		CH/SC 130
		inner bottom plating		0,20	2,2	2,2		CH/SC 160
	side girders	bottom and inner bottom plating		0,13	3,5	3,0	4,6	ST 260
		floors (interrupted girders)		0,20	2,2			CH 160
	floors	bottom and inner bottom plating	in general	0,13	3,5	3,0	4,6	ST 260
			at ends (20% of span) for longitudinally framed double bottom	0,25	1,8			CH 130
		inner bottom plating in way of brackets of primary supporting members		0,25	1,8			CH 130
		girders (interrupted floors)		0,20	2,2			CH 160
		side girders in way of hopper tanks		0,35				
	partial side girders	floors		0,25	1,8			CH 130
	web stiffeners	floor and girder webs		0,13	3,5	3,0	4,6	ST 260
Side and inner side	ordinary stiffeners	side and inner side plating		0,13	3,5	3,0	4,6	ST 260
	girders in double side skin ships	side and inner side plating		0,35				
Deck	strength deck	side plating		Partial penetration welding				
	non-watertight decks	side plating		0,20	2,2			CH 160
	ordinary stiffeners and intercostal girders	deck plating		0,13	3,5	3,0	4,6	ST 260
	hatch coamings	deck plating	in general	0,35				
			at corners of hatchways for 15% of the hatch length	0,45				
	web stiffeners	coaming webs		0,13	3,5	3,0	4,6	ST 260

Hull area	Connection			w_F **(1)**	φ**(2)(3)**			p_1, in mm (see [2.3.6])**(3)**
	of	to			CH	SC	ST	
Bulkheads	tank bulkhead structures	tank bottom	plating and ordinary stiffeners (plane bulkheads)	0,45				
			vertical corrugations (corrugated bulkheads)	Full penetration welding, in general				
		boundaries other than tank bottom		0,35				
	watertight bulkhead structures	boundaries		0,35				
	non-watertight bulkhead structures	boundaries	wash bulkheads	0,20	2,2	2,2		CH/SC 160
			others	0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	bulkhead plating	in general **(5)**	0,13	3,5	3,0	4,6	ST 260
			at ends (25% of span), where no end brackets are fitted	0,35				
Structures located forward of 0,75 L from the AE **(6)**	bottom longitudinal ordinary stiffeners	bottom plating		0,20	2,2			CH 160
	floors and girders	bottom and inner bottom plating		0,25	1,8			CH 130
	side frames in panting area	side plating		0,20	2,2			CH 160
	webs of side girders in single side skin structures	side plating and face plate	$A < 65$ cm² **(7)**	0,25	1,8	1,8		CH/SC 130
			$A \geq 65$ cm² **(7)**	see Tab 3				
After peak **(6)**	internal structures	each other		0,20				
	side ordinary stiffeners	side plating		0,20				
	floors	bottom and inner bottom plating		0,20				
Machinery space **(6)**	centre girder	keel and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	side girders	bottom and inner bottom plating	in way of main engine foundations	0,45				
			in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors (except in way of main engine foundations)	bottom and inner bottom plating	in way of seating of auxiliary machinery and boilers	0,35				
			elsewhere	0,20	2,2	2,2		CH/SC 160
	floors in way of main engine foundations	bottom plating		0,35				
		foundation plates		0,45				
	floors	centre girder	single bottom	0,45				
			double bottom	0,25	1,8	1,8		CH/SC 130
Superstructures and deckhouses	external bulkheads	deck	in general	0,35				
			engine and boiler casings at corners of openings (15% of opening length)	0,45				
	internal bulkheads	deck		0,13	3,5	3,0	4,6	ST 260
	ordinary stiffeners	external and internal bulkhead plating		0,13	3,5	3,0	4,6	ST 260
Hatch covers	ordinary stiffener	plating		0,13	3,5	3,0	4,6	ST 260

Hull area	Connection of	Connection to		w_F **(1)**	φ**(2)(3)** CH	SC	ST	p_1, in mm (see [2.3.6])**(3)**
Pillars	elements composing the pillar section	each other (fabricated pillars)		0,13				
	pillars	deck	pillars in compression	0,35				
			pillars in tension	Full penetration welding				
Ventilators	coamings	deck		0,35				
Rudders	horizontal and vertical webs directly connected to solid parts	each other		0,45				
	other webs	each other		0,20		2,2		SC 160
	webs	plating	in general	0,20		2,2		SC 160
			top and bottom plates of rudder plating	0,35				
		solid parts or rudder stock		according to Ch 9, Sec 1, [7.4] or Ch 9, Sec 1, [7.5]				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted and continuous welding is to be adopted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) Ends of ordinary stiffeners means the area extended 75 mm from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 50 mm beyond the bracket toes.
(5) In tanks intended for the carriage of ballast or fresh water, continuous welding with $w_F = 0,35$ is to be adopted.
(6) For connections not mentioned, the requirements for the central part apply.
(7) A is the face plate sectional area of the side girders, in cm².

2.3.5 Throat thickness of fillet weld T connections

The throat thickness of fillet weld T connections is to be obtained, in mm, from the following formula:

$$t_T = w_F t \frac{p}{d}$$

where:

w_F : Welding factor, defined in Tab 2 for the various hull structural connections; for connections of primary supporting members belonging to single skin structures and not mentioned in Tab 2, w_F is defined in Tab 3

t : Actual gross thickness, in mm, of the structural element which constitutes the web of the T connection

p, d : Spacing and length, in mm, of an intermittent weld, defined in [2.3.4].

For continuous fillet welds, p/d is to be taken equal to 1.

In no case may the throat thickness be less than:

- 3,0 mm, where the gross thickness of the thinner plate is less than 6 mm
- 3,5 mm, otherwise.

The throat thickness may be required by the Society to be increased, depending on the results of structural analyses.

The leg length of fillet weld T connections is to be not less than 1,4 times the required throat thickness.

2.3.6 Weld dimensions in a specific case

Where intermittent fillet welding is adopted with:

- length d = 75 mm
- throat thickness t_T specified in Tab 4 depending on the thickness t defined in [2.3.5],

the weld spacing may be taken equal to the value p_1 defined in Tab 1. The values of p_1 in Tab 2 may be used when 8 mm ≤ t ≤ 16 mm.

For thicknesses t less than 8 mm, the values of p_1 may be increased, with respect to those in Tab 2, by:

- 10 mm, for chain or scallop welding
- 20 mm, for staggered welding,

without exceeding the limits given in [2.3.4].

For thicknesses t greater than 16 mm, the values of p_1 are to be reduced, with respect to those in Tab 2, by:

- 10 mm, for chain or scallop welding
- 20 mm, for staggered welding.

Table 3 : Welding factor w_F and coefficient φ for connections of primary supporting members

Primary supporting member	Connection of	Connection to		w_F **(1)**	φ **(2) (3)** CH	SC	ST	p_1, in mm (see [2.3.6])**(3)**
General**(4)**	web, where A < 65 cm²	plating and face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	web, where A ≥ 65 cm²	plating		0,35				
		face plate	at ends	0,35				
			elsewhere	0,25	1,8	1,8		CH/SC 130
	end brackets	face plate		0,35				
In tanks, where A < 65 cm² **(5)**	web	plating	at ends	0,25				
			elsewhere	0,20	2,2	2,2		CH/SC 160
		face plate	at ends	0,20				
			elsewhere	0,15	3,0	3,0		CH/SC 210
	end brackets	face plate		0,35				
In tanks, where A ≥ 65 cm²	web	plating	at ends	0,45				
			elsewhere	0,35				
		face plate		0,35				
	end brackets	face plate		0,45				

(1) In connections for which $w_F \geq 0,35$, continuous fillet welding is to be adopted.
(2) For coefficient φ, see [2.3.4]. In connections for which no φ value is specified for a certain type of intermittent welding, such type is not permitted.
(3) CH = chain welding, SC = scallop welding, ST = staggered welding.
(4) For cantilever deck beams, continuous welding is to be adopted.
(5) For primary supporting members in tanks intended for the carriage of ballast or fresh water, continuous welding is to be adopted.
Note 1: A is the face plate sectional area of the primary supporting member, in cm².
Note 2: Ends of primary supporting members means the area extended 20% of the span from the span ends. Where end brackets are fitted, ends means the area extended in way of brackets and at least 100 mm beyond the bracket toes.

Table 4 : Required throat thickness t_T

t, in mm	t_T, in mm	t, in mm	t_T, in mm
6	3,0	17	7,0
8	3,5	18	7,0
9	4,0	19	7,5
10	4,5	20	7,5
11	5,0	21	8,5
12	5,5	22	8,5
13	6,0	23	9,0
14	6,0	24	9,0
15	6,5	25	10,0
16	6,5	26	10,0

2.3.7 Throat thickness of welds between cut-outs

The throat thickness of the welds between the cut-outs in primary supporting member webs for the passage of ordinary stiffeners is to be not less than the value obtained, in mm, from the following formula:

$$t_{TC} = t_T \frac{\varepsilon}{\lambda}$$

where:

t_T : Throat thickness defined in [2.3.5]

ε, λ : Dimensions, in mm, to be taken as shown in:

- Fig 4, for continuous welding
- Fig 5, for intermittent scallop welding.

Figure 4 : Continuous fillet welding between cut-outs

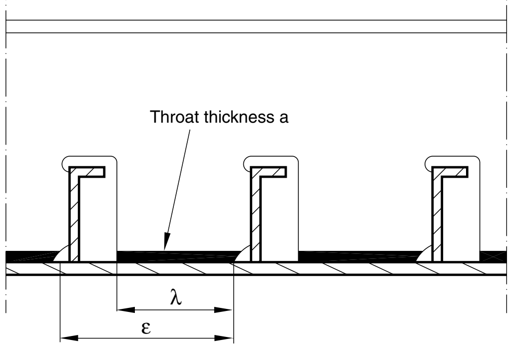
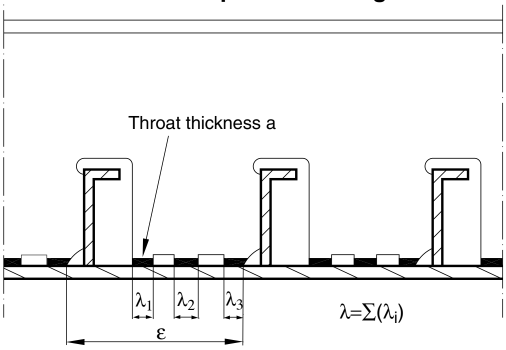


Figure 5 : Intermittent scallop fillet welding between cut-outs



2.3.8 Throat thickness of welds connecting ordinary stiffeners with primary supporting members

The throat thickness of fillet welds connecting ordinary stiffeners and collar plates, if any, to the web of primary supporting members is to be not less than $0,35t_W$, where t_W is the web gross thickness, in mm. Further requirements are specified in Ch 11, Sec 2.

Where primary supporting member web stiffeners are welded to ordinary stiffener face plates, in certain cases the Society may require the above throat thickness to be obtained, in mm, from the following formula:

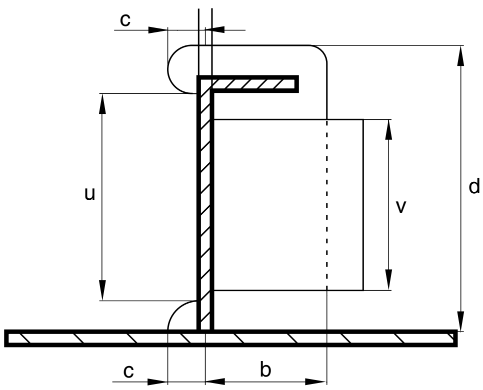
$$t_T = \frac{4(p_S + p_W)s\ell\left(1 - \frac{s}{2\ell}\right)}{u + v\left(\frac{c + 0,2d}{b + 0,2d}\right)}$$

where:

p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 7, Sec 2, [3.3.2]

b,c,d,u,v: Main dimensions, in mm, of the cut-out shown in Fig 6.

Figure 6 : End connection of ordinary stiffener - Dimensions of the cut-out



2.3.9 Throat thickness of deep penetration fillet welding

When fillet welding is carried out with automatic welding procedures, the throat thickness required in [2.3.5] may be reduced up to 15%, depending on the properties of the electrodes and consumables. However, this reduction may not be greater than 1,5 mm.

The same reduction applies also for semi-automatic procedures where the welding is carried out in the downhand position.

2.4 Partial and full T penetration welding

2.4.1 General

Partial or full T penetration welding is to be adopted for connections subjected to high stresses for which fillet welding is considered unacceptable by the Society.

Partial or full T penetration welding is required, depending on the ship type. Further requirements are specified in Ch 11, Sec 2.

Typical edge preparations are indicated in:

- for partial penetration welds: Fig 7 and Fig 8, in which f, in mm, is to be taken between 3 mm and t/3, and α between 45° and 60°
- for full penetration welds: Fig 9 and Fig 10, in which f, in mm, is to be taken between 0 and 3 mm, and α between 45° and 60°.

  Back gouging is generally required for full penetration welds.

2.4.2 Lamellar tearing

Precautions are to be taken in order to avoid lamellar tears, which may be associated with:

- cold cracking when performing T connections between plates of considerable thickness or high restraint
- large fillet welding and full penetration welding on higher strength steels.

Figure 7 : Partial penetration weld

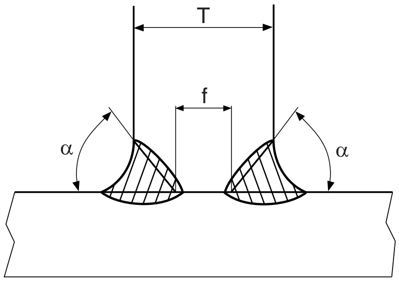


Figure 8 : Partial penetration weld

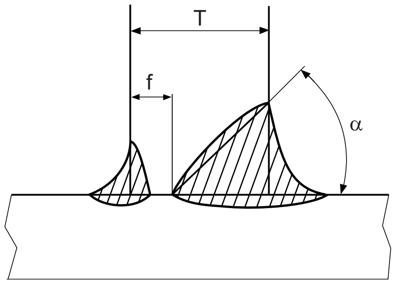


Figure 9 : Full penetration weld

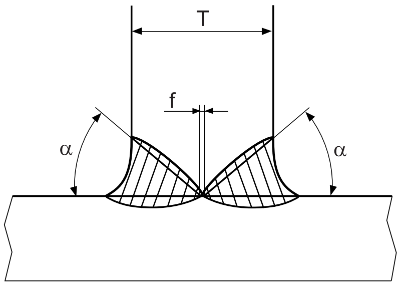
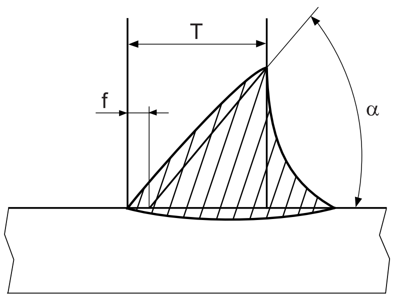


Figure 10 : Full penetration weld



2.5 Lap-joint welding

2.5.1 General

Lap-joint welding may be adopted for:

- peripheral connection of doublers
- internal structural elements subjected to very low stresses.

Elsewhere, lap-joint welding may be allowed by the Society on a case-by-case basis, if deemed necessary under specific conditions.

Continuous welding is generally to be adopted.

2.5.2 Gap

The surfaces of lap-joints are to be in sufficiently close contact.

2.5.3 Dimensions

The dimensions of the lap-joint are to be specified and are considered on a case-by-case basis. Typical details are given in Ch 11, App 1, [1.3].

2.6 Slot welding

2.6.1 General

Slot welding may be adopted in very specific cases subject to the special agreement of the Society, e.g. for doublers according to Ch 4, Sec 3, [2.1].

In general, slot welding of doublers on the outer shell and strength deck is not permitted within 0,6 L amidships. Beyond this zone, slot welding may be accepted by the Society on a case-by-case basis.

Slot welding is, in general, permitted only where stresses act in a predominant direction. Slot welds are, as far as possible, to be aligned in this direction.

2.6.2 Dimensions

Slot welds are to be of appropriate shape (in general oval) and dimensions, depending on the plate thickness, and may not be completely filled by the weld.

Typical dimensions of the slot weld and the throat thickness of the fillet weld are given in Ch 11, App 1.

The distance between two consecutive slot welds is to be not greater than a value which is defined on a case-by-case basis taking into account the:

- transverse spacing between adjacent slot weld lines
- stresses acting in the connected plates
- structural arrangement below the connected plates.

2.7 Plug welding

2.7.1 Plug welding may be adopted only when accepted by the Society on a case-by-case basis, according to specifically defined criteria. Typical details are given in Ch 11, App 1.

3 Specific weld connections

3.1 Corner joint welding

3.1.1 Corner joint welding, as adopted in some cases at the corners of tanks, performed with ordinary fillet welds, is permitted provided the welds are continuous and of the required size for the whole length on both sides of the joint.

3.1.2 Alternative solutions to corner joint welding may be considered by the Society on a case-by-case basis.

3.2 Bilge keel connection

3.2.1 Except where indicated, the following requirements apply to single web bilge keels. Additional requirements for other types of design will be considered on a case-by-case basis.

3.2.2 The ground bar is to be connected to the shell with a continuous fillet weld, and the bilge keel to the ground bar with a continuous fillet weld in accordance with Tab 5. Throat thicknesses differing from these values will be specially considered by the Society, if designed so that joints between the bilge keel and ground bar will fail before the joints between the ground bar and shell.

3.2.3 In the case of box type bilge keels, direct connection of members to the shell (i.e. without doublers) is to be by continuous full tee penetration welding. The type of bevel and the gap between the members to be assembled are to be such as to ensure a proper penetration of the welds.

3.2.4 Butt welds, in the bilge keel and ground bar, are to be well clear of each other and of butts in the shell plating as shown in Fig 11. In general, shell butts are to be flush in way of the ground bar and ground bar butts are to be flush in way of the bilge keel. Direct connection between ground bar butt welds and shell plating is not permitted. This may be obtained by use of removable backing.

In the case of box type bilge keels, the butt welds in longitudinal members of the bilge keel are to be shifted from the shell butts.

3.2.5 At the ends of the ground bar, the throat thickness is to be increased as given in Tab 5, without exceeding 0,707 times the as-built thickness of the ground bar as shown in Fig 11. The welded transition at the ends of the ground bar to the plating connection should be formed with the weld flank angle of 45° or less.

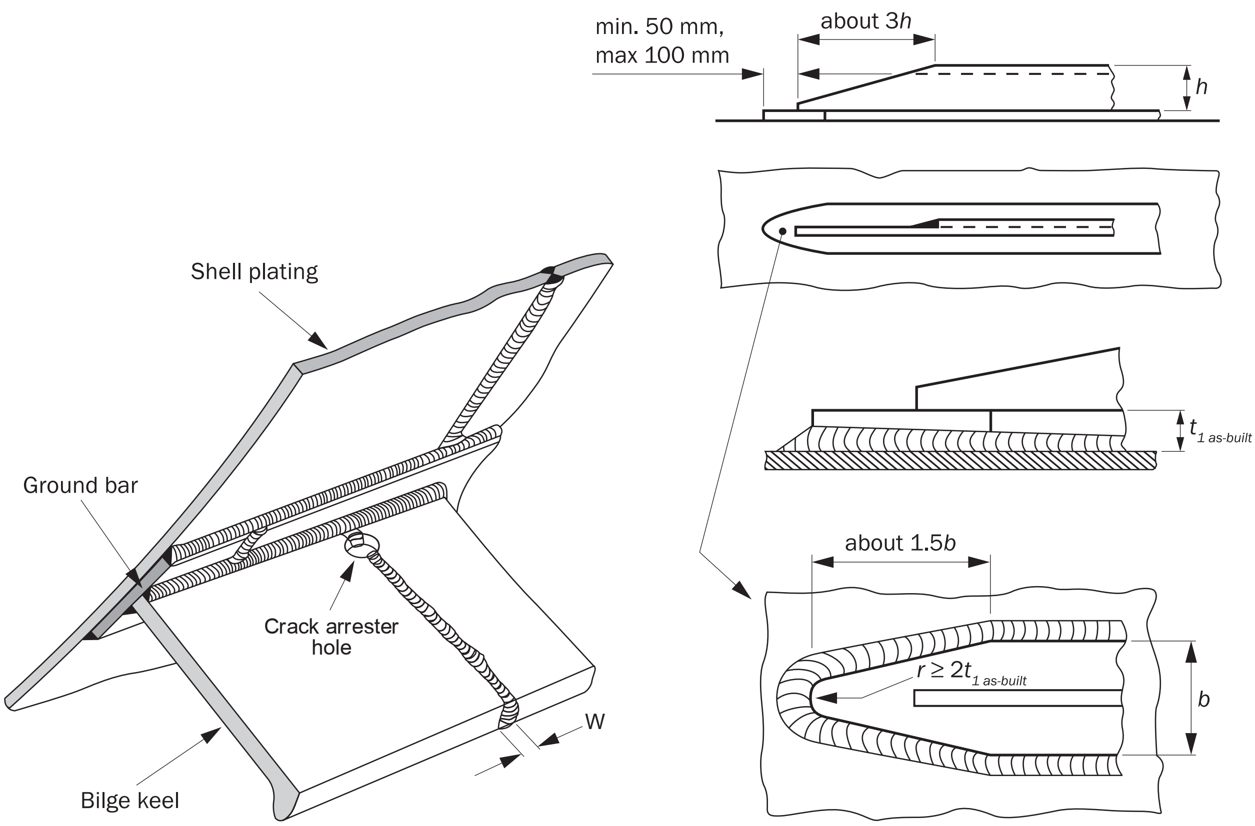
3.2.6 In general, scallops and cut-outs are not to be used in single web bilge keels. Crack arresting holes are to be drilled in the bilge keel butt welds as close as practicable to the ground bar. The diameter of the hole is to be greater than the width W of the butt weld and is to be a minimum of 25 mm. Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

Table 5 : Connections of single web bilge keels

Structural items being joined	Throat thickness of weld, in mm	
	At ends **(1)**	Elsewhere
Ground bar to the shell	0,44 $t_{1as\text{-}built}$	0,34 $t_{1as\text{-}built}$
Bilge keel web to ground bar	0,34 $t_{2as\text{-}built}$	0,21 $t_{2as\text{-}built}$

$t_{1as\text{-}built}$: As-built thickness of ground bar, in mm
$t_{2as\text{-}built}$: As-built thickness of web of bilge keel, in mm.
(1) Zone “b” in Ch 4, Sec 4, Fig 3 and Ch 4, Sec 4, Fig 4 for definition of “ends”

Figure 11 : Connections of single web bilge keels



3.3 Connection between propeller post and propeller shaft bossing

3.3.1 Fabricated propeller posts are to be welded with full penetration welding to the propeller shaft bossing.

3.4 Bar stem connection

3.4.1 The bar stem is to be welded to the bar keel generally with butt welding.

The shell plating is also to be welded directly to the bar stem with butt welding.

4 Workmanship

4.1 Welding procedures and consumables

4.1.1 The various welding procedures and consumables are to be used within the limits of their approval and in accordance with the conditions of use specified in the respective approval documents.

4.2 Welding operations

4.2.1 Weather protection

Adequate protection from the weather is to be provided to parts being welded; in any event, such parts are to be dry.

In welding procedures using bare, cored or coated wires with gas shielding, the welding is to be carried out in weather protected conditions, so as to ensure that the gas outflow from the nozzle is not disturbed by winds and draughts.

4.2.2 Butt connection edge preparation

The edge preparation is to be of the required geometry and correctly performed. In particular, if edge preparation is carried out by flame, it is to be free from cracks or other detrimental notches.

Recommendations for edge preparation are given in the "Guide for welding".

4.2.3 Surface condition

The surfaces to be welded are to be free from rust, moisture and other substances, such as mill scale, slag caused by oxygen cutting, grease or paint, which may produce defects in the welds.

Effective means of cleaning are to be adopted particularly in connections with special welding procedures; flame or mechanical cleaning may be required.

The presence of a shop primer may be accepted, provided it has been approved by the Society.

Shop primers are to be approved by the Society for a specific type and thickness according to NR216 Materials and Welding, Ch 5, Sec 3.

4.2.4 Assembling and gap

The setting appliances and system to be used for positioning are to ensure adequate tightening adjustment and an appropriate gap of the parts to be welded, while allowing maximum freedom for shrinkage to prevent cracks or other defects due to excessive restraint.

The gap between the edges is to comply with the required tolerances or, when not specified, it is to be in accordance with normal good practice.

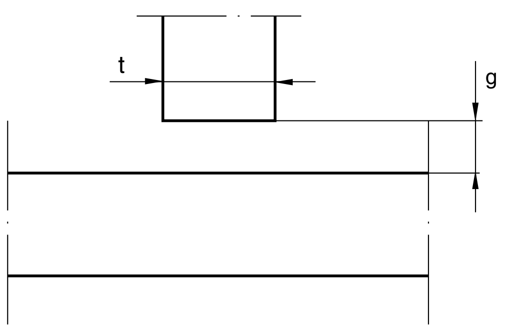
4.2.5 Gap in fillet weld T connections

In fillet weld T connections, a gap g, as shown in Fig 12, not greater than 2 mm may be accepted without increasing the throat thickness calculated according to [2.3.5] to [2.3.9], as applicable.

In the case of a gap greater than 2 mm, the above throat thickness is to be increased accordingly as specified in Ch 11, Sec 2 for some special connections of various ship types.

In any event, the gap g may not exceed 4 mm.

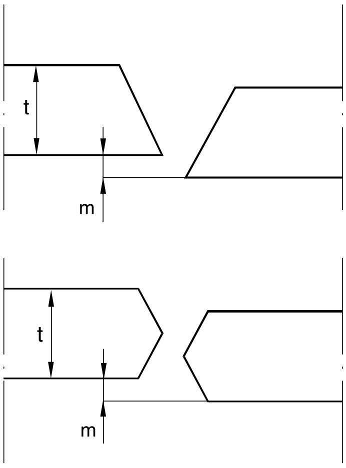
Figure 12 : Gap in fillet weld T connections



4.2.6 Plate misalignment in butt connections

The misalignment m, measured as shown in Fig 13, between plates with the same gross thickness t is to be less than 0,15 t, without being greater than 3 mm.

Figure 13 : Plate misalignment in butt connections



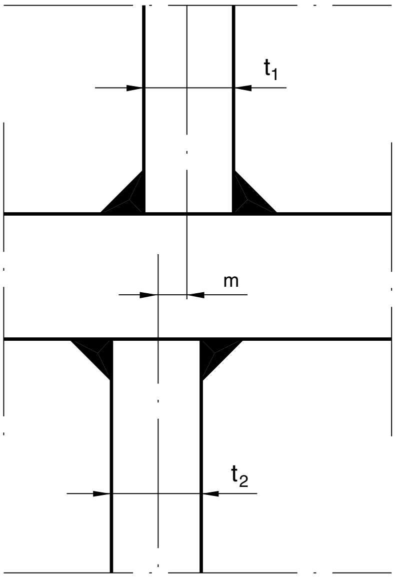
4.2.7 Misalignment in cruciform connections

The misalignment m in cruciform connections, measured on the median lines as shown in Fig 14, is to be less than:

- t/2, in general, where t is the gross thickness of the thinner abutting plate
- the values specified in Ch 11, Sec 2 for some special connections of various ship types.

The Society may require lower misalignment to be adopted for cruciform connections subjected to high stresses.

Figure 14 : Misalignment in cruciform connections



4.2.8 Assembling of aluminium alloy parts

When welding aluminium alloy parts, particular care is to be taken so as to:

- reduce as far as possible restraint from welding shrinkage, by adopting assembling and tack welding procedures suitable for this purpose
- keep possible deformations within the allowable limits.

4.2.9 Preheating and interpass temperatures

Suitable preheating, to be maintained during welding, and slow cooling may be required by the Society on a case-by-case basis.

4.2.10 Welding sequences

Welding sequences and direction of welding are to be determined so as to minimize deformations and prevent defects in the welded connection.

All main connections are generally to be completed before the ship is afloat.

Departures from the above provision may be accepted by the Society on a case-by-case basis, taking into account any detailed information on the size and position of welds and the stresses of the zones concerned, both during ship launching and with the ship afloat.

4.2.11 Interpass cleaning

After each run, the slag is to be removed by means of a chipping hammer and a metal brush; the same precaution is to be taken when an interrupted weld is resumed or two welds are to be connected.

4.2.12 Stress relieving

It is recommended and in some cases it may be required that special structures subject to high stresses, having complex shapes and involving welding of elements of considerable thickness (such as rudder spades and stern frames), are prefabricated in parts of adequate size and stress-relieved in the furnace, before final assembly, at a temperature within the range 550°C ÷ 620°C, as appropriate for the type of steel. Concerned structures are agreed on case-by-case basis.

4.3 Crossing of structural elements

4.3.1 In the case of T crossing of structural elements (one element continuous, the other physically interrupted at the crossing) when it is essential to achieve structural continuity through the continuous element (continuity obtained by means of the welded connections at the crossing), particular care is to be devoted to obtaining the correspondence of the interrupted elements on both sides of the continuous element. Suitable systems for checking such correspondence are to be adopted.

5 Modifications and repairs during construction

5.1 General

5.1.1 Deviations in the joint preparation and other specified requirements, in excess of the permitted tolerances and found during construction, are to be repaired as agreed with the Society on a case-by-case basis.

5.2 Gap and weld deformations

5.2.1 Welding by building up of gaps exceeding the required values and repairs of weld deformations may be accepted by the Society upon special examination.

5.3 Defects

5.3.1 Defects and imperfections on the materials and welded connections found during construction are to be evaluated for possible acceptance on the basis of the applicable requirements of the Society.

Where the limits of acceptance are exceeded, the defective material and welds are to be discarded or repaired, as deemed appropriate by the Surveyor on a case-by-case basis.

When any serious or systematic defect is detected either in the welded connections or in the base material, the manufacturer is required to promptly inform the Surveyor and submit the repair proposal.

The Surveyor may require destructive or non-destructive examinations to be carried out for initial identification of the defects found and, in the event that repairs are undertaken, for verification of their satisfactory completion.

5.4 Repairs on structures already welded

5.4.1 In the case of repairs involving the replacement of material already welded on the hull, the procedures to be adopted are to be agreed with the Society on a case-by-case basis.

6 Inspections and checks

6.1 General

6.1.1 Materials, workmanship, structures and welded connections are to be subjected, at the beginning of the work, during construction and after completion, to inspections by the Shipbuilder suitable to check compliance with the applicable requirements, approved plans and standards.

6.1.2 The Shipbuilder is to make available to the Surveyor a list of the manual welders and welding operators and their respective qualifications.

The Shipbuilder's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective valid qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

6.1.3 The Shipbuilder is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognised good welding practice.

6.1.4 The Shipbuilder is responsible for ensuring that non-destructive examination (NDE) procedures and plans are adhered to during the construction and that NDE reports are made available to the Society.

6.2 Non-destructive examination (NDE)

6.2.1 Non-destructive examination techniques refer to the testing methods applicable to the detection of surface imperfections (Visual Testing, Magnetic particle Testing, Liquid penetrant Testing) or sub-surface imperfections (Ultrasonic Testing, Radiographic Testing).

6.2.2 NDE of hull welds are to be performed in accordance with written procedures accepted by the Society. Such procedures are to contain appropriate details about the applied codes or standards, testing method, equipment, calibration, testing conditions and personnel qualification. For each NDE technique, appropriate details means typically the details described in IACS Recommendation 20.

6.2.3 The NDE acceptance criteria defined by the Shipbuilder are to be submitted to the Society and should comply with the IACS Recommendation 20 or with a recognized standard which has been accepted by the Society.

Where applicable, specific criteria defined in Ch 11, Sec 2, for special structural details are to be referred to.

6.2.4 All finished welds are to be subjected to visual testing by the Shipbuilder's qualified personnel.

6.2.5 After completion of the welding operation and workshop inspection, the structure is to be presented to the Surveyor for general visual examination at a suitable stage of fabrication.

As far as possible, the results on non-destructive examinations are to be submitted.

6.2.6 Radiographic testing is to be carried out on the welded connections of the hull in accordance with [6.3]. The results are to be made available to the Society. The Surveyor may require to witness some testing preparations.

6.2.7 The Society may accept radiographic testing to be replaced by ultrasonic testing.

6.2.8 The Shipbuilder's NDE plan describing the extent, type and location of NDE is to be submitted to the Society for acceptance.

6.2.9 When the non-destructive examinations reveal the presence of unacceptable indications, the relevant connection is to be repaired to an extent and according to a procedure agreed with the Surveyor.

The repaired zone is then to be submitted to non-destructive examination, using a method deemed suitable by the Surveyor to verify that the repair is satisfactory.

Additional examinations may be required by the Surveyor on a case-by-case basis.

6.2.10 Ultrasonic and magnetic particle testing may also be required by the Surveyor in specific cases to check the base material.

6.3 Radiographic testing

6.3.1 Radiographic testing is to be carried out on the welded butts of shell plating, strength deck plating as well as of members contributing to the longitudinal strength.

Radiographic Testing may also be required for the joints of members subject to heavy stresses.

The requirements [6.3.2] to [6.3.5] constitute general rules: the number of radiographs may be increased where requested by the Surveyor, mainly where visual inspection or radiographic soundings have revealed major defects, specially for butts of sheerstrake, stringer plate, bilge strake or keel plate.

Provisions alteration to these rules may be accepted by the Society when justified by the organisation of the Shipbuilder or of the inspection department. The inspection is then to be equivalent to that deduced from [6.3.2] to [6.3.5].

6.3.2 As far as automatic welding of the panels butt welds during the premanufacturing stage is concerned, the Shipbuilder is to carry out random non-destructive testing of the welds (radiographic or ultrasonic testing) in order to ascertain the regularity and the constancy of the welding inspection.

6.3.3 In the midship area, radiographies are to be taken at the joinings of panels.

Each radiography is situated in a butt joint at a cross-shaped welding.

In a given ship cross-section bounded by the panels, a radiography is to be made of each butt of sheerstrake, stringer, bilge and keel plate; in addition, the following radiographies are to be taken:

- bottom plating: two
- deck plating: two
- side shell plating: two on each side.

For ships where $B + D \leq 15$ m, only one radiography for each of the above items is required.

This requirement remains applicable where panel butts are shifted or where some strakes are built independently from the panels. It is recommended to take most of these radiographies at the intersections of butt and panel seams.

Still in the midship area, radiographic testing is to be carried out, at random, of the following main members of the structure:

- butts of continuous longitudinal bulkheads
- butts of longitudinal stiffeners, deck and bottom girders contributing to the overall strength
- assembly joints of insert plates at the corners of the openings.

Moreover, radiographic testing is to be carried out, at random, of the weldings of the bilge keel and of intermediate flat.

6.3.4 Outwards the midship area, a programme of radiographic testing at random is to be set up by the Shipbuilder in agreement with the Surveyor for the major points. It is further recommended to take:

- a number of radiographies of the very thick parts and those comprising restrained joint, such as sternframes, shaft brackets, stabiliser recesses, masts
- a complete set of radiographies or to increase the number of radiographies for the first joint of a series of identical joints. This recommendation is applicable not only to the assembly joints of prefabricated members completed on the slip, but also to joints completed in the workshop to prepare such prefabricated members.

6.3.5 Where a radiography is rejected and where it is decided to carry out a repair, the Shipbuilder is to determine the length of the defective part, then a set of radiographies of the repaired joint and of adjacent parts is to be taken. Where the repair has been decided by the inspection office of the Shipbuilder, the film showing the initial defect is to be submitted to the Surveyor together with the film taken after repair of the joint.

Section 2 Special Structural Details

Symbols

T_B : Ship draught in light ballast condition, see Ch 5, Sec 1, [2.4.3].

1 General

1.1 Application

1.1.1 Special structural details are those characterized by complex geometry, possibly associated with high or alternate stresses.

1.1.2 For special structural details, specific requirements are to be fulfilled during:

- design
- construction
- selection of materials
- welding
- survey.

The purpose of these requirements is specified in [1.2] to [1.6].

1.1.3 Special structural details are those listed in Article [2] together with the specific requirements which are to be fulfilled.

Other structural details may be considered by the Society as special details, when deemed necessary on the basis of the criteria in [1.1.1]. The criteria to be fulfilled in such cases are defined by the Society on a case-by-case basis.

1.1.4 As regards matters not explicitly specified in Article [2], the rule requirements are to be complied with in any event, in particular:

- Part B, Chapter 4 for design principles and structural arrangements
- Part B, Chapter 7 for structural scantling
- Part B, Chapter 11 for construction and welding requirements
- the applicable requirements in Part D and Part E.

1.2 Design requirements

1.2.1 General requirements

Design requirements specify:

- the local geometry, dimensions and scantlings of the structural elements which constitute the detail
- any local strengthening
- the cases where a fatigue check is to be carried out according to Ch 7, Sec 4.

1.2.2 Fatigue check requirements

Where a fatigue check is to be carried out, the design requirements specify (see Ch 7, Sec 4, [1.1]):

- the locations (hot spots) where the stresses are to be calculated and the fatigue check performed
- the direction in which the normal stresses are to be calculated
- the stress concentration factors K_h and $K\ell$ to be used for calculating the hot spot stress range.

1.3 Constructional requirements

1.3.1 Constructional requirements specify the allowable misalignment and tolerances, depending on the detail arrangement and any local strengthening.

1.4 Material requirements

1.4.1 Material requirements specify the material quality to be used for specific elements which constitute the detail, depending on their manufacturing procedure, the type of stresses they are subjected to, and the importance of the detail with respect to the ship operation and overall safety.

In addition, these requirements specify where material inspections are to be carried out.

1.5 Welding requirements

1.5.1 Welding requirements specify where partial or full T penetration welding (see Ch 11, Sec 1, [2.4]) or any particular welding type or sequence is to be adopted. In addition, these requirements specify when welding procedures are to be approved.

Since weld shape and undercuts are influencing factors on fatigue behaviour, fillet welds are to be elongated in the direction of the highest stresses and care is to be taken to avoid undercuts, in particular at the hot spots.

1.6 Survey requirements

1.6.1 Survey requirements specify where non-destructive examinations of welds are to be carried out and, where this is the case, which type is to be adopted.

2 List and characteristics of special structural details

2.1 General

2.1.1 This Article lists and describes, depending on the ship type, the special structural details and specifies the specific requirements which are to be fulfilled according to [1.2] to [1.6]. This is obtained through:

- a description of the hull areas where the details are located
- the detail description
- the requirements for the fatigue check
- a reference to a sheet in the Appendixes where a picture of the detail is shown together with the specific requirements which are to be fulfilled.

2.1.2 The special structural details relevant to all types of longitudinally framed ships are listed and described in Tab 1.

Table 1 : Special structural details

Area reference number	Area description	Detail description	Fatigue check	Reference tables in Ch 11, App 2
1	Part of side extended: • longitudinally, between the after peak bulkhead and the collision bulkhead • vertically, between 0,7 T_B and 1,15 T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members	No	Ch 11, App 2, Tab 1 to Ch 11, App 2, Tab 6
		Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members, or transverse bulkheads	for $L \geq 90$ m	Ch 11, App 2, Tab 7 to Ch 11, App 2, Tab 13
2	Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors	for $L \geq 90$ m	Ch 11, App 2, Tab 14 to Ch 11, App 2, Tab 17
3	Hatch corners	Deck plating in way of hatch corners	No	Ch 11, App 2, Tab 18
		Ends of longitudinal hatch coamings	No	Ch 11, App 2, Tab 19 and Ch 11, App 2, Tab 20

Section 3 Testing

1 Pressure tests

1.1 Application

1.1.1 The following requirements determine the testing conditions for:

- gravity tanks, excluding independent tanks of less than 5m^3 in capacity
- watertight or weathertight structures.

The purpose of these tests is to check the tightness and/or the strength of structural elements.

1.1.2 Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion so that any subsequent work would not impair the strength and tightness of the structure.

In particular, tests are to be carried out after air vents and sounding pipes are fitted.

When tests are performed before final air vents and sounding pipes are fitted, temporary air vents and sounding pipes may be accepted, provided they are deemed equivalent by the Surveyor.

1.1.3 The Society may accept that structural testing of a sister ship is limited to a single tank for each type of structural arrangement.

However, if the Surveyor detects anomalies, he may require the number of tests is increased or that the same number of tests is provided as for the first ship in a series.

1.2 Definitions

1.2.1 Shop primer

Shop primer is a thin coating applied after surface preparation and prior to fabrication as a protection against corrosion during fabrication.

1.2.2 Protective coating

Protective coating is a final coating protecting the structure from corrosion.

1.2.3 Structural testing

Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of the tank), hydropneumatic testing may be carried out instead.

Structural testing is to be carried out according to [2.2].

1.2.4 Hydropneumatic testing

Hydropneumatic testing is a combination of hydrostatic and air testing, consisting in filling the tank to the top with water and applying an additional air pressure.

Hydropneumatic testing is to be carried out according to [2.3].

1.2.5 Leak testing

Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

Leak testing is to be carried out according to [2.4].

1.2.6 Hose testing

Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing and of other components which contribute to the watertight or weathertight integrity of the hull.

Hose testing is to be carried out according to [2.5].

1.2.7 Sister ship

A sister ship is a ship having the same main dimensions, general arrangement, capacity plan and structural design as those of the first ship in a series.

2 Watertight compartments

2.1 General

2.1.1 The requirements in [2.1] to [2.6] intend generally to verify the adequacy of the structural design of the tanks, based on the loading conditions which prevailed when determining the tank structure scantlings.

2.1.2 General requirements for testing of watertight compartments are given in Tab 1, in which the types of testing referred to are defined in [1.2].

2.2 Structural testing

2.2.1 Structural testing may be carried out before or after launching.

2.2.2 Structural testing may be carried out after application of the shop primer.

2.2.3 Structural testing may be carried out after the protective coating has been applied, provided that one of the following two conditions is satisfied:

- all the welds are completed and carefully inspected visually to the satisfaction of the Surveyor prior to the application of the protective coating
- leak testing is carried out prior to the application of the protective coating.

In the absence of leak testing, protective coating is to be applied after the structural testing of:

- all erection welds, both manual and automatic
- all manual fillet weld connections on tank boundaries and manual penetration welds.

2.3 Hydropneumatic testing

2.3.1 When a hydropneumatic testing is performed, the conditions are to simulate, as far as practicable, the actual loading of the tank.

The value of the additional air pressure is at the discretion of the Society, but is to be at least as defined in [2.4.2] for leak testing.

The same safety precautions as for leak testing (see [2.4.2]) are to be adopted.

2.4 Leak testing

2.4.1 An efficient indicating liquid, such as a soapy water solution, is to be applied to the welds.

2.4.2 Where leak testing is carried out, in accordance with Tab 1, an air pressure of $0,15 \cdot 10^5$ Pa is to be applied during the test.

Prior to inspection, it is recommended that the air pressure in the tank should be raised to $0,2 \cdot 10^5$ Pa and kept at this level for approximately 1 hour to reach a stabilized state, with a minimum number of personnel in the vicinity of the tank, and then lowered to the test pressure.

The test may be conducted after the pressure has reached a stabilized state at $0,2 \cdot 10^5$ Pa, without lowering the pressure, provided the Society is satisfied of the safety of the personnel involved in the test.

2.4.3 A U-tube filled with water up to a height corresponding to the test pressure is to be fitted to avoid overpressure of the compartment tested and verify the test pressure.

The U-tube is to have a cross-section larger than that of the pipe supplying air.

In addition, the test pressure is also to be verified by means of one master pressure gauge.

Alternative means which are considered to be equivalently reliable may be accepted at the discretion of the Surveyor.

2.4.4 Leak testing is to be carried out, prior to the application of a protective coating, on all fillet weld connections on tank boundaries, and penetration and erection welds on tank boundaries excepting welds made by automatic processes.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may be required to be similarly tested to the satisfaction of the Surveyor, taking account of the quality control procedures operating in the shipyard.

For other welds, leak testing may be carried out after the protective coating has been applied, provided that such welds have been carefully inspected visually to the satisfaction of the Surveyor.

2.4.5 Any other recognized method may be accepted to the satisfaction of the Surveyor.

2.5 Hose testing

2.5.1 When hose testing is required to verify the tightness of the structures, as defined in Tab 1, the minimum pressure in the hose, at least equal to $2,0 \cdot 10^5$ Pa, is to be applied at a maximum distance of 1,5 m.

The nozzle diameter is to be not less than 12 mm.

Table 1 : Watertight compartments - General testing requirements

<table>
<tr><th>Compartment or structure to be tested</th><th>Type of testing</th><th>Structural test pressure</th><th>Remarks</th></tr>
<tr><td>Double bottom tanks</td><td>Structural (1)</td><td>The greater of the following:
• head of water up to the top of overflow
• head of water up to the margin line</td><td>Tank boundaries tested from at least one side</td></tr>
<tr><td>Double side tanks</td><td>Structural (1)</td><td>The greater of the following:
• head of water up to the top of overflow
• 2,4 m head of water above highest point of tank (5)</td><td>Tank boundaries tested from at least one side</td></tr>
<tr><td>Tank bulkheads, deep tanks</td><td>Structural (1)</td><td rowspan="2">The greater of the following (2):
• head of water up to the top of overflow
• 2,4 m head of water above highest point of tank (5)
• setting pressure of the safety relief valves, where relevant</td><td rowspan="2">Tank boundaries tested from at least one side</td></tr>
<tr><td>Fuel oil bunkers</td><td>Structural</td></tr>
<tr><td>Fore and after peaks used as tank</td><td>Structural</td><td>The greater of the following:
• head of water up to the top of overflow
• 2,4 m head of water above highest point of tank (5)</td><td>Test of the after peak carried out after the sterntube has been fitted</td></tr>
<tr><td>Fore peak not used as tank</td><td>Structural</td><td>The greater of the following:
• maximum head of water to be sustained in the event of damage
• head of water up to the margin line</td><td></td></tr>
<tr><td>After peak not used as tank</td><td>Leak</td><td></td><td></td></tr>
<tr><td>Cofferdams</td><td>Structural (3)</td><td>The greater of the following:
• head of water up to the top of overflow
• 2,4 m head of water above highest point of tank (5)</td><td></td></tr>
<tr><td>Watertight bulkheads</td><td>Hose (4)</td><td></td><td></td></tr>
<tr><td>Watertight doors below the watertight or bulkhead deck (5)</td><td>Structural</td><td>Head of water up to the bulkhead deck</td><td>Test to be carried out before the ship is put into service, either before or after the door is fitted on board</td></tr>
<tr><td>Watertight hatch covers and closing appliances (5) (6)</td><td>Leak and structural</td><td>Damage equilibrium waterline (see Ch 8, Sec 7, [10])</td><td></td></tr>
<tr><td>Double plate rudders</td><td>Leak</td><td></td><td></td></tr>
<tr><td>Shaft tunnel clear of deep tanks</td><td>Hose</td><td></td><td></td></tr>
<tr><td>Shell doors</td><td>Hose</td><td></td><td></td></tr>
<tr><td>Weathertight hatch covers and closing appliances</td><td>Hose</td><td></td><td></td></tr>
<tr><td>Chain locker (if aft of collision bulkhead)</td><td>Structural</td><td>Head of water up to the top</td><td></td></tr>
<tr><td>Independent tanks</td><td>Structural</td><td>Head of water up to the top of overflow, but not less than 0,90 m</td><td></td></tr>
<tr><td>Ballast ducts</td><td>Structural</td><td>Ballast pump maximum pressure</td><td></td></tr>
</table>

(1) Hydropneumatic or leak testing may be accepted under the conditions specified in [2.3] and [2.4], respectively, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. In general, structural testing need not be repeated for subsequent ships of a series of identical new buildings. If the structural test reveals weakness or severe faults not detected by the leak test, all tanks are to be structurally tested.
(2) Where applicable, the highest point of the tank is to be measured to deck and excluding hatches.
(3) Hydropneumatic or leak testing may be accepted under the conditions specified in [2.3] and [2.4], respectively, when, at the Society’s discretion, it is considered significant also in relation to the construction techniques and the welding procedures adopted.
(4) When a hose test cannot be performed without damaging possible outfitting (machinery, cables, switchboards, insulation, etc.) already installed, it may be replaced, at the Society’s discretion, by a careful visual inspection of all the crossings and welded joints. Where necessary, a dye penetrant test or ultrasonic leak test may be required.
(5) The means of closure are to be subjected to a hose test after fitting on board.
(6) A prototype pressure test of each type and size of hatch may be carried out instead of individual hatch tests.

2.6 Other testing methods

2.6.1 Other testing methods may be accepted, at the discretion of the Society, based upon equivalency considerations.

3 Miscellaneous

3.1 Watertight decks, trunks, etc.

3.1.1 *After completion, a hose or flooding test is to be applied to watertight decks and a hose test to watertight trunks, tunnels and ventilators.*

3.2 Doors in bulkheads above the bulkhead deck

3.2.1 Doors are to be designed and constructed as weathertight doors and, after installation, subjected to a hose test from each side for weathertightness.

3.3 Semi-watertight doors

3.3.1 These means of closure are to be subjected to a structural test at the manufacturer's works. The head of water is to be up to the highest waterline after damage at the equilibrium of the intermediate stages of flooding. The duration of the test is to be at least 30 min.

A leakage quantity of approximately 100 l/hour is considered as being acceptable for a 1,35 m^2 opening.

The means of closure are to be subjected to a hose test after fitting on board.

3.4 Steering nozzles

3.4.1 Upon completion of manufacture, the nozzle is to be subjected to a leak test.

3.5 Working test of windlass

3.5.1 The working test of the windlass is to be carried out on board in the presence of a Surveyor.

3.5.2 The test is to demonstrate that the windlass complies with the requirements of Ch 9, Sec 4, [3.6] and, in particular, that it works adequately and has sufficient power to successively weigh the two bower anchors (excluding the housing of the anchors in the hawse pipe) when both are suspended to 82,5 m of chain cable, at a speed not less than 9 m/min.

3.5.3 Where two windlasses operating separately on each chain cable are adopted, the weighing test is to be carried out for both, weighing an anchor suspended to 82,5m of chain cable and verifying that speed for the weighing (excluding the housing in the hawse pipe) is not less than 9m/min.

Appendix 1 Welding Details

1 Contents

1.1 General

1.1.1 Types and edge plate preparation of the manual welds carried out on the various parts of the hull are dealt with in this Appendix.
Other types and tolerances may be used after special examination of the Society.

1.1.2 The method used to prepare the parts to be welded is left to the discretion of each shipyard, according to its own technology and experience. It is approved at the same time as the approval of the welding procedures referred to in Ch 11, Sec 1, [1.3.1].

1.2 Butt welding edge preparation

1.2.1 Typical butt weld plate edge preparation for manual welding is specified in Tab 1 and Tab 2.

1.3 Lap-joint, slot and plug welding

1.3.1 Welding details of lap-joint, slot and plug welds are specified in Tab 3.

Table 1 : Typical butt weld plate edge preparation (manual welding) - See Note 1

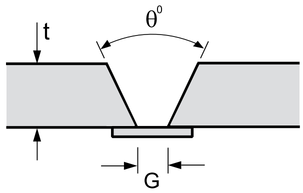
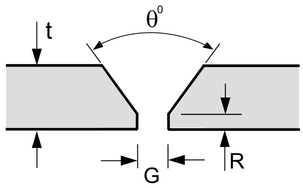
Detail	Standard
Single vee butt, one side welding with backing strip (temporary or permanent) 	$3 \leq G \leq 9$ mm $30° \leq \theta \leq 45°$
Single vee butt 	$G \leq 3$ mm $50° \leq \theta \leq 70°$ $R \leq 3$ mm
Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.	

Table 2 : Typical butt weld plate edge preparation (manual welding) - See Note 1

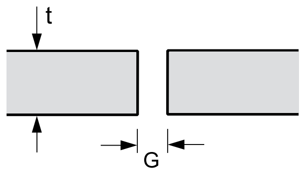
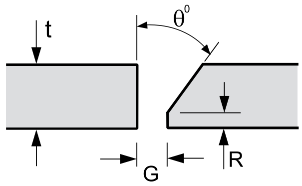
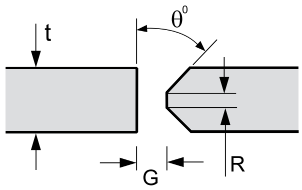
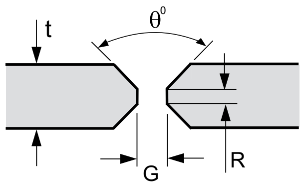
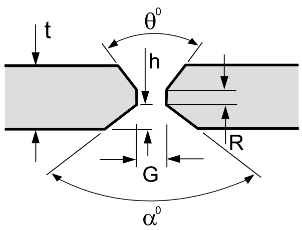
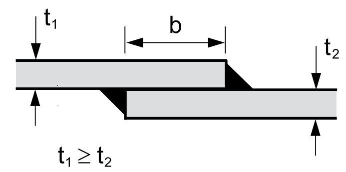
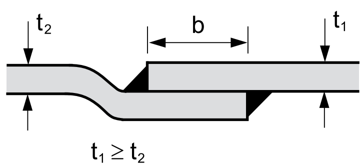
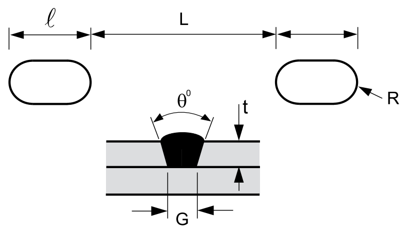
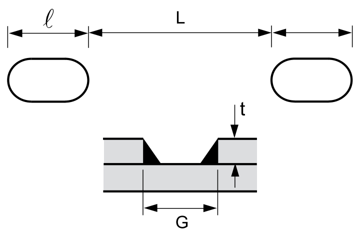
Detail	Standard
Square butt 	t ≤ 5 mm G = 3 mm
Single bevel butt 	t > 5 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double bevel butt 	t > 19 mm G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, uniform bevels 	G ≤ 3 mm R ≤ 3 mm 50° ≤ θ ≤ 70°
Double vee butt, non-uniform bevels 	G ≤ 3 mm R ≤ 3 mm 6 ≤ h ≤ t/3 mm θ = 50° α = 90°
Note 1: Different plate edge preparation may be accepted or approved by the Society on the basis of an appropriate welding procedure specification.	

Table 3 : Typical lap joint, plug and slot welding (manual welding)

Detail	Standard	Remark
Fillet weld in lap joint 	$b = 2\ t_2 + 25$ mm	location of lap joint to be approved by the Society
Fillet weld in joggled lap joint 	$b \geq 2\ t_2 + 25$ mm	
Plug welding 	• $t \leq 12$ mm $\ell = 60$ mm $R = 6$ mm $40° \leq \theta \leq 50°$ $G = 12$ mm $L > 2\ \ell$ • $12 \text{ mm} < t \leq 25$ mm $\ell = 80$ mm $R = 0,5\ t$ mm $\theta = 30°$ $G = t$ mm $L > 2\ \ell$	
Slot welding 	• $t \leq 12$ mm $G = 20$ mm $\ell = 80$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm • $t > 12$ mm $G = 2\ t$ $\ell = 100$ mm $2\ \ell \leq L \leq 3\ \ell$, max 250 mm	

Appendix 2 Reference Sheets for Special Structural Details

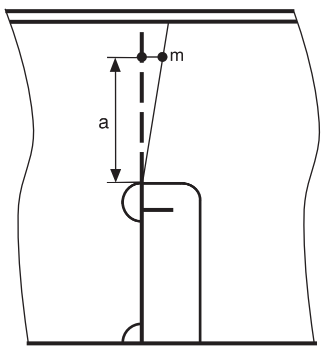
1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for special structural details, as referred to in Ch 11, Sec 2.

Table 1 :

AREA 1: Side between $0,7T_B$ and $1,15T$ from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - No collar plate	Sheet 1.1



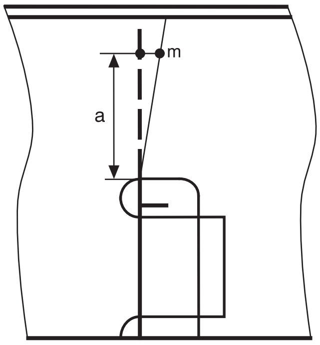
t_W = web thickness of transverse primary supporting member

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Cut-outs in the web free of sharp notches. • Gap between web and side longitudinal to be not greater than 4 mm.	Visual examination 100%.
WELDING AND MATERIALS:	

Welding requirements:
- continuous fillet welding along the connection of web with side longitudinal,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
- weld around the cuts in the web at the connection with the longitudinal and the side shell,
- avoid burned notches on web.

Table 2 :

AREA 1: Side between $0,7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One collar plate	Sheet 1.2



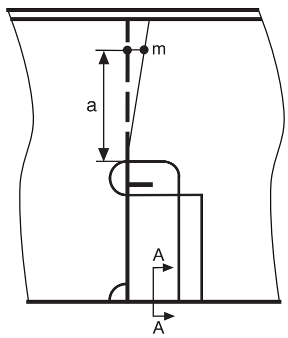
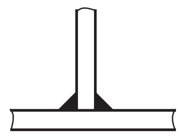
t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between web and collar plate ≤ t_{CP}. • Cut-outs in the web free of sharp notches. • Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - weld around the cuts in the web at the connection with the longitudinal and the side shell,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

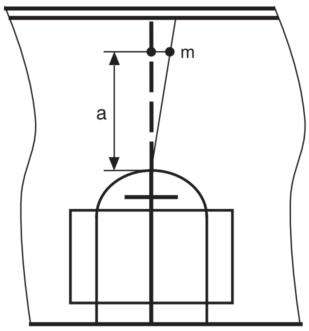
Table 3 :

<table>
<tr><td>AREA 1: Side between 0,7T_B and 1,15T from the baseline</td><td>Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - One large collar plate</td><td>Sheet 1.3</td></tr>
<tr><td colspan="3">

Section A-A

t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness</td></tr>
<tr><td colspan="2">SCANTLINGS:</td><td>FATIGUE:</td></tr>
<tr><td colspan="2">Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].</td><td>Fatigue check not required.</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td>NDE:</td></tr>
<tr><td colspan="2">• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50.
• Misalignment between web and collar plate ≤ t_{CP}.
• Cut-outs in the web free of sharp notches.
• Gap between web and side longitudinal and between collar plate and side longitudinal to be not greater than 4 mm.</td><td>Visual examination 100%.</td></tr>
<tr><td colspan="3">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="3">• Welding requirements:
- continuous fillet welding along the connection of web and collar plate with side longitudinal and at the lap joint between web and collar plate,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
- T joint connection of collar plate with side shell: see section A-A,
- weld around the cuts in the web at the connection with the longitudinal and the side shell,
- avoid burned notches on web.
• Fillet welding of overlapped joint to be done all around.</td></tr>
</table>

Table 4 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two collar plates	Sheet 1.4



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

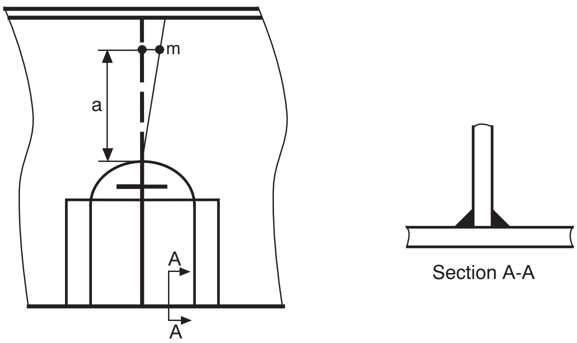
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharp notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 5 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with transverse primary supporting members - Two large collar plates	Sheet 1.5



t_W = web thickness of transverse primary supporting member
t_{CP} = collar plate thickness

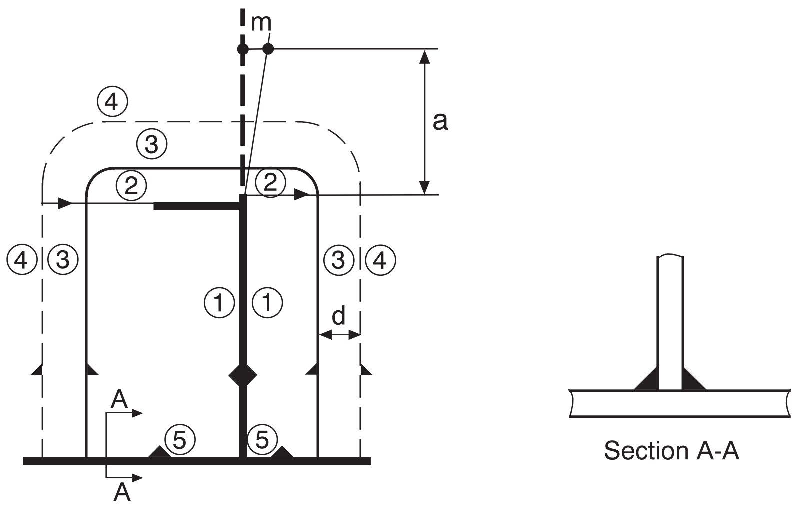
SCANTLINGS:	FATIGUE:
Net sectional area of the web stiffener according to Ch 4, Sec 3, [4.7].	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between collar plates across the side longitudinal ≤ t_{CP} / 2. • Cut-outs in the web free of sharp notches. • Gap between collar plates and side longitudinal to be not greater than 4 mm.	Visual examination 100%.

WELDING AND MATERIALS:

- Welding requirements:
  - continuous fillet welding along the connection of collar plates with side longitudinal and at the lap joint between web and collar plates,
  - throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
  - T joint connection of collar plates with side shell: see section A-A,
  - avoid burned notches on web.
- Fillet welding of overlapped joint to be done all around.

Table 6 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Watertight connection of side longitudinal ordinary stiffeners with watertight side diaphragms or transverse bulkheads – Example of connection with lugs**	**Sheet 1.6**



t_W = transverse bulkhead web thickness
t_L = lug thickness

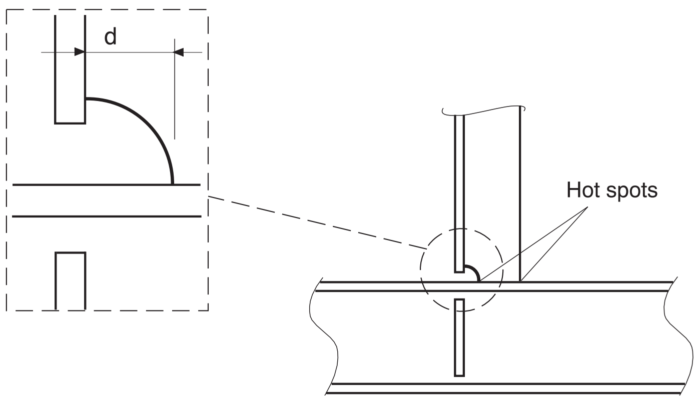
SCANTLINGS:	**FATIGUE:**
• d = 30 ÷ 60 mm. • $t_L \geq t_W$.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Web stiffener not compulsory. When fitted, its misalignment m with the web of the side longitudinal ≤ a / 50. • Misalignment between lugs across the side longitudinal ≤ t_L / 2. • Misalignment at the butts within lug parts ≤ t_L / 5. • Gap between bulkhead plating and lugs to be not greater than 4 mm.	• Visual examination 100%. • Magnetic particle or dye penetrant examination: when deemed necessary depending on the quality of the lap joint weld.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding along the connection of lugs with the side longitudinal and at the lap joints between web and lugs,
- throat thickness according to Ch 11, Sec 1, [2.3.7]; in case of gap g greater than 2 mm, increase the throat thickness by 0,7 (g – 2) mm,
- T joint connection of collar plates with side shell: see section A-A,
- welding sequence: 1 to 5 (see sketch).

Table 7 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 1.7



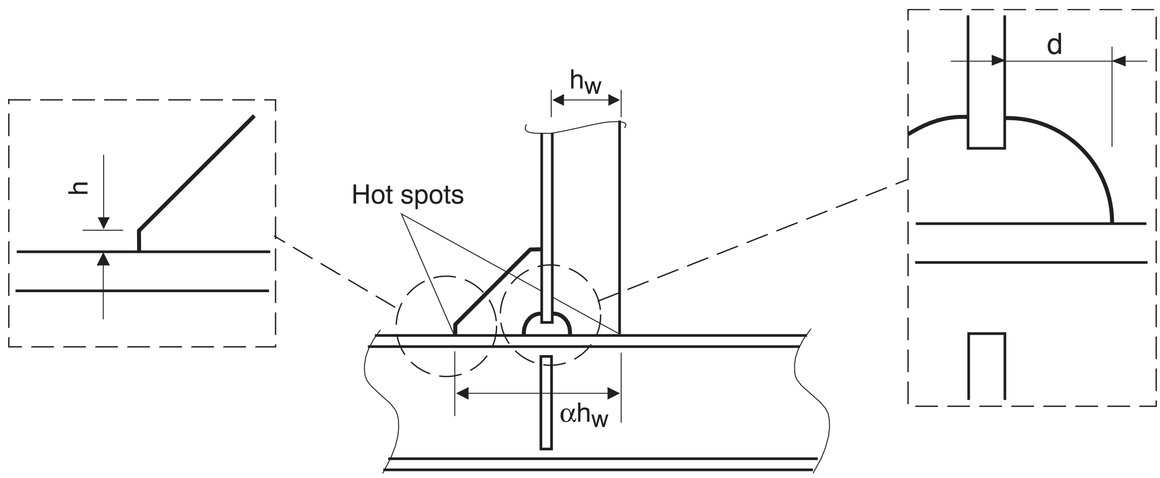
t = minimum thickness between those of:
- web of side longitudinal,
- stiffener of transverse primary supporting member.

SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: K_h = 1,30 $K\ell$ = 1,65 • with full collar plate (watertight): K_h = 1,25 $K\ell$ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 8 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	**Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket**	**Sheet 1.8**

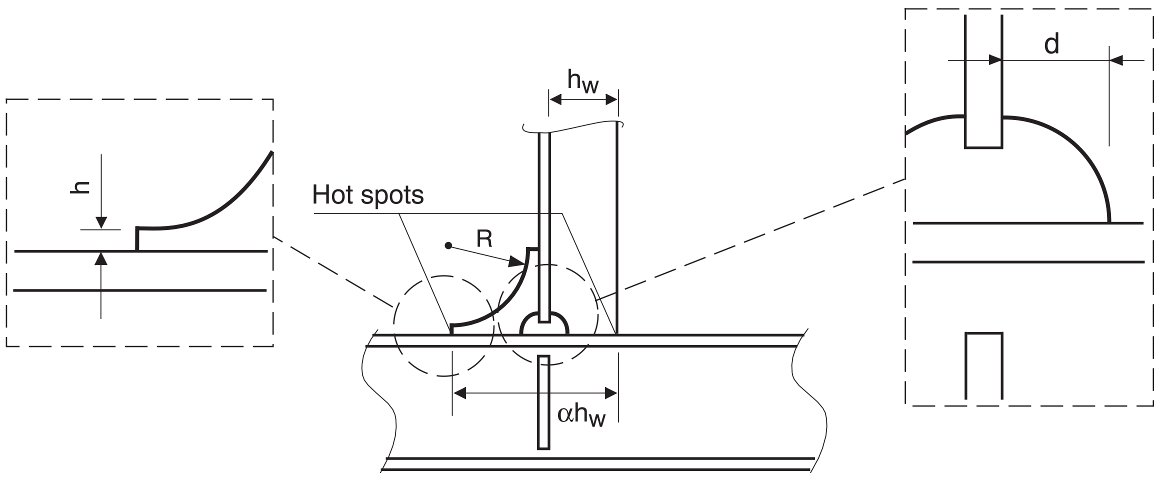


t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}20$ $K\ell = 1{,}40$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}15$ $K\ell = 1{,}40$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}15$ $K\ell = 1{,}32$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}10$ $K\ell = 1{,}32$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.
WELDING AND MATERIALS:	
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.	

Table 9 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.9



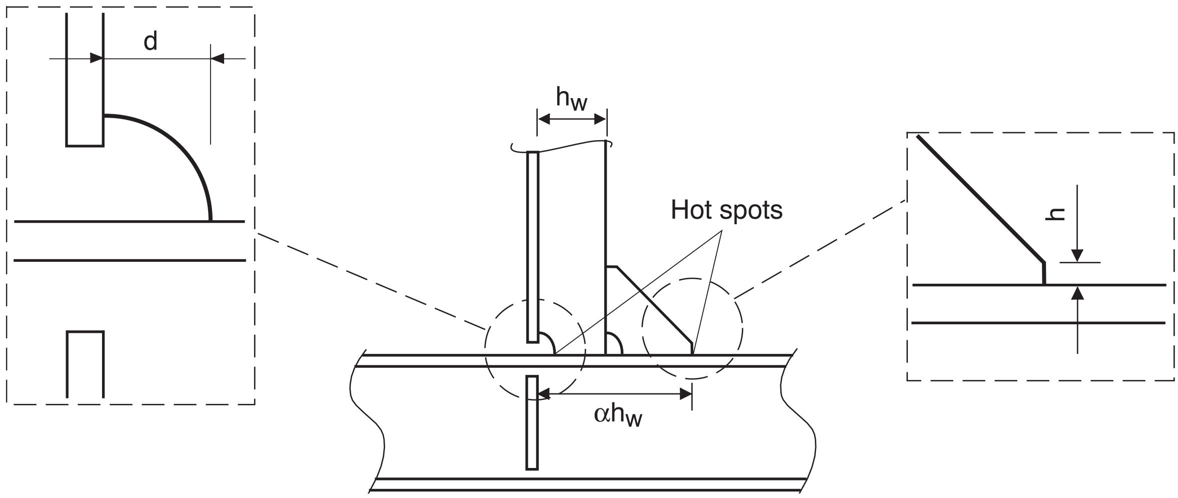
t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,15$ $K\ell = 1,35$ - for $\alpha \geq 2,5$ $K_h = 1,10$ $K\ell = 1,35$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,13$ $K\ell = 1,30$ - for $\alpha \geq 2,5$ $K_h = 1,08$ $K\ell = 1,30$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 10 :

AREA 1: Side between $0{,}7T_B$ and $1{,}15T$ from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 1.10



t = minimum thickness among those of the connected elements

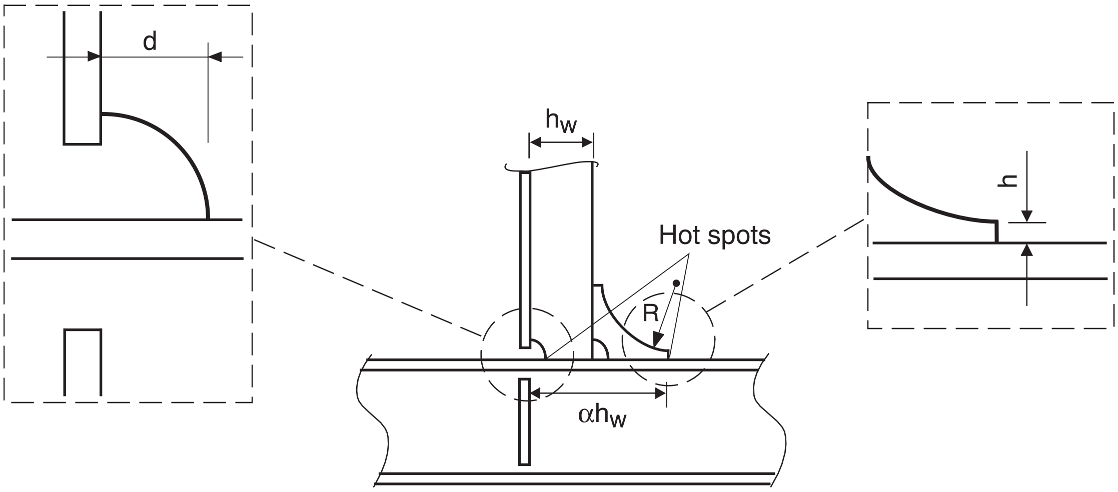
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}30$ $K\ell = 1{,}55$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}25$ $K\ell = 1{,}50$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ $K_h = 1{,}25$ $K\ell = 1{,}46$ - for $\alpha \geq 2{,}5$ $K_h = 1{,}20$ $K\ell = 1{,}41$

CONSTRUCTION:	NDE:
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction.

Table 11 :

AREA 1: Side between 0,7T_B and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.11



t = minimum thickness among those of the connected elements

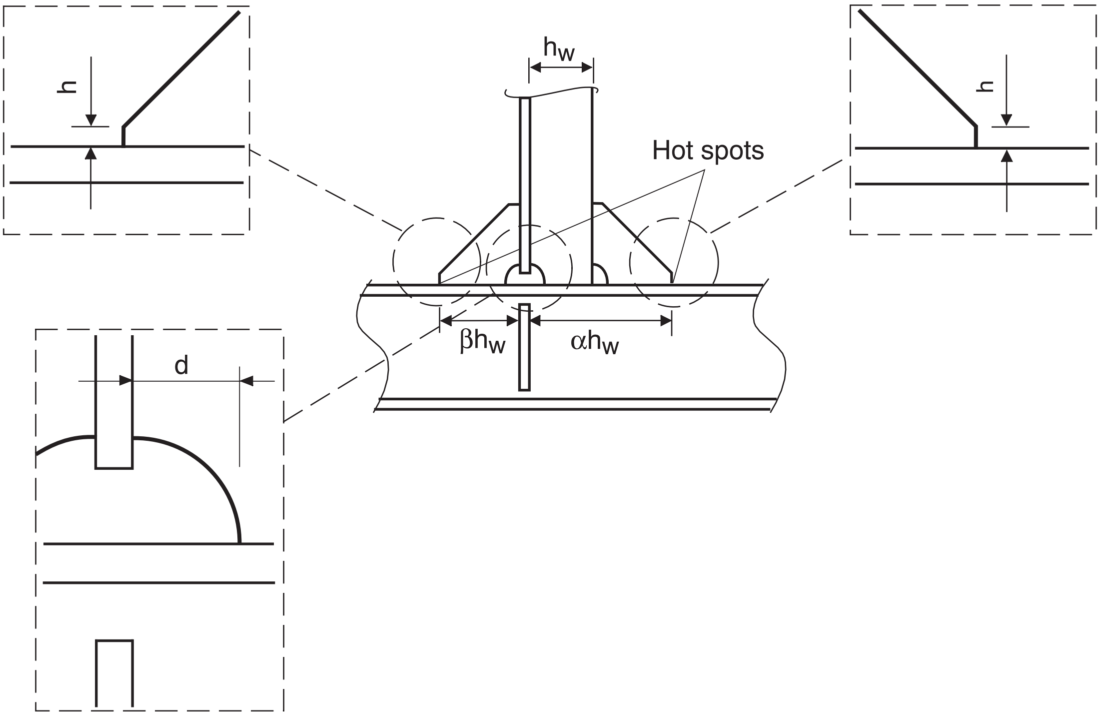
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • $R \geq 1,5\ (\alpha - 1)\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2,5$ $K_h = 1,25$ $K\ell = 1,50$ - for $\alpha \geq 2,5$ $K_h = 1,20$ $K\ell = 1,45$ • with full collar plate (watertight): - for $2 \leq \alpha < 2,5$ $K_h = 1,22$ $K\ell = 1,44$ - for $\alpha \geq 2,5$ $K_h = 1,18$ $K\ell = 1,39$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and bracket ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 12 :

AREA 1: Side between $0{,}7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 1.12

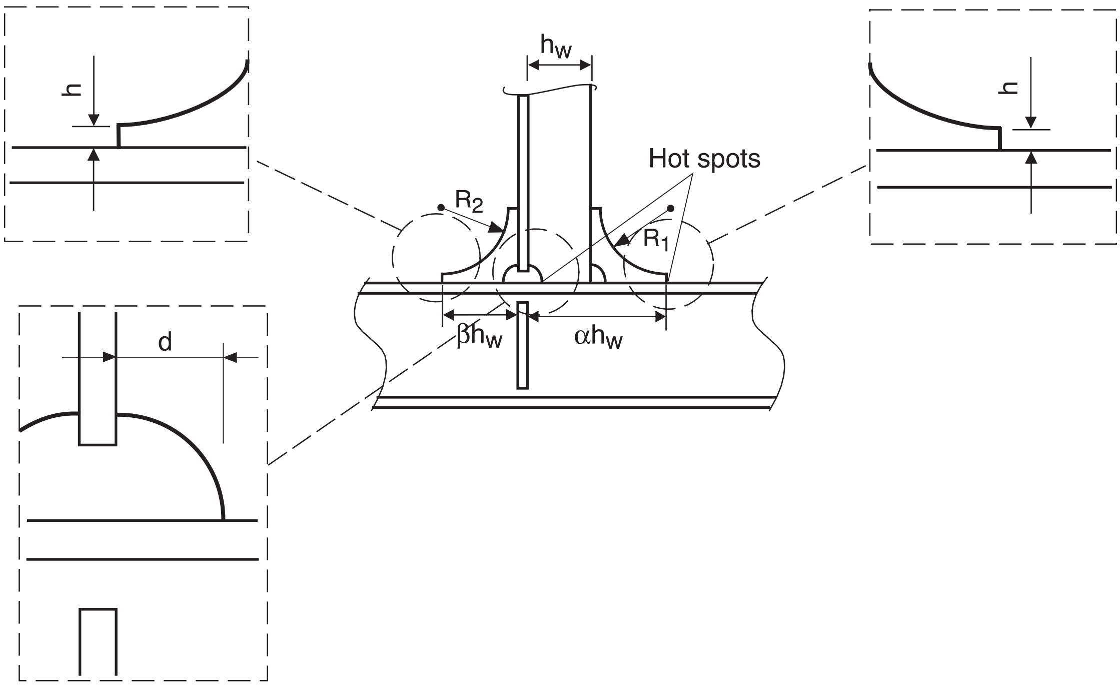


t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 90 m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K\ell = 1{,}15$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K\ell = 1{,}10$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K\ell = 1{,}10$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K\ell = 1{,}05$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.
WELDING AND MATERIALS:	
• Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: - material of brackets to be the same of longitudinals.	

Table 13 :

AREA 1: Side between $0{,}7T_B$ and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 1.13

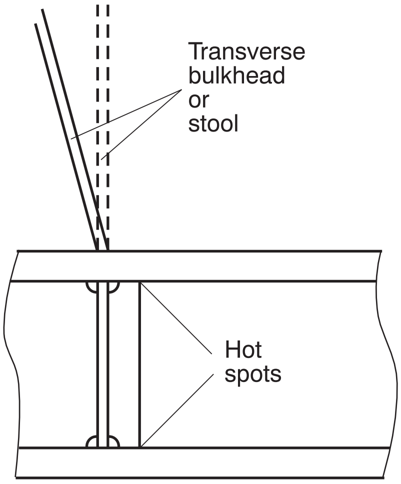


t = minimum thickness among those of the connected elements

SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • $\beta \geq 1$. • Brackets to be symmetric. • $R_1 \geq 1{,}5\ (\alpha - 1)\ h_W$ • $R_2 \geq 1{,}5\ \beta\ h_W$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the brackets to be not less than that of web stiffener.	Fatigue check to be carried out for $L \geq 90$ m: • with non-watertight collar plate: - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K\ell = 1{,}10$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K\ell = 1{,}05$ • with full collar plate (watertight): - for $2 \leq \alpha < 2{,}5$ and $1 \leq \beta < 1{,}5$ $K_h = K\ell = 1{,}10$ - for $\alpha \geq 2{,}5$ and $\beta \geq 1{,}5$ $K_h = K\ell = 1{,}05$
CONSTRUCTION:	**NDE:**
• Misalignment between side longitudinal, web stiffener and brackets ≤ t /3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:
• Welding requirements: - continuous fillet welding, - weld around the stiffener's toes, - fair shape of fillet at toes in longitudinal direction. • Material requirements: - material of brackets to be the same of longitudinals.

Table 14 :

<table>
<tr><td colspan="2">AREA 2: Double bottom in way of transverse bulkheads</td><td colspan="2">Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket</td><td>Sheet 2.1</td></tr>
<tr><td colspan="5">

t = minimum thickness between those of:
- web of bottom or inner bottom longitudinal,
- floor stiffener.</td></tr>
<tr><td colspan="3">SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td colspan="3"></td><td colspan="2">Fatigue check to be carried out for L ≥ 90 m:
K_h = 1,30
$K\ell$ = 1,65</td></tr>
<tr><td colspan="3">CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td colspan="3">• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3.
• In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.</td><td colspan="2">Visual examination 100%.</td></tr>
<tr><td colspan="5">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="5">Welding requirements:
- floor stiffeners to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- weld all around the stiffeners,
- fair shape of fillet at toes in longitudinal direction.</td></tr>
</table>

Table 15 :

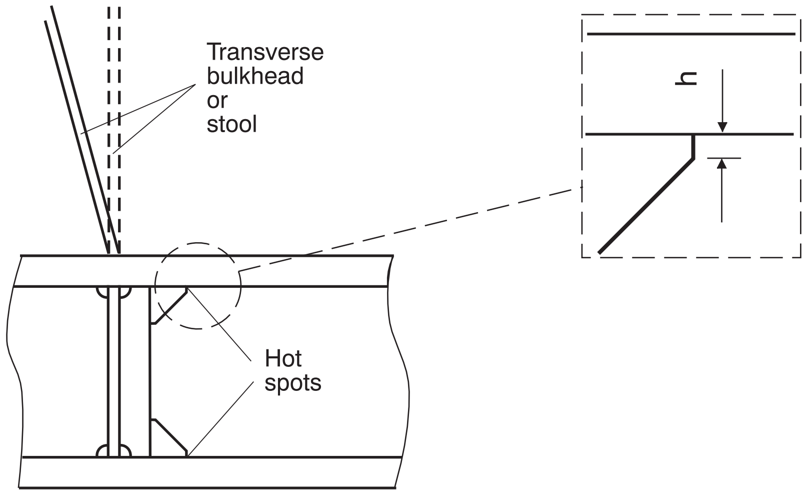
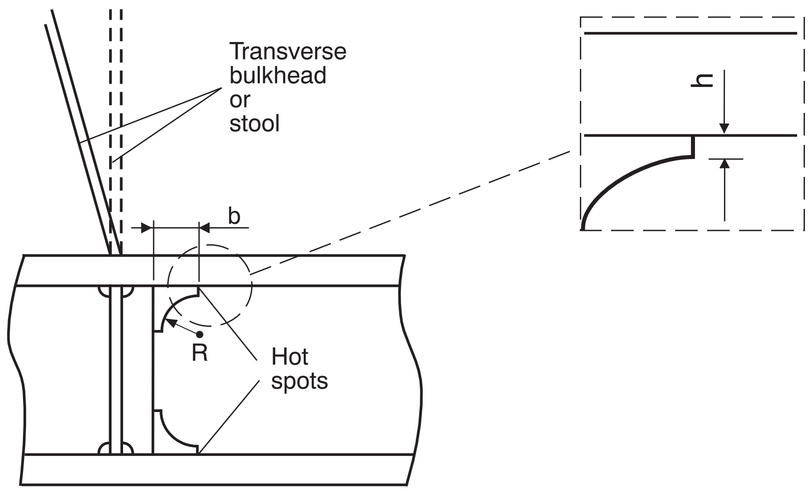
AREA 2: Double bottom in way of transverse bulkheads	**Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets**	**Sheet 2.2**
 t = minimum thickness among those of the connected elements		
SCANTLINGS:	**FATIGUE:**	
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 90 m: K_h = 1,30 $K\ell$ = 1,55	
CONSTRUCTION:	**NDE:**	
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.	
WELDING AND MATERIALS:		
Welding requirements: - floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals, - partial penetration welding between stiffeners and brackets, - weld all around the stiffeners and brackets, - fair shape of fillet at toes in longitudinal direction.		

Table 16 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets	Sheet 2.3



t = minimum thickness among those of the connected elements

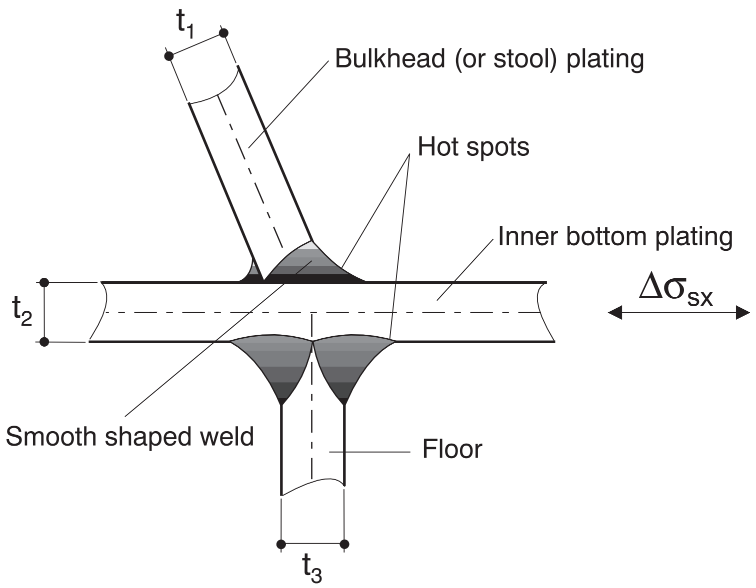
SCANTLINGS:	FATIGUE:
• Brackets to be symmetric. • R ≥ 1,5 b • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 90 m: K_h = 1,25 $K\ell$ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between webs of bottom and inner bottom longitudinal with floor stiffener ≤ t / 3. • In case of fillet weld, misalignment may be as necessary to allow the required fillet leg size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- floor stiffeners and brackets to be connected with continuous fillet welding to bottom and inner bottom longitudinals,
- partial penetration welding between stiffeners and brackets,
- weld all around the stiffeners and brackets,
- fair shape of fillet at toes in longitudinal direction.

Table 17 :

AREA 2: Double bottom in way of transverse bulkheads	Connection of inner bottom with transverse bulkheads or lower stools	Sheet 2.4



Hot spot stresses:
$\Delta\sigma_{SX} = K_{SX} \cdot \Delta\sigma_{sX}$

$t = \min(t_1, t_2, t_3)$

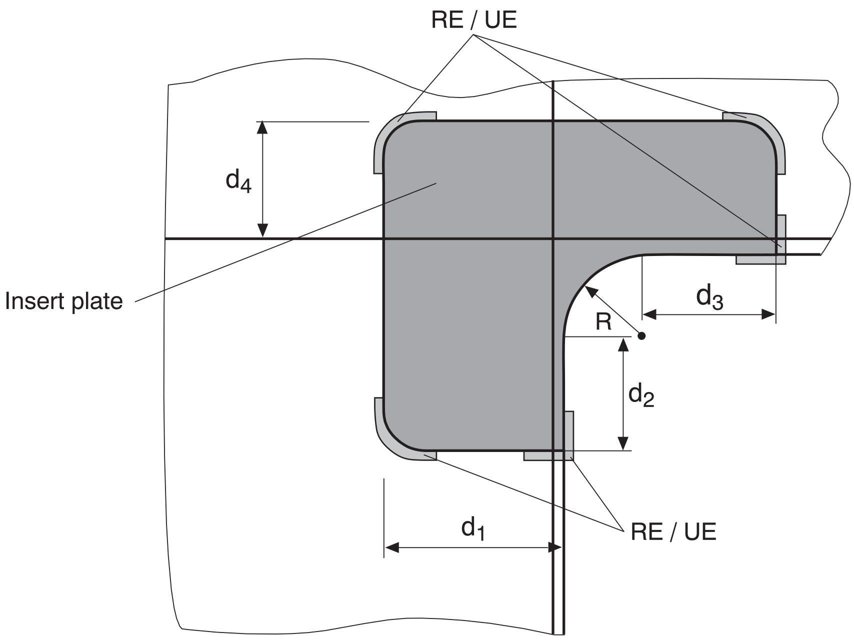
SCANTLINGS:	FATIGUE:
	Fatigue check to be carried out for $L \geq 90$ m: $K_{SX} = 3,85$
CONSTRUCTION:	**NDE:**
• Misalignment (median lines) between floor and bulkhead (or stool) plating $\leq t / 3$. • Cut-outs for connections of the inner bottom longitudinals to double bottom floors to be closed by collar plates welded to the inner bottom.	The following NDE are required: • VE 100%, • UE 35% of full penetration weld for absence of cracks, lack of penetration and lamellar tears.

WELDING AND MATERIALS:

- Welding requirements:
  - bulkhead (or stool) plating and supporting floors generally to be connected with full penetration welding to inner bottom plating (if not full penetration welding, the weld preparation is to be indicated on the approved drawings),
  - special approval of the procedure on a sample representative of the actual conditions foreseen in production,
  - welding sequence against the risk of lamellar tearing,
  - weld finishing well faired to the inner bottom plating.
- Material requirements:
  - the strake of inner bottom plating in way of the connection is recommended to be of Z25/ZH25 quality. If a steel of such a quality is not adopted, 100% UE of the plate in way of the weld is required prior to and after welding.
- Partial fillet welding may also be accepted in place of full penetration welding between floor and inner bottom plating. In such a case, the preparation is to be specified on drawing.

Table 18 :

AREA 3: Hatch corners	Deck plating in way of hatch corners	Sheet 3.1

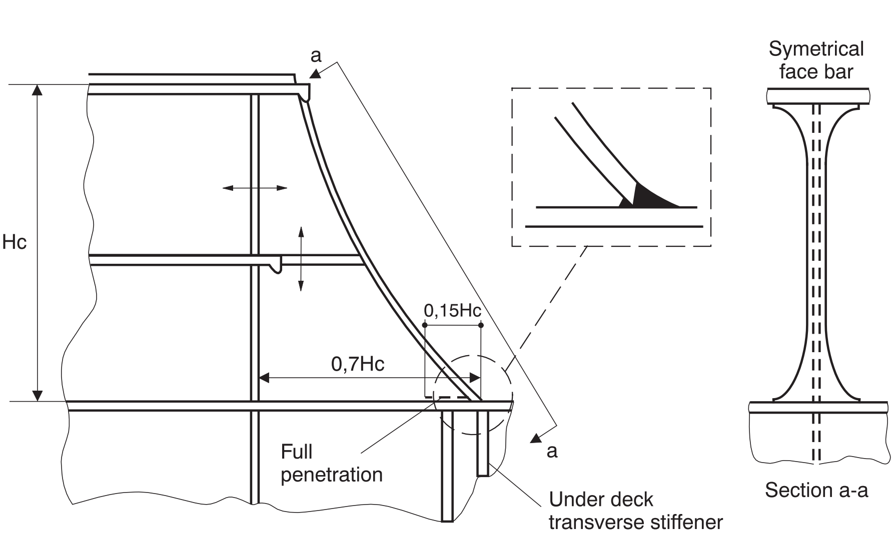


SCANTLINGS:	FATIGUE:
• Insert plates with circular profiles in general to be fitted in way of corners of hatchways located within the cargo area. The radius of circular corners to be in accordance with Ch 4, Sec 6, [6.2.1]. • Insert plates not required in way of corners of hatchways located in the above positions, where corners have an elliptical or parabolic profile according to Ch 4, Sec 6, [6.2.2]. • Where insert plates are required, their thickness to be defined according to Ch 4, Sec 6, [6.2.3] and their extension to be such that d_1 , d_2 , d_3 and $d_4 \geq s$, s being the ordinary frame spacing.	Fatigue check not required.
CONSTRUCTION:	**NDE:**
• Corners of insert plates to be rounded, unless corresponding to joints of deck strakes. • Insert cut edges to be carefully executed.	The following NDE are required: • VE 100%, • RE / UE in areas indicated in the sketch.

WELDING AND MATERIALS:

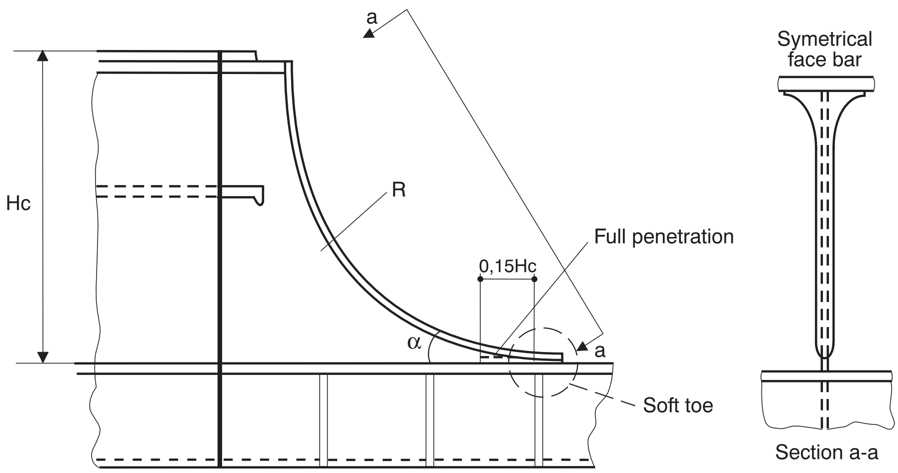
- Welding requirements:
  - welds recommended to be continued on auxiliary pieces temporarily fitted at the free end of each joint, to be cut away; the joint ends are to be carefully ground.
- Materials requirements:
  - insert plate material of same or higher quality than the adjacent deck plating, depending on the insert thickness according to Ch 4, Sec 1, [2].

Table 19 :

<table>
<tr><td>AREA 3: Hatch corners</td><td>Ends of longitudinal hatch coamings - Bracket welded to deck plating</td><td>Sheet 3.2</td></tr>
<tr><td colspan="2">
</td><td>t_A = minimum among:
- thickness of bracket flange at lower end,
- deck plating thickness,
- under deck transverse stiffener web thickness,

t_B = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.</td></tr>
<tr><td>SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td>An additional under deck transverse stiffener is to be fitted in way of termination bracket toe, where the toe is clear of normal stiffener.</td><td colspan="2">Fatigue check not required.</td></tr>
<tr><td>CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td>• Misalignment between bracket flange and under deck transverse stiffener ≤ t_A / 3.
• Misalignment between bracket and under deck longitudinal ≤ t_B / 3.</td><td colspan="2">The following NDE are required:
• VE 100%, with particular care for the weld shape and undercuts on deck plating at the bracket flange connection,
• UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.</td></tr>
<tr><td colspan="3">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="3">Welding requirements:
- bracket flange to be connected with full penetration welding to deck plating, with half V bevel and weld shape elongated on deck plating (see sketch),
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel,
- under deck transverse stiffener to be connected with full penetration welding to deck plating in way of the bracket flange,
- care is to be taken to ensure soundness of the crossing welds at the bracket toe, if the case, adopting small scallop to be closed by welding.</td></tr>
</table>

Table 20 :

<table>
<tr><th colspan="2">AREA 3: Hatch corners</th><th colspan="2">Ends of longitudinal hatch coamings - Bracket sniped at deck plating</th><th>Sheet 3.3</th></tr>
<tr><td colspan="3">
</td><td colspan="2">t = minimum among:
- bracket web thickness,
- deck plating thickness,
- thickness of the under deck longitudinal member.</td></tr>
<tr><td colspan="2">SCANTLINGS:</td><td colspan="3">FATIGUE:</td></tr>
<tr><td colspan="2">R ≥ 500 mm.
α ≤ 30°.</td><td colspan="3">Fatigue check not required.</td></tr>
<tr><td colspan="2">CONSTRUCTION:</td><td colspan="3">NDE:</td></tr>
<tr><td colspan="2">• Misalignment between bracket and under deck longitudinal ≤ t_B / 3.
• Soft toe: tapering of bracket flange at ends: thickness 1:3, width 1:5.</td><td colspan="3">The following NDE are required:
• VE 100%, with particular care for the weld shape and undercuts on deck plating,
• UE 100% of full penetration welds for absence of cracks, lack of penetration and lamellar tears.</td></tr>
<tr><td colspan="5">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="5">Welding requirements:
- ends of bracket webs to be connected with full penetration welding to deck plating for the extension shown in the sketch, with half X bevel.</td></tr>
</table>

NR483

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part C
Machinery, Systems and Fire Protection

Chapter 1	Machinery
Chapter 2	Electrical Installations
Chapter 3	Automation
Chapter 4	Fire Protection, Detection and Extinction

January 2024

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CHAPTER 1
MACHINERY

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Section 1 General Requirements

1 General

1.1 Application

1.1.1 Part C, Chapter 1 applies to the design, construction, installation, tests and trials of main propulsion and essential auxiliary machinery systems and associated equipment, boilers and pressure vessels, piping systems, and steering and manoeuvring systems installed on board classed ships, as indicated in each Section of this Chapter.

For computerized Machinery systems, requirements contained in Part C, Chapter 3 shall be refered to.

1.2 Additional requirements

1.2.1 Additional requirements for machinery are given in:

- Part D, for the assignment of the service notations
- Part E, for the assignment of additional class notations.

1.3 Documentation to be submitted

1.3.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in the relevant Sections of this Chapter.

1.4 Definitions

1.4.1 Dead ship condition

Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operations due to absence of power.

Note 1: Dead ship condition is the condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc. for bringing the main propulsion into operation and for the restoring of the main power supply are not available.

2 Design and construction

2.1 General

2.1.1 The machinery, boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

2.1.2 Propulsion machinery and related auxiliaries are to be so designed and installed as to comply with the availability requirements stated in Part D for the service notation of the ship and with the requirements of Part E, Chapter 3 when the ship is to be assigned an **AVM** additional class notation.

2.2 Materials, welding and testing

2.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of NR216 Materials and Welding, and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [2.2.2] apply.

2.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with NR216 Materials and Welding, Chapter 12 and NR476 Approval testing of welders.

References to welding procedures adopted are to be clearly indicated on the plans submitted for approval.

Joints transmitting loads are to be either:

- full penetration butt-joints welded on both sides, except when an equivalent procedure is approved
- full penetration T- or cruciform joints.

2.3 Vibrations

2.3.1 Special consideration is to be given to the design, construction and installation of propulsion machinery systems and auxiliary machinery so that any mode of their vibrations shall not cause undue stresses in this machinery in the normal operating ranges.

2.4 Operation in inclined position

2.4.1 Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the ship are, as fitted in the ship, be designed to operate when the ship is upright and when inclined at any angle of list either way and trim by bow or stern as stated in Tab 1.

The Society may permit deviations from angles given in Tab 1, taking into consideration the type, size and service conditions of the ship.

Machinery with a horizontal rotation axis is generally to be fitted on board with such axis arranged alongships. If this is not possible, the Manufacturer is to be informed at the time the machinery is ordered.

2.5 Ambient conditions

2.5.1 Machinery and systems covered by the Rules are to be designed to operate properly under the ambient conditions specified in Tab 2, unless otherwise specified in each Section of this Chapter.

Table 1 : Inclination of ship

Installations, components	Angle of inclination (degrees) **(1)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(3)** and remote control systems	22,5 **(2)**	22,5 **(2)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.
(2) In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.
(3) Up to an angle of inclination of 45° no undesired switching operations or operational changes may occur.

Table 2 : Ambient conditions

AIR TEMPERATURE	
Location, arrangement	Temperature range, in °C
In enclosed spaces	between 0 and +45**(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	according to specific local conditions
On exposed decks	between –25 and +45**(1)**

WATER TEMPERATURE	
Coolant	Temperature, in °C
Sea water or, if applicable, sea water at charge air coolant inlet	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Part C, Chapter 2).
(2) Different temperatures may be accepted by the Society in the case of ships intended for restricted service.

2.5.2 The full propulsion capability of the ship is to remain available under the following temperature conditions unless other specification:

- air: from –15 to +35°C
- water: from –2 to +30°C.

2.6 Power of machinery

2.6.1 Unless otherwise stated in each Section of this Chapter, where scantlings of components are based on power, the values to be used are determined as follows:

- for main propulsion machinery, the power/rotational speed for which classification is requested. This power/rotational speed should take in account the most stress-inducing propulsion system configuration mode.
- for auxiliary machinery, the power/rotational speed which is available in service.

2.7 Astern power

2.7.1 Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.

Note 1: Attention is to be paid to maximum stopping distance and to minimum astern thrust, which may be imposed by the ship specification.

For main propulsion systems with reversing gears, controllable pitch propellers or electrical propeller drive, running astern is not to lead to an overload of propulsion machinery.

During the sea trials, the ability of the main propulsion machinery to reverse the direction of thrust of the propeller is to be demonstrated and recorded (see also Ch 1, Sec 16).

2.8 Safety devices

2.8.1 Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.

2.8.2 Where main or auxiliary machinery including pressure vessels or any parts of such machinery are subject to internal pressure and may be subject to dangerous overpressure, means shall be provided, where practicable, to protect against such excessive pressure.

2.8.3 Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shut-off arrangements in the case of failures, such as lubricating oil supply failure, which could lead rapidly to complete breakdown, serious damage or explosion.

The Society may permit provisions for overriding automatic shut-off devices.

See also the specific requirements given in the other Sections of this Chapter.

2.9 Fuels

2.9.1 Fuel oils employed for engines and boilers are, in general, to have a flash point (determined using the closed cup test) of not less than 60°C.

For ships assigned with a restricted navigation notation, or whenever special precautions are taken to the Society’s satisfaction, fuel oils having a flash point of less than 60°C but not less than 43°C may be used for engines, provided that, from previously effected checks, it is evident that the temperature of spaces where fuel oil is stored or employed will be at least 10°C below the fuel oil flash point at all times.

Fuel oil having flash points of less than 43°C may be employed on board provided that it is stored on an open deck.

3 Arrangement and installation on board

3.1 General

3.1.1 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.

Suitable demountable openings are to be foreseen in decks and bulkheads for the purpose of disembarking main machinery whose maintenance is intended to be carried out ashore.

Easy access to the various parts of the propulsion machinery is to be provided by means of metallic ladders and gratings fitted with strong and safe handrails.

Spaces containing main and auxiliary machinery are to be provided with adequate lighting and ventilation.

3.1.2 In machinery spaces of Category A, electric switchboard, cabinet or junction box and electric equipment of essential services are to be located above the level corresponding to the lowest generating line of the propeller shaft.

In machinery spaces without propeller shaft this level is corresponding to the lowest generating line of the output shaft of main or auxiliary prime mover installed.

3.2 Floors

3.2.1 Floors in engine rooms are to be made of steel, divided into easily removable panels.

3.3 Bolting down

3.3.1 Bedplates of machinery are to be securely fixed to the supporting structures by means of foundation bolts which are to be distributed as evenly as practicable and of a sufficient number and size so as to ensure a perfect fit.

Where the bedplates bear directly on the inner bottom plating, the bolts are to be fitted with suitable gaskets so as to ensure a tight fit and are to be arranged with their heads within the double bottom.

Continuous contact between bedplates and foundations along the bolting line is to be achieved by means of chocks of suitable thickness, carefully arranged to ensure a complete contact.

The same requirements apply to thrust block and shaft line bearing foundations.

Particular care is to be taken to obtain a perfect levelling and general alignment between the propulsion engines and their shafting (see Ch 1, Sec 7).

3.3.2 Chocking resins are to be type approved.

3.4 Safety devices on moving parts

3.4.1 Suitable protective devices are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid injuries to personnel.

3.5 Gauges

3.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

3.6 Ventilation in machinery spaces

3.6.1 Machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather condition, including heavy weather, a sufficient supply of air is maintained to the spaces for the safety of personnel and the operation of the machinery, without exceeding the temperature values under Tab 2.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

Machinery air intake is to be ducted from an open space; the size and fittings of ducts are to be such as to satisfy the machinery flow, pressure and quality requirements for developing maximum continuous power.

3.7 Hot surfaces and fire protection

3.7.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials coming into contact with them. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

Fire protection, detection and extinction is to comply with the requirements of Part C, Chapter 4.

3.8 Communications

3.8.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigating bridge, with audible alarm mismatch between order and response.

Appropriate means of communication shall be provided from the navigating bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled.

The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

Where the main propulsion system of the ship is controlled from the navigating bridge by a remote control system, the second means of communication may be the same bridge control system.

The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended.

For ships assigned with a restricted navigation notation these requirements may be relaxed at the Society's discretion.

3.9 Machinery remote control, alarms and safety systems

3.9.1 For remote control systems of main propulsion machinery and essential auxiliary machinery and relevant alarms and safety systems, the requirements of Part C, Chapter 3 apply.

4 Tests and trials

4.1 Works tests

4.1.1 Equipment and its components are subjected to works tests which are detailed in the relevant Sections of this Chapter and are to be witnessed by the Surveyor.

In particular cases, where such tests cannot be performed in the workshop, the Society may allow them to be carried out on board, provided this is not judged to be in contrast either with the general characteristics of the machinery being tested or with particular features of the shipboard installation. In such cases, the Surveyor entrusted with the acceptance of machinery on board and the purchaser are to be informed in advance and the tests are to be carried out in accordance with the provisions of NR216 Materials and Welding relative to incomplete tests.

All boilers, all parts of machinery, all steam, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time as detailed in the other Sections of this Chapter.

4.2 Trials on board

4.2.1 Trials on board of machinery are detailed in Ch 1, Sec 16.

Section 2 Diesel Engines

1 General

1.1 Application

1.1.1 Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of a Surveyor of the Society:

a) main propulsion engines

b) engines driving electric generators, including emergency generators

c) engines driving other auxiliaries essential for safety and navigation when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [2.4.4], and delivered with the relevant works' certificate (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]).

Engines intended for propulsion of lifeboats and compression ignition engines intended for propulsion of rescue boats are to comply with the relevant Rules requirements.

Other procedures proposed or accepted by the ship Owner will be also considered on a case by case basis.

In addition to the requirements of this Section, those given in Ch 1, Sec 1 apply.

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1 for engine type approval.

Plans listed under items 2 and 3 in Tab 1 are also to contain details of the lubricating oil sump in order to demonstrate compliance with Ch 1, Sec 1, [2.4].

Where changes are made to an engine type for which the documents listed in Tab 1 have already been examined or approved, the engine Manufacturer is to resubmit to the Society for consideration and approval only those documents concerning the engine parts which have undergone substantial changes.

If the engines are manufactured by a licensee, the licensee is to submit, for each engine type, a list of all the drawings specified in Tab 1, indicating for each drawing the relevant number and revision status from both licensor and licensee.

Where the licensee proposes design modifications to components, the associated documents are to be submitted by the licensee to the Society for approval or for information purposes. In the case of significant modifications, the licensee is to provide the Society with a statement confirming the licensor's acceptance of the changes. In all cases, the licensee is to provide the Surveyor entrusted to carry out the testing, with a complete set of the documents specified in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A**(1)**	Document	Document details
1	I	Engine particulars as per the Society form "Particulars of diesel engines" or equivalent form	–
2	I	Engine transverse cross-section	Max inclination angles, oil surface lines, oil suction strum position
3	I	Engine longitudinal section	Max inclination angles, oil surface lines, oil suction strum position
4	I / A	Bedplate or crankcase, cast or welded For welded bedplates or cranks, welding details and instructions	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
5	A	Thrust bearing assembly **(2)**	–
6	I / A	Thrust bearing bedplate, cast or welded. For welded bedplates or cranks, welding details and instructions **(2)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
7	I / A	Frame/column, cast or welded with welding details and instructions **(3)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
8	I	Tie rod	–
9	I	Cylinder cover, assembly	–

No.	I/A**(1)**	Document	Document details
10	I	Cylinder jacket or engine block **(3)** **(4)**	–
11	I	Cylinder liner **(4)**	–
12	A	Crankshaft, details, for each cylinder number	–
13	A	Crankshaft, assembly, for each cylinder number	–
14	A	Thrust shaft or intermediate shaft (if integral with engine)	–
15	A	Coupling bolts	–
16	A	Counterweights (if not integral with crankshaft), with associated fastening bolts	Bolt fastening instructions
17	I	Connecting rod	–
18	I	Connecting rod, assembly **(4)**	Bolt fastening instructions
19	I	Crosshead, assembly **(4)**	–
20	I	Piston rod, assembly **(4)**	–
21	I	Piston, assembly	–
22	I	Camshaft drive, assembly	–
23	A	Material specifications of main parts of engine, with detailed information on: - non-destructive tests, and - pressure tests	Required for items 4, 7, 8, 9, 10, 11, 12, 15, 18, 21, including acceptable defects and repair procedures Required for items 4, 7, 9, 10, 11, 21 and for injection pumps and exhaust manifold
24	A	Arrangement of foundation bolts (for main engines only)	–
25	A	Schematic layout or other equivalent documents for starting air system on the engine **(5)**	–
26	A	Schematic layout or other equivalent documents for fuel oil system on the engine **(5)**	–
27	A	Schematic layout or other equivalent documents for lubricating oil system on the engine **(5)**	–
28	A	Schematic layout or other equivalent documents for cooling water system on the engine **(5)**	–
29	A	Schematic diagram of engine control and safety system on the engine **(5)** (see also [2.10])	List, specification and layout of sensors, automatic controls and other control and safety devices
30	I	Shielding and insulation of exhaust pipes, assembly	–
31	A	Shielding of high pressure fuel pipes, assembly (see also [2.7.2])	Recovery and leak detection devices
32	A	Crankcase explosion relief valves **(6)** (see also [2.4.4])	Volume of crankcase and other spaces (camshaft drive, scavenge, etc.)
33	I	Operation and service manuals	–
34	I	Data sheet for torsional vibration calculations	Inertia and stiffness
35	I	Bearing load calculation or oil film thickness calculation	–

(1) A = to be submitted for approval ; I = to be submitted for information.
Where two indications I / A are given, the first refers to cast design and the second to welded design.
(2) To be submitted only if the thrust bearing is not integral with the engine and not integrated in the engine bedplate.
(3) Only for one cylinder.
(4) To be submitted only if sufficient details are not shown on the engine transverse and longitudinal cross-sections.
(5) Dimensions and materials of pipes, capacity and head of pumps and compressors and any additional functional information are to be included. The layout of the entire system is also required, if this is part of the goods to be supplied by the engine Manufacturer.
(6) Required only for engines with cylinder bore of 200 mm and above or crankcase gross volume of 0,6 m^3 and above.

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging
- the charging air cooling system (with or without intercooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

Note 1: Power corrections are to be made in accordance with ISO 3046 standard.

The rated power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions [1.3.3], which the engine is capable of delivering as set after the works trials [4.5].

1.3.3 Ambient reference conditions

The power of engines as per [1.1.1], items a), b) and c) is to be referred to the following conditions:

- barometric pressure = 0,1 MPa
- relative humidity = 60%
- ambient air temperature = 45°C
- sea water temperature (and temperature at inlet of sea water cooled charge air cooler) = 32°C.

In the case of ships assigned with a navigation notation other than unrestricted navigation, different temperatures may be accepted by the Society.

The engine Manufacturer is not expected to provide the above ambient conditions at a test bed. The rating is to be adjusted according to a recognised standard accepted by the Society.

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.4], it being taken for granted that the documentation concerning the essential engine components listed in [1.2] and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

2 Design and construction

2.1 General

2.1.1 Operating conditions

Attention is to be paid to the specific operating conditions of the engine (e.g. continuous operation at low load) which may be imposed by the ship specification.

2.2 Materials and welding

2.2.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm^2 and not greater than 1000 N/mm^2.

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel or cast alloyed steel of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

- between 400 N/mm² and 560 /mm² for cast carbon steel
- between 400 N/mm² and 700 N/mm² for cast alloyed steel.

2.2.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of NR216 Materials and Welding is to be in accordance with the requirements of Ch 1, Sec 1, [2.2].

2.3 Crankshaft

2.3.1 Check of the scantling

The check of crankshaft strength is to be carried out in accordance with Ch 1, App 1.

Other methods accepted by the ship Owner will be considered on a case by case basis.

2.4 Crankcase

2.4.1 Strength

The scantling of crankcases and crankcase doors is to be designed to be of sufficient strength, and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

2.4.2 Ventilation and drainage

Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted.

Vent pipes, where provided, are to be as small as practicable. If provision is made for the forced extraction of gases from the crankcase (e.g. for detection of explosive mixtures), the vacuum in the crankcase is not to exceed $2{,}5.10^{-4}$ MPa.

Where two or more engines are installed, their vent pipes and lubricating oil drain pipes are to be independent to avoid intercommunication between crankcases.

Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged in the latter at their outlet ends.

2.4.3 Warning notice

A warning notice is to be fitted, preferably on a crankcase door on each side of the engine, or alternatively on the control stand.

This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling of the crankcase.

2.4.4 Crankcase explosion relief valves

a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m³ and above are to be provided with crankcase explosion relief valves in accordance with the following requirements.

b) Engines having a cylinder bore not exceeding 250 mm, are to have at least one valve near each end, but over eight crankthrows, an additional valve is to be fitted near the middle of the engine. Engines having a cylinder bore exceeding 250 mm, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves. Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.

c) Additional relief valves are to be fitted on separate spaces of the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m³ or above. Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.

d) The free area of each relief valve is not to be less than 45 cm².

e) The combined free area of the valves fitted on an engine is not to be less than 115 cm² per cubic metre of the crankcase gross volume. (See Note 1).

f) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent any inrush of air thereafter.

g) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

h) Crankcase explosion relief valves are to be designed and constructed to open quickly and to be fully open at a pressure not greater than 0,02 MPa.

i) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

j) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine.

The purpose of type testing crankcase explosion valves is:

- to verify the effectiveness of the flame arrester
- to verify that the valve closes after an explosion
- to verify that the valve is gas/air tight after an explosion
- to establish the level of overpressure protection provided by the valve.

Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

k) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

- description of valve with details of function and design limits
- copy of type test certification
- installation instructions
- maintenance in service instructions to include testing and renewal of any sealing arrangements
- actions required after a crankcase explosion.

l) A copy of the installation and maintenance manual required in i) above is to be provided on board the unit.

m) Valves are to be provided with suitable markings that include the following information:

- name and address of manufacturer
- designation and size
- month/year of manufacture
- approved installation orientation.

Note 1: The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

2.5 Cylinder overpressure gauge

2.5.1 Means are to be provided to indicate a predetermined overpressure in the cylinders of engines having a bore exceeding 230 mm.

2.6 Scavenge manifolds

2.6.1 Fire-extinguishing

For two-stroke crosshead type engines, scavenge spaces in open connection (without valves) to the cylinders are to be connected to a fixed fire-extinguishing system, which is to be entirely independent of the fire-extinguishing system of the machinery space.

2.6.2 Blowers

Where a single two-stroke propulsion engine is equipped with an independently driven blower, alternative means to drive the blower or an auxiliary blower are to be provided ready for use.

2.6.3 Relief valves

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [2.4.4].

2.7 Systems

2.7.1 General

In addition to the requirements of the present sub-article, those given in Ch 1, Sec 10 are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

2.7.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

a) All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a shielded piping system capable of containing fuel from a high pressure line failure.

A shielded pipe incorporates an outer pipe into which the high pressure fuel pipe is placed forming a permanent assembly.

The shielded piping system is to include a means for collection of leakages and arrangements are to be provided for an alarm to be given in the event of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

b) For ships classed for restricted navigation, the requirements under a) may be relaxed at the Society’s discretion.

2.7.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.7.4 Charge air system

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Ch 1, Sec 15.

b) When two-stroke propulsion engines are supercharged by exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering turbocharger casings and causing damage to blades and nozzle rings.

2.8 Starting air system

2.8.1 The requirements given in [3.1] apply.

2.9 Cooling system

2.9.1 The requirements given in Ch 1, Sec 10, [10] apply.

2.10 Control and monitoring

2.10.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 3 apply.

2.10.2 Governors of main and auxiliary engines

Each engine, except the auxiliary engines for driving electric generators for which [2.10.5] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.10.3 Overspeed protective devices of main and auxiliary engines

In addition to the speed governor, each

- main propulsion engine having a rated power of 220kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220kW and above, except those for driving electric generators, for which [2.10.6] applies,

is to be fitted with a separate overspeed protective device so adjusted that the engine cannot exceed the rated speed n by more than:

- 12% in case of mechanical device
- 15% in case of electrical device.

Equivalent arrangements may be accepted subject to special consideration by the Society in each case.

The overspeed protective device, including its driving mechanism or speed sensor, is to be independent of the governor.

2.10.4 Governors for auxiliary engines driving electric generators

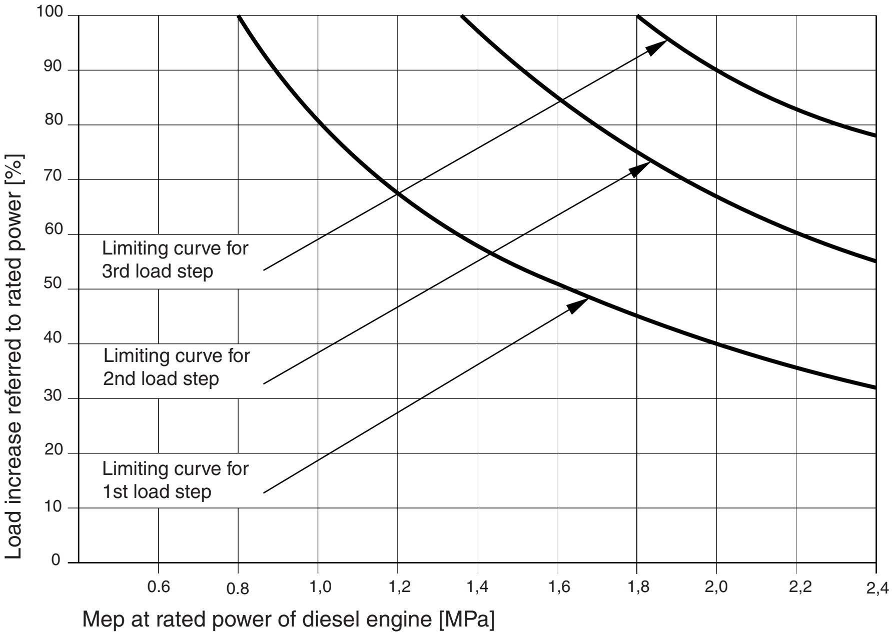
a) Auxiliary engines intended for driving electric generators are to be fitted with a speed governor which prevents any transient speed variations in excess of 10% of the rated speed when the rated power is suddenly thrown off or specific loads are suddenly thrown on.

b) At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.

c) Prime movers are to be selected in such a way that they meet the load demand within the ship’s mains and, when running at no load, can satisfy the requirement in item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s.

Note 1: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

Figure 1 : Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as a function of the brake mean effective pressure



d) Application of the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance) and provided that this is already allowed for in the designing stage.

This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected

This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

e) When the rated power is suddenly thrown off, steady state conditions should be achieved in not more than 5s.

f) Emergency generator sets must satisfy the governor conditions as per items a) and b) even when their total emergency consumer load is applied suddenly.

g) For alternating current generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.10.5 Overspeed protective devices of auxiliary engines driving electric generators

In addition to the speed governor, auxiliary engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

2.10.6 Use of electronic governors

a) Type approval

Provisions are to be made for controlling the engine speed in case of failure of the electrical supply.

Electronic governors and their actuators are to be type approved by the Society.

b) Electronic governors for main propulsion engines

If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to "zero".

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis.

2.10.7 Summary tables

Diesel engines installed on ships without automation notations are to be equipped with monitoring equipment as detailed in Tab 2 and Tab 3 for main propulsion, in Tab 4 for auxiliary services and in Tab 5 for emergency services.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

Table 2 : Monitoring of main propulsion slow speed diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shutdown	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Fuel rack position		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L **(4)**	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate	L **(4)**	local					
	LL			X			
Lubricating oil to camshaft pressure when separate	L **(4)**	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Main, crank, cross-head bearing, oil outlet temp	H						
Cylinder fresh cooling water system inlet pressure	L	local**(3)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local					
	HH		X				
Piston coolant inlet pressure on each cylinder **(1)**	L	local					
Piston coolant outlet temperature on each cylinder**(1)**		local					
Piston coolant outlet flow on each cylinder **(1)** **(2)**	L						
Speed of turbocharger		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local**(5)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine.
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.
(3) For engines of 220 KW and above.
(4) Audible and visual alarm.
(5) Indication is required after each cylinder, for engines of 500 kW per cylinder and above.

Table 3 : Monitoring of main propulsion medium or high speed diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shutdown	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Fuel rack position		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L **(2)**	local					
	LL			X			
Lubricating oil filter differential pressure	H	local					
Turbocharger lubricating oil inlet pressure **(4)**		local					
Lubricating oil inlet temperature		local					
Cylinder fresh cooling water system inlet pressure	L	local**(1)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local					
	HH		X				
Cylinder fresh cooling water, expansion tank level	L	local					
	LL		X				
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local**(3)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) For engines of 220 kW and above.
(2) Audible and visual alarm.
(3) Indication is required after each cylinder, for engines of 500 kW per cylinder and above.
(4) If without integrated self-contained oil lubrication system.

Table 4 : Monitoring of diesel engines used for auxiliary services

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local		X**(1)**			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Cylinder fresh cooling water, expansion tank level	L	local					
	LL		X				
Engine speed		local					
	H			X			
Exhaust gas temperature		local					
Fault in the electronic governor system	X						

(1) Not applicable to emergency generator set.

Table 5 : Monitoring of emergency diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil leakage from pressure pipes	H						
Lubricating oil temperature**(1)**	H	local					
Lubricating oil pressure	L	local					
Oil mist concentration in crankcase **(2)**	H	local					
Pressure or flow of cooling water **(1)**	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X**(1)**			
Fault in the electronic governor system	X						

(1) Not applicable to emergency generator set of less than 220 kW.
(2) For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.
Note 1: The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.
Note 2: Regardless of the engine output, if shutdowns additional to those above specified except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.
Note 3: The alarm system is to function in accordance with **AUT** notation, with additional requirements that grouped alarms are to be arranged on the bridge.
Note 4: In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.
Note 5: The local indications are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

a) The total capacity of air receivers of each propulsion line is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of main engines of the reversible type, and not less than 6 consecutive starts of main non-reversible type engines connected to a controllable pitch propeller or other device enabling the start without opposite torque.

When other users such as auxiliary engine starting systems, control systems, whistle etc. are connected to the starting air receivers of main propulsion engines, their air consumption is also to be taken into account.

For multi-engine propulsion plants, the capacity of the starting air receivers is to be sufficient to ensure at least 3 consecutive starts per engine. However, the total capacity is not to be less than 12 starts and need not exceed 18 starts.

Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced subject to the agreement of the Society and depending upon the arrangement of the engines and the transmission of their output to the propellers.

b) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:

- An isolating non-return valve, or equivalent, at the starting air supply connection to each engine.
- A bursting disc or flame arrester:
  - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
  - at least at the supply inlet to the starting air manifold, for non-reversing engines.

  The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

c) Compressed air receivers are to comply with the requirements of Ch 1, Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Ch 1, Sec 10.

3.1.2 Electrical starting

a) Where main internal combustion engines are arranged for electrical starting, at least two separate batteries are to be fitted.

The arrangement is to be such that the batteries cannot be connected in parallel.

Each battery is to be capable of starting the main engine when in cold and ready to start condition.

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [3.1.1] b) in the event of air starting.

b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.

d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

3.1.3 Special requirements for starting arrangements for emergency generating sets

a) Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society shall be made for the maintenance of heating arrangements, to ensure ready starting of the generating sets.

b) Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the Society with a stored energy capability of at least three consecutive starts.

The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

c) The stored energy is to be maintained at all times, as follows:

- electrical and hydraulic starting systems shall be maintained from the emergency switchboard
- compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard
- all of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.

d) Where automatic starting is not required, manual starting, such as manual cranking, inertia starters, manually charged hydraulic accumulators, or powder charge cartridges, is permissible where this can be demonstrated as being effective.

e) When manual starting is not practicable, the requirements of items b) and c) are to be complied with, except that starting may be manually initiated.

3.2 Turning gear

3.2.1 Each engine is to be provided with hand-operated turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations.

3.3 Trays

3.3.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.4 Exhaust gas system

3.4.1 In addition to the requirements given in Ch 1, Sec 10, the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C (see also Ch 1, Sec 1, [3.7]).

3.4.2 Pressure losses in the exhaust ducting are to comply with the limits stated by the engine manufacturer.

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalisation of the engine design for production of every new engine type intended for installation on board ships, one engine is to be presented for type testing as required below.

A type test carried out for a particular type of engine at any place in any manufacturer's works will be accepted for all engines of the same type (see [1.3.4]) built by licensees and licensors.

In any case, one type test suffices for the whole range of engines having different numbers of cylinders.

Engines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the engine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable engine operation have been carried out during preliminary internal tests by the engine Manufacturer
- the documentation to be submitted as required in [1.2] has been examined and, when necessary, approved by the Society and the latter has been informed about the nature and extent of investigations carried out during pre-production stages.

4.1.2 At the request of the Manufacturer, an increase in power and/or mean effective pressure up to a maximum of 10% may be accepted by the Society for an engine previously subjected to a type test without any further such test being required, provided the engine reliability has been proved successfully by the service experience of a sufficient number of engines of the same type.

For the purpose of the acceptance of the above performance increase, the Manufacturer is in any case to submit for examination and, where necessary, approval, the documentation listed in [1.2] relevant to any components requiring modification in order to achieve the increased performance.

4.1.3 The Society reserves the right to impose additional requirements or grant dispensations to the following type test programs.

4.2 Type tests of engines not admitted to an alternative inspection scheme

4.2.1 General

Engines which are not admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) are to be type tested in the presence of a Surveyor in accordance with the requirements of [4.2].

The type test is subdivided into three stages, namely:

a) Stage A - Preliminary internal tests carried out by the Manufacturer.

   Stage A includes functional tests and collection of operating values including the number of testing hours during the internal tests, the results of which are to be presented to the Surveyor during the type test. The number of testing hours of components which are inspected according to [4.2.5] is to be stated by the Manufacturer.

b) Stage B - Type approval test

   The type approval test is to be carried out in the presence of the Surveyor.

c) Stage C - Inspection of main engine components.

After completion of the test programme, the main engine components are to be inspected.

The engine Manufacturer is to compile all results and measurements for the engine tested during the type test in a type test report, which is to be submitted to the Society.

4.2.2 Stage A - Internal tests (function tests and collection of operating data)

During the internal tests the engine is to be operated at the load points considered important by the engine Manufacturer and the relevant operating values are to be recorded (see item a)).

The load points may be selected according to the range of application (see Fig 2).

If an engine can be satisfactorily operated at all load points without using mechanically driven cylinder lubricators, this is to be verified.

For engines which may operate on heavy fuel oil, their suitability for this is to be proved to the satisfaction of the Society.

a) Functional tests under normal operating conditions

   Functional tests under normal operating conditions include:

   1) The load points 25%, 50%, 75%, 100% and 110% of the maximum continuous power for which type approval is requested, to be carried out:

      - along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
      - at constant speed, for engines intended for generating sets.

   2) The limit points of the permissible operating range.

      These limit points are to be defined by the engine Manufacturer.

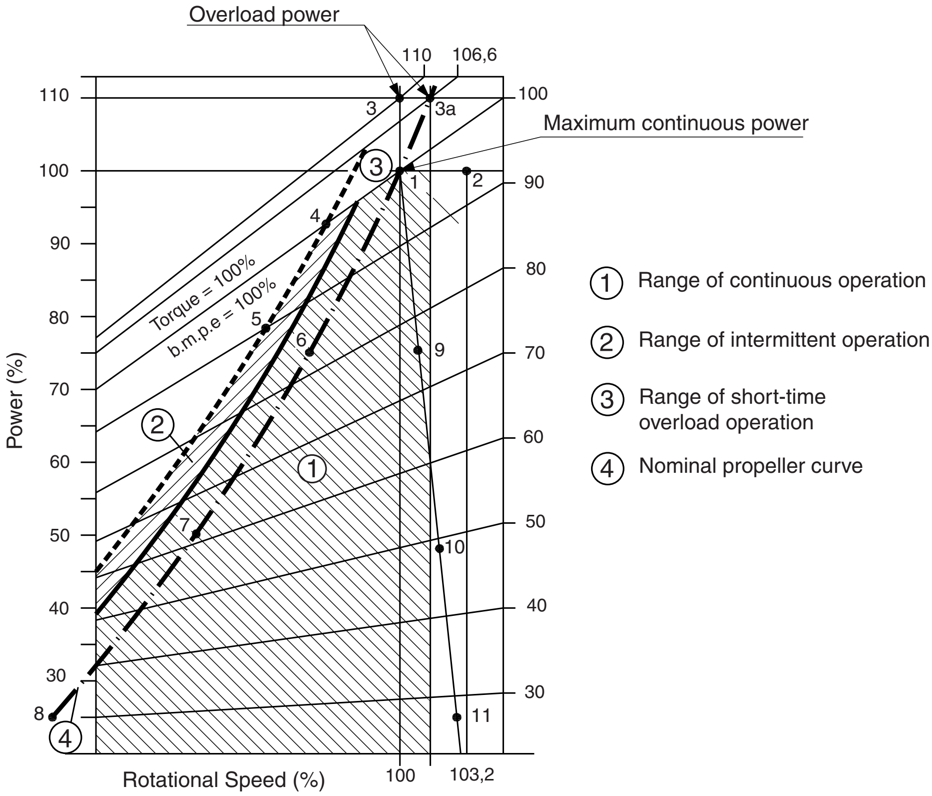
   The maximum continuous power P is defined in [1.3.2].

b) Tests under emergency operating conditions

   For turbocharged engines, the achievable continuous output is to be determined for a situation when one turbocharger is damaged, i.e.:

   - for engines with one turbocharger, when the rotor is blocked or removed
   - for engines with two or more turbochargers, when the damaged turbocharger is shut off.

Figure 2 : Power/speed diagram



4.2.3 Stage B - Type approval tests in the presence of the Surveyor

During the type test, the tests listed below are to be carried out in the presence of the Surveyor and the results are to be recorded in a report signed by both the engine Manufacturer and the Surveyor.

For engines not yet adequately experienced in service the scope of test will be agreed on a case by case basis.

Any departures from this programme are to be agreed upon by the engine Manufacturer and the Society.

a) Load points

The load points at which the engine is to be operated according to the power/speed diagram (see Fig 2) are those listed below. The data to be measured and recorded when testing the engine at various load points are to include all necessary parameters for engine operation.

The operating time per load point depends on the engine characteristics (achievement of steady-state condition) and the time for collection of the operating values.

Normally, an operating time of 0,5 hour per load point can be assumed.

At the maximum continuous power as per the following item 1) an operating time of two hours is required. Two sets of readings are to be taken at a minimum interval of one hour.

1) Test at maximum continuous power P: i.e. 100% output at 100% torque and 100% speed, corresponding to load point 1 in the diagram in Fig 2.

2) Test at 100% power at maximum permissible speed, corresponding to load point 2 in the diagram in Fig 2.

3) Test at maximum permissible torque (normally 110% of nominal torque T) at 100% speed, corresponding to load point 3 in the diagram in Fig 2; or test at maximum permissible power (normally 110% of P) and speed according to the nominal propeller curve, corresponding to load point 3a in the diagram in Fig 2.

4) Test at minimum permissible speed at 100% of torque T, corresponding to load point 4 in the diagram in Fig 2.

5) Test at minimum permissible speed at 90% of torque T, corresponding to load point 5 in the diagram in Fig 2.

6) Tests at part loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve, corresponding to load points 6, 7 and 8 in the diagram in Fig 2; and tests at the above part loads and at speed n with constant governor setting, corresponding to load points 9, 10 and 11 in the diagram in Fig 2.

b) Tests under emergency operating conditions

These are tests at maximum achievable power when operating along the nominal propeller curve and when operating with constant governor setting for speed n, in emergency operating conditions as stated in [4.2.2] b).

c) Additional tests
- Test at lowest engine speed according to the nominal propeller curve.
- Starting tests for non-reversible engines, or starting and reversing tests for reversible engines.
- Governor tests.
- Testing of the safety system, particularly for overspeed and low lubricating oil pressure.

For engines intended to be used for emergency services, supplementary tests may be required to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C.

4.2.4 Evaluation of test results

The results of the tests and checks required by [4.2.3] will be evaluated by the attending Surveyor. Normally the main operating data to be recorded during the tests are those listed in [4.3.4].

In particular, the maximum combustion pressure measured with the engine running at the maximum continuous power P is not to exceed the value taken for the purpose of checking the scantlings of the engine crankshaft, according to the applicable requirements of Chapter 1, Appendix 1.

The values of temperatures and pressures of media, such as cooling water, lubricating oil, charge air, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the engine tested.

4.2.5 Stage C - Inspection of main engine components

Immediately after the test run as per [4.2.3], the components of one cylinder for in-line engines, and two cylinders for V-type engines, are to be presented for inspection to the Surveyor.

The following main engine components are to be inspected:
- piston removed and dismantled
- crosshead bearing, dismantled
- crank bearing and main bearing, dismantled
- cylinder liner in the installed condition
- cylinder head and valves, disassembled
- control gear, camshaft and crankcase with opened covers.

Where deemed necessary by the Surveyor, further dismantling of the engine may be required.

4.3 Type tests of engines admitted to an alternative inspection scheme

4.3.1 General

Engines for which the Manufacturer is admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) and which have a cylinder bore not exceeding 300 mm are to be type tested in the presence of a Surveyor in accordance with the requirements of the present [4.3].

The selection of the engine to be tested from the production line is to be agreed upon with the Surveyor.

4.3.2 Type test

The programme of the type test is to be in general as specified below, P being the maximum continuous power and n the corresponding speed. The maximum continuous power is that stated by the engine Manufacturer and accepted by the Society, as defined in [1.3.2].

a) 80 hours at power P and speed n
b) 8 hours at overload power (110% of power P)
c) 10 hours at partial loads (25%, 50%, 75% and 90% of power P)
d) 2 hours at intermittent loads
e) starting tests
f) reverse running for direct reversing engines
g) testing of speed governor, overspeed device and lubricating oil system failure alarm device
h) testing of the engine with one turbocharger out of action, when applicable
i) testing of the minimum speed along the nominal (theoretical) propeller curve, for main propulsion engines driving fixed pitch propellers, and of the minimum speed with no brake load, for main propulsion engines driving controllable pitch propellers or for auxiliary engines.

The tests at the above-mentioned outputs are to be combined together in working cycles which are to be repeated in succession for the entire duration within the limits indicated.

In particular, the overload test, to be carried out at the end of each cycle, is to be of one hour’s duration and is to be carried out alternately:
- at 110% of the power P and 103% of the speed n
- at 110% of the power P and 100% of the speed n.

The partial load tests specified in item c) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
- at constant speed, for engines intended for generating sets.

For engines intended to be used for emergency services, supplementary tests may be required, to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C, as required in [3.1.3].

In the case of prototype engines, the duration and programme of the type test will be not lower than the one specified in this paragraph.

4.3.3 In cases of engines for which the Manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society, at its discretion, may allow a type test to be carried out in the presence of the Surveyor according to a programme to be agreed upon in each instance.

In the case of engines which are to be type approved for different purposes and performances, the programme and duration of the type test will be decided by the Society in each case to cover the whole range of engine performances for which approval is requested, taking into account the most severe values.

4.3.4 During the type test, at least the following particulars are to be recorded:

a) ambient air temperature, pressure and atmospheric humidity in the test room

b) cooling raw water temperature at the inlet of heat exchangers

c) characteristics of fuel and lubricating oil used during the test

d) engine speed

e) brake power

f) brake torque

g) maximum combustion pressure

h) indicated pressure diagrams, where practicable

i) exhaust smoke (with a smoke meter deemed suitable by the Surveyor)

j) lubricating oil pressure and temperature

k) cooling water pressure and temperature

l) exhaust gas temperature in the exhaust manifold and, where facilities are available, from each cylinder

m) minimum starting air pressure necessary to start the engine in cold condition.

In addition to the above, for supercharged engines the following data are also to be measured and recorded:

- turbocharger speed
- air temperature and pressure before and after turbocharger and charge air coolers
- exhaust gas temperatures and pressures before and after turbochargers and cooling water temperature at the inlet of charge air coolers.

4.3.5 Inspection of main engine components and evaluation of test results

The provisions of [4.2.4] and [4.2.5] are to be complied with, as far as applicable.

4.4 Material and non-destructive tests

4.4.1 Material tests

Engine components are to be tested in accordance with Tab 6 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 6 and are to be effected in positions mutually agreed upon by the Manufacturer and the Society Surveyor, where experience shows defects are most likely to occur.

The magnetic particle test of tie rods/stay bolts is to be carried out at each end, for a portion which is at least twice the length of the thread.

For important structural parts of engines, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any engine component, non-destructive tests using approved detecting methods may be required.

Engines of a cylinder diameter not exceeding 300 mm may be tested according to an alternative survey scheme.

4.4.2 Hydrostatic tests

Parts of engines under pressure are to be hydrostatically tested at the test pressure specified for each part in Tab 7.

The following parts of auxiliaries which are necessary for operation of engines as per [1.1.1] a), b) and c):

- cylinders, cylinder covers, coolers and receivers of independent air compressors
- water, oil and air coolers (tube bundles or coils, shells and heads) not fitted on the engine and filters
- independently driven lubricating oil, fuel oil and water pumps
- pressure pipes (water, lubricating oil, fuel oil, and compressed air pipes), valves and other fittings

are to be subjected to hydrostatic tests at 1,5 times the maximum working pressure, but not less than 0,4 MPa.

4.5 Workshop inspections and testing

4.5.1 General

In addition to the type test, diesel engines are to be subjected to works trials, which are to be witnessed by the Surveyor also when an Alternative Inspection Scheme has been granted.

For all stages at which the engine is to be tested, the relevant operating values are to be measured and recorded by the engine Manufacturer.

In each case all measurements conducted at the various load points are to be carried out at steady operating conditions.

The readings for 100% of the rated power P at the corresponding speed n are to be taken twice at an interval of at least 30 minutes.

At the discretion of the Surveyor, the programme of trials given in [4.5.2], [4.5.3] or [4.5.4] may be expanded depending on the engine application.

4.5.2 Main propulsion engines driving propellers

Main propulsion engines are to be subjected to trials to be performed as follows:

a) at least 60 min, after having reached steady conditions, at rated power P and rated speed n
b) 30 min, after having reached steady conditions, at 110% of rated power P and at a speed equal to 1,032 of rated speed
c) tests at 90% (or normal continuous cruise power), 75%, 50% and 25% of rated power P, carried out:
   - at the speed corresponding to the nominal (theoretical) propeller curve, for engines driving fixed pitch propellers
   - at constant speed, for engines driving controllable pitch propellers
d) idle run
e) starting and reversing tests (when applicable)
f) testing of the speed governor and of the independent overspeed protective device
g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system is to be so adjusted that the engine cannot deliver more than 100% of the rated power at the corresponding speed (overload power cannot be obtained in service).

4.5.3 Engines driving electric generators used for main propulsion purposes

Engines driving electric generators are to be subjected to trials to be performed with a constant governor setting, as follows:

a) at least 60 min, after having reached steady conditions, at 100% of rated power P and rated speed n
b) 45 min, after having reached steady conditions, at 110% of rated power and rated speed
c) 75%, 50% and 25% of rated power P, carried out at constant rated speed n
d) idle run
e) starting tests
f) testing of the speed governor ([2.10.5]) and of the independent overspeed protective device (when applicable)
g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be maintained at all times.

4.5.4 Engines driving auxiliary machinery

Engines driving auxiliary machinery are to be subjected to the tests stated in [4.5.2] or [4.5.3] for variable speed and constant speed drives, respectively.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be fulfilled at all times.

4.5.5 Inspection of engine components

Random checks of components to be presented for inspection after works trials are left to the discretion of the Surveyor.

4.5.6 Parameters to be measured

The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for engine operation. The crankshaft deflection is to be verified when this check is required by the Manufacturer during the operating life of the engine.

4.5.7 Testing report

In the testing report for each engine the results of the tests carried out are to be compiled and the reference number and date of issue of the Type Approval Certificate (see [4.6]), relevant to the engine type, are always to be stated; the testing report is to be issued by the Manufacturer and enclosed with the testing certificate as per [4.6].

4.6 Certification

4.6.1 Type Approval Certificate and its validity

After the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the engine manufacturer a "Type Approval Certificate" valid for all engines of the same type.

The Society reserves the right to consider the test carried out on one engine type valid also for engines having a different cylinder arrangement, following examination of suitable, detailed documentation submitted by the Manufacturer and including bench test results.

Table 6 : Material and non-destructive tests

Engine component	Material tests **(1)** (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Crankshaft	all	all	all
2) Crankshaft coupling flange (non-integral) for main power transmissions	if bore > 400 mm	–	–
3) Coupling bolts for crankshaft	if bore > 400 mm	–	–
4) Steel piston crowns **(2)**	if bore > 400 mm	if bore > 400 mm	all
5) Piston rods	if bore > 400 mm	if bore > 400 mm	if bore > 400 mm
6) Connecting rods, together with connecting rod bearing caps	all	all	if bore > 400 mm
7) Crossheads	if bore > 400 mm	–	–
8) Cylinder liners	if bore > 300 mm	–	–
9) Steel cylinder covers **(2)**	if bore > 300 mm	if bore > 400 mm	all
10) Bedplates of welded construction; plates and transverse bearing girders made of forged or cast steel **(2)(3)**	all	all	all
11) Frames and crankcases of welded construction **(3)**	all	–	–
12) Entablatures of welded construction **(3)**	all	–	–
13) Tie rods	all	if bore > 400 mm	–
14) Shafts and rotors, including blades, for turbochargers **(4)**	(see Ch 1, Sec 15)	–	–
15) Bolts and studs for cylinder covers, crossheads, main bearings and connecting rod bearings; nuts for tie rods	if bore > 300 mm	if bore > 400 mm	–
16) Steel gear wheels for camshaft drives	if bore > 400 mm	if bore > 400 mm	–

(1) In addition, material tests may also be required, at the Society’s discretion, for piping and valves for starting air lines and any other pressure piping fitted on the engines.
(2) For items 4), 9) and 10), it is implicit that as well as for steel parts, material tests are also required for parts made of other materials which are comparable to steel on account of their mechanical properties in general and their ductility in particular: e.g. aluminium and its alloys, ductile and spheroidal or nodular graphite cast iron.
(3) Material tests for bedplates, frames, crankcases and entablatures are required even if these parts are not welded and for any material except grey cast iron.
(4) Turbocharger is understood as turbocharger itself and engine driven compressor (incl. "root blowers", but not auxiliary blowers).

4.6.2 Testing certification

a) Engines admitted to an alternative inspection scheme

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 6 and Tab 7.

b) Engines not admitted to an alternative inspection scheme

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in Tab 6 and for works trials as per [4.5].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for non-destructive and hydrostatic tests of components in Tab 6 and Tab 7.

In both cases a) and b), the Manufacturer is to supply:

a) the following information:
- engine type
- rated power
- rated speed
- driven equipment
- operating conditions
- list of auxiliaries fitted on the engine

b) a statement certifying that the engine is in compliance with that type tested, except for modifications already notified to the Society. The reference number and date of the Type Approval Certificate are also to be indicated in the statement.

Table 7 : Test pressure of engine parts

Parts under pressure		Test pressure (MPa) **(1)** **(2)**
1	Cylinder cover, cooling space **(3)**	0,7
2	Cylinder liner, over the whole length of cooling space	0,7
3	Cylinder jacket, cooling space	0,4 (but not less than 1,5 p)
4	Exhaust valve, cooling space	0,4 (but not less than 1,5 p)
5	Piston crown, cooling space **(3)** **(4)**	0,7
6	Fuel injection system a) Fuel injection pump body, pressure side b) Fuel injection valve c) Fuel injection pipes	 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser)
7	Hydraulic system • Piping, pumps, actuators etc. for hydraulic drive of valves	 1,5 p
8	Scavenge pump cylinder	0,4
9	Turbocharger, cooling space	0,4 (but not less than 1,5p)
10	Exhaust pipe, cooling space	0,4 (but not less than 1,5 p)
11	Engine driven air compressor (cylinders, covers, intercoolers and aftercoolers) a) Air side b) Water side	 1,5 p 0,4 (but not less than 1,5 p)
12	Coolers, each side **(5)**	0,4 (but not less than 1,5 p)
13	Engine driven pumps (oil, water, fuel, bilge)	0,4 (but not less than 1,5 p)

(1) In general, parts are to be tested at the hydraulic pressure indicated in the Table. Where design or testing features may call for modification of these testing requirements, special consideration will be given by the Society.
(2) p is the maximum working pressure, in MPa, in the part concerned.
(3) For forged steel cylinder covers and forged steel piston crowns, test methods other than hydrostatic testing may be accepted, e.g. suitable non-destructive tests and documented dimensional tests.
(4) Where the cooling space is sealed by the piston rod, or by the piston rod and the shell, the pressure test is to be carried out after assembly.
(5) Turbocharger air coolers need to be tested on the water side only.

Section 3 Pressure Equipment

1 General

1.1 Principles

1.1.1 Scope of the Rules

The boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and is to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards. The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

So these Rules apply to “pressure equipment” for the following requirements:

- be safe in sight of pressure risk
- be safe in sight of other risks, moving parts, hot surfaces
- ensure capability of propulsion and other essential services.

“Pressure equipment” means pressure vessels, piping (Ch 1, Sec 10), safety accessories and pressure accessories.

1.1.2 Overpressure risk

Where main or auxiliary boilers and other pressure vessels or any parts thereof may be subject to dangerous overpressure, means are to be provided where practicable to protect against such excessive pressure.

1.1.3 Propulsion capability

Means are to be provided whereby normal operation of main boilers can be sustained or restored even through one of the essential auxiliaries become inoperative. Special consideration is to be given to the malfunctioning of:

- the source of steam supply
- the boiler feed water systems
- the fuel oil supply system for boilers
- the mechanical air supply for boilers.

However the Society, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.

1.1.4 Tests

All boilers and other pressure vessels including their associated fittings which are under internal pressure are to be subjected to appropriate tests including a pressure test before being put into service for the first time (see also Article [7]).

1.2 Application

1.2.1 Pressure vessels covered by the Rules

The requirements of this Section apply to:

- all fired or unfired pressures vessels of metallic construction, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2]
- all boilers and other steam generators, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2].

1.2.2 Pressure vessels not covered by the Rules

Among others the following boilers and pressure vessels are not covered by the Rules and are to be considered on a case by case basis:

a) boilers with design pressure $p > 10$ MPa

b) pressure vessel intended for radioactive material

c) equipment comprising casings or machinery where the dimensioning, choice of material and manufacturing rules are based primarily on requirements for sufficient strength, rigidity and stability to meet the static and dynamic operational effects or other operational characteristics and for which pressure is not a significant design factor. Such equipment may include:
   - engines including turbines and internal combustion engines
   - steam engines, gas/steam turbines, turbo-generators, compressors, pumps and actuating devices

d) small pressure vessels included in self-contained domestic equipment.

1.3 Definitions

1.3.1 Pressure vessel

"Pressure vessel" means a housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

1.3.2 Fired pressure vessel

Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases or otherwise heated pressure vessel with a risk of overheating.

a) Boiler

   Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a temperature above 120°C.

   Any equipment directly connected to the boiler, such as economisers, superheaters and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered as part of the boiler upstream of the isolating valve and as part of the associated piping system downstream of the isolating valve.

b) Thermal oil heater

   Thermal oil heater is one or more fired pressure vessels and associated piping systems in which organic liquids (thermal oils) are heated. When heated by electricity thermal oil heater is considered as an unfired pressure vessel.

1.3.3 Unfired pressure vessel

Any pressure vessel which is not a fired pressure vessel is an unfired pressure vessel.

a) Heat exchanger

   A heat exchanger is an unfired pressure vessel used to heat or cool a fluid with an another fluid. In general heat exchangers are composed of a number of adjacent chambers, the two fluids flowing separately in adjacent chambers. One or more chambers may consist of bundles of tubes.

b) Steam generator

   A steam generator is a heat exchanger and associated piping used for generating steam. In general in these Rules, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.

1.3.4 Safety accessories

"Safety accessories" means devices designed to protect pressure equipment against the allowable limits being exceeded. Such devices include:

- devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems, and
- limiting devices, which either activate the means for correction or provide for shutdown or shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and safety related measurement control and regulation devices.

1.3.5 Design pressure

The design pressure is the pressure used by the manufacturer to determine the scantlings of the vessel. This pressure cannot be taken less than the maximum working pressure and is to be limited by the set pressure of the safety valve, as prescribed by the applicable Rules. Pressure is indicated as gauge pressure above atmospheric pressure, vacuum is indicated as negative pressure.

1.3.6 Design temperature

a) Design temperature is the actual metal temperature of the applicable part under the expected operating conditions, as modified in Tab 1. This temperature is to be stated by the manufacturer and is to take in account of the effect of any temperature fluctuations which may occur during the service.

b) The design temperature is not to be less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case by case basis.

1.3.7 Volume

Volume V means the internal volume of a chamber, including the volume of nozzles to the first connection or weld and excluding the volume of permanent internal parts.

1.3.8 Boiler heating surface

Heating surface is the area of the part of the boiler through which the heat is supplied to the medium, on the side exposed to fire or hot gases.

1.3.9 Maximum steam output

Maximum steam output is the maximum quantity of steam than can be produced continuously by the boiler or steam generator operating under the design steam conditions.

Table 1 : Minimum design temperature

Type of vessel	Minimum design temperature
Pressure parts of pressure vessels and boilers not heated by hot gases or adequately protected by insulation	Maximum temperature of the internal fluid
Pressure vessel heated by hot gases	25°C in excess of the temperature of the internal fluid
Water tubes of boilers mainly subjected to convection heat	25°C in excess of the temperature of the saturated steam
Water tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to convection heat	35°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Economiser tubes	35°C in excess of the temperature of the internal fluid
For combustion chambers of the type used in wet-back boilers	50°C in excess of the temperature of the internal fluid
For furnaces, fire-boxes, rear tube plates of dry-back boilers and other pressure parts subjected to similar rate of heat transfer	90°C in excess of the temperature of the internal fluid

1.3.10 Toxic and corrosive substances

Toxic and corrosive substances are those which are listed in the IMO “International Maritime Dangerous Goods Code (IMDG Code)”, as amended.

1.3.11 Liquid and gaseous substances

a) liquid substances are liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar above normal atmospheric pressure

b) gaseous substances are gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar above normal atmospheric pressure.

1.3.12 Ductile material

For the purpose of this Section, ductile material is a material having an elongation over 12%.

1.3.13 Incinerator

Incinerator is a shipboard facility for incinerating solid garbage approximating in composition to household garbage and liquid garbage deriving from the operation of the ship (e.g. domestic garbage, cargo-associated garbage, maintenance garbage, operational garbage, cargo residue, and fishing gear), as well as for burning sludge with a flash point above 60°C.

These facilities may be designed to use the heat energy produced.

Incinerators are not generally pressure vessels, however when their fittings are of the same type than those of boilers the requirements for these fittings apply.

1.4 Classes

1.4.1 Significant parameters

Pressure vessels are classed in three class in consideration of the:

- type of equipment: pressure vessel or steam generator
- state (gaseous or liquid) of the intended fluid contents
- substances listed or not in the IMDG Code
- design pressure p, in MPa
- design temperature T, in °C
- actual thickness of the vessel t_A, in mm
- volume V, in litres.

1.4.2 Pressure vessel classification

Pressure vessels are classed as indicated in Tab 2.

1.4.3 Implication of class

The class of a pressure vessel has, among others, implication in:

- design
- material allowance
- welding design
- efficiency of joints
- examination and non-destructive tests
- thermal stress relieving.

See Tab 24.

Table 2 : Pressure vessel classification

Equipment	Class 1	Class 2	Class 3
Steam generators or boilers	$p > 3{,}2$ and $V > 2$ or $p\,V > 20$ and $V > 2$	if not class 1 or class 3	$p\,V \leq 5$ or $V \leq 2$
Pressure vessels for toxic substances	all	–	–
Pressure vessels for corrosive substances	$p > 20$ or $p\,V > 20$ or $T > 350$	if not in class 1	–
Pressure vessels for gaseous substances	$p > 100$ or $p\,V > 300$	$V > 1$ and $p\,V > 100$ and not in class 1	all pressure vessels which are not class 1 or class 2
Pressure vessels for liquid substances	$V > 10$ and $p\,V > 1000$ and $p > 50$	$V \leq 10$ and $p > 100$ or $1 < p \leq 50$ and $p\,V > 1000$	all pressure vessels and heat exchangers which are not class 1 or class 2
Pressure vessels for thermal oil	$p > 1{,}6$ or $T > 300$	if not class 1 or class 3	$p \leq 0{,}7$ and $T \leq 150$
Pressure vessels for fuel oil, lubricating oil or flammable hydraulic oil	$p > 1{,}6$ or $T > 150$	if not class 1 or class 3	$p \leq 0{,}7$ and $T \leq 60$
Whatever type of equipment	$t_A > 40$	$15 < t_A \leq 40$	–

Note 1: Whenever the class is defined by more than one characteristic, the equipment is to be considered belonging to the highest class of its characteristics, independently of the values of the other characteristics.

1.5 Applicable Rules

1.5.1 Alternative standards

a) Boilers and pressure vessels are to be designed, constructed, installed and tested in accordance with the applicable requirements of this Section.

b) The acceptance of national and international standards as an alternative to the requirements of this Section may be considered by the Society on a case by case basis.

c) In particular composite wrapped cylinders are to be designed, constructed, installed and tested in accordance with a Standard to be accepted by the Society on a case by case basis.

1.6 Documentation to be submitted

1.6.1 General

Documents mentioned in the present sub-article are to be submitted for class 1 and class 2 and not for class 3, unless the equipment is considered as critical.

1.6.2 Boilers and steam generators

The plans listed in Tab 3 are to be submitted.

The drawings listed in Tab 3 are to contain:

- the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles
- strengthening members, such as stays, brackets, opening reinforcements and covers
- installation arrangements, such as saddles and anchoring system,

as well as the information and data indicated in Tab 4.

1.6.3 Pressure vessels

The plans listed in Tab 5 are to be submitted.

The drawings listedin Tab 5 are to contain the constructional details of:

- pressure parts, such as shells, headers, tubes, tube plates, nozzles, opening reinforcements and covers
- strengthening members, such as stays, brackets and reinforcements.

1.6.4 Incinerators

Incinerators are to be considered on a case by case basis, based on their actual arrangement, using the applicable requirements for boilers and pressure vessels.

Table 3 : Drawings to be submitted for boilers and steam generators

No	A/I	Item
1	I	General arrangement plan, including valves and fittings
2	A	Material specifications
3	A	Sectional assembly
4	A	Evaporating parts
5	A	Superheater
6	A	De-superheater
7	A	Economiser
8	A	Air heater
9	A	Tubes and tube plates
10	A	Nozzles and fittings
11	A	Safety valves and their arrangement
12	A	Boiler seating
13	I	Fuel oil burning arrangement
14	I	Forced draft system
15	I	Refractor or insulation arrangement
16	A	Boiler instrumentation, monitoring and control system
17	A	Type of safety valves and their lift, discharge rate and setting
18	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatment
Note 1: A = to be submitted for approval; I = to be submitted for information.		

Table 4 : Information and data to be submitted for boilers and steam generators

No.	Item
1	Design pressure and temperature
2	Pressure and temperature of the superheated steam
3	Pressure and temperature of the saturated steam
4	Maximum steam production per hour
5	Evaporating surface of the tube bundles and water-walls
6	Heating surface of the economiser, superheater and air-heater
7	Surface of the furnace
8	Volume of the combustion chamber
9	Temperature and pressure of the feed water
10	Type of fuel to be used and fuel consumption at full steam production
11	Number and capacity of burners

Table 5 : Drawings, information and data to be submitted for pressure vessels and heat exchangers

No	A/I	Item
1	I	General arrangement plan, including nozzles and fittings
2	A	Sectional assembly
3	A	Safety valves (if any) and their arrangement
4	A	Material specifications
5	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatments
6	I	Design data, including at least design pressure and design temperatures (as applicable)
7	A	For seamless (extruded) pressure vessels, the manufacturing process, including: • a description of the manufacturing process with indication of the production controls normally carried out in the manufacturer's works • details of the materials to be used (specification, yield point, tensile strength, impact strength, heat treatment) • details of the stamped marking to be applied.
8	I	Type of fluid or fluids contained
Note 1: A = to be submitted for approval ; I = to be submitted for information.		

2 Design and construction - Scantlings of pressure parts

2.1 General

2.1.1 Application

a) In general, the formulae in the present Article do not take into account additional stresses imposed by effects other than pressure, such as stresses deriving from the static and dynamic weight of the pressure vessel and its content, external loads from connecting equipment and foundations, etc. For the purpose of the Rules these additional loads may be neglected, provided it can reasonably be presumed that the actual average stresses of the vessel, considering all these additional loads, would not increase more than 10% with respect to the stresses calculated by the formulae in this Article.

b) Where it is necessary to take into account additional stresses, such as dynamic loads, the Society reserves the right to ask for additional requirements on a case by case basis.

2.1.2 Alternative requirements

When pressure parts are of an irregular shape, such as to make it impossible to check the scantlings by applying the formulae of this Article, the approval is to be based on other means, such as burst and/or deformation tests on a prototype or by another method agreed upon between the manufacturer and the Society.

2.2 Materials

2.2.1 Materials for high temperatures

a) Materials for pressure parts having a design temperature exceeding the ambient temperature are to be selected by the Manufacturer and to have mechanical and metallurgical properties adequate for the design temperature. Their allowable stress limits are to be determined as a function of the temperature, as per [2.3.2].

b) When the design temperature of pressure parts exceeds 400°C, alloy steels are to be used. Other materials are subject of special consideration by the Society.

2.2.2 Materials for low temperatures

Materials for pressure parts having a design temperature below the ambient temperature are to have notch toughness properties suitable for the design temperature.

2.2.3 Cast iron

Cast iron is not to be used for:

a) class 1 and class 2 pressure vessels

b) class 3 pressure vessels with design pressure p > 0,7 MPa or product p·V > 1000, where V is the internal volume of the pressure vessel in litres

c) Bolted covers and closures of pressure vessels having a design pressure p > 1 MPa, except for covers intended for boiler shells, for which [3.2.4] applies.

2.2.4 Valves and fittings for boilers

a) Ductile materials are to be used for valves and fittings intended to be mounted on boilers. The material is to have mechanical and metallurgical characteristics suitable for the design temperature and for the thermal and other loads imposed during the operation.

b) Grey cast iron is not to be used for valves and fittings which are subject to dynamic loads, such as safety valves and blow-down valves, and in general for fittings and accessories having design pressure p exceeding 0,3 MPa and design temperature T exceeding 220°C.

c) Spheroidal cast iron is not to be used for parts having a design temperature T exceeding 350°C.

d) Bronze is not to be used for parts having design temperature T exceeding 220°C for normal bronzes and 260°C for bronzes suitable for high temperatures. Copper and aluminium brass are not to be used for fittings with design temperature T above 200°C and copper-nickel fittings with design temperature T exceeding 300°C.

2.2.5 Alternative materials

In the case of boilers or pressure vessels constructed in accordance with one of the standards considered acceptable by the Society as per [1.5], the material specifications are to be in compliance with the requirements of the standard used.

2.3 Permissible stresses

2.3.1 The permissible stresses K, in N/mm^2, for steels, to be used in the formulae of this Article, may be determined from Tab 6, Tab 7, Tab 8 and Tab 9, where R_m is the ultimate strength of the material, in N/mm^2. For intermediate values of the temperature, the value of K is to be obtained by linear interpolation.

Table 6 : Permissible stresses K for carbon steels intended for boilers and thermal oil heaters

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	109	107	105	94	77	73	72
	15 mm < t ≤ 40 mm	128	106	105	101	90	77	73	72
	40 mm < t ≤ 60 mm	122	101	99	95	88	77	73	72
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	127	116	103	79	79	72	69
	15 mm < t ≤ 40 mm	133	122	114	102	79	79	72	69
	40 mm < t ≤ 60 mm	133	112	107	99	79	79	72	69
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	132	130	126	112	94	89	86
	15 mm < t ≤ 40 mm	147	131	124	119	107	94	89	86
	40 mm < t ≤ 60 mm	141	120	117	113	105	94	89	86
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	147	135	121	107	95	88	84
	15 mm < t ≤ 40 mm	152	142	133	120	107	95	88	84
	40 mm < t ≤ 60 mm	152	134	127	117	107	95	88	84
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	164	154	139	124	111	104	99
	15 mm < t ≤ 40 mm	169	162	151	137	124	111	104	99
	40 mm < t ≤ 60 mm	162	157	147	136	124	111	104	99
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	170	170	169	159	147	134	125	112

Table 7 : Permissible stresses K for carbon steels intended for other pressure vessels

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	117	115	112	100	83	78	77
	15 mm < t ≤ 40 mm	133	114	113	108	96	83	78	77
	40 mm < t ≤ 60 mm	130	108	105	101	94	83	78	77
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	133	123	110	97	85	77	73
	15 mm < t ≤ 40 mm	133	131	122	109	97	85	77	73
	40 mm < t ≤ 60 mm	133	119	115	106	97	85	77	73
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	141	139	134	120	100	95	92
	15 mm < t ≤40 mm	152	134	132	127	114	100	95	92
	40 mm < t ≤ 60 mm	150	128	121	112	112	100	95	92
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	152	144	129	114	101	94	89
	15 mm < t ≤ 40 mm	152	152	142	128	114	101	94	89
	40 mm < t ≤ 60 mm	152	143	139	125	114	101	94	89
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	170	165	149	132	118	111	105
	15 mm < t ≤ 40 mm	170	170	161	147	132	118	111	105
	40 mm < t ≤ 60 mm	170	167	157	145	132	118	111	105
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	189	189	180	170	157	143	133	120

Table 8 : Permissible stresses K for alloy steels intended for boilers and thermal oil heaters

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	153	143	134	125	106	100	94	91	89	87	36			
1Cr 0,5Mo	t ≤ 60 mm	167	167	157	144	137	128	119	112	106	104	103	55	31	19	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	170	167	157	147	144	137	131	125	119	115	112	61	41	30	22
2,25Cr 1Mo **(2)**	t ≤ 60 mm	170	167	164	161	159	147	141	130	128	125	122	61	41	30	22

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

Table 9 : Permissible stresses K for alloy steels intended for other pressure vessels

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	159	153	143	133	113	107	100	97	95	93	38			
1Cr 0,5Mo	t ≤ 60 mm	167	167	167	154	146	137	127	119	113	111	110	59	33	20	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	183	174	167	157	154	146	140	133	127	123	119	65	44	32	23
2,25Cr 1Mo **(2)**	t ≤ 60 mm	174	174	174	172	170	157	150	139	137	133	130	65	44	32	23

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

2.3.2 Direct determination of permissible stress

The permissible stresses K, where not otherwise specified, may be taken as indicated below.

a) Steel:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{2,7}$$

$$K = \frac{R_{S,MIN,T}}{A}$$

$$K = \frac{S_A}{A}$$

where:

$R_{m,20}$: Minimum tensile strength at ambient temperature (20°C), in N/mm^2

$R_{S,MIN,T}$: Minimum between R_{eH} and $R_{p\,0,2}$ at the design temperature T, in N/mm^2

S_A : Average stress to produce creep rupture in 100000 hours, in N/mm^2, at the design temperature T

A : Safety factor taken as follows, when reliability of $R_{S,MIN,T}$ and S_A values are proved to the Society's satisfaction:

- 1,6 for boilers and other steam generators
- 1,5 for other pressure vessels
- specially considered by the Society if average stress to produce creep rupture in more than 100000 hours is used instead of S_A.

In the case of steel castings, the permissible stress K, calculated as above, is to be decreased by 20%. Where steel castings are subjected to non-destructive tests, a smaller reduction up to 10% may be taken into consideration by the Society.

b) Spheroidal cast iron:

The permissible stress is be to the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{4,8}$$

$$K = \frac{R_{S,MIN,T}}{3}$$

c) Grey cast iron:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,20}}{10}$$

d) Copper alloys:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,T}}{4}$$

where:

$R_{m,T}$: Minimum tensile strength at the design temperature T, in N/mm^2

e) Aluminium and aluminium alloys:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,T}}{4}$$

$$K = \frac{R_{e,H}}{1,5}$$

where:

$R_{e,H}$: Minimum yield stress, in N/mm^2

f) Additional conditions:
- In special cases the Society reserves the right to apply values of permissible stress K lower than those specified above.
- In the case of boilers or other steam generators, the permissible stress K is not to exceed 170 N/mm^2.
- For materials other than those listed above the permissible stress is to be agreed with the Society on a case by case basis.

2.4 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure

2.4.1 Cylindrical shell thickness

a) The minimum thickness of cylindrical, spherical and conical shells with circular cross-sections is not to be less than the value t, in mm, calculated by one of the following formulae, as appropriate. Cylindrical tube plates pierced by a great number of tube holes are to have thickness calculated by the applicable formulae in [2.4.3], [2.4.4], [2.4.5] and [2.9.2].

b) The thicknesses obtained by the formulae in [2.4.3], [2.4.4] and [2.4.5] are "net" thicknesses, as they do not include any corrosion allowance. The thickness obtained by the above formulae is to be increased by 0,75 mm. See also [2.4.7].

2.4.2 Efficiency

The values of efficiency e to be used in the formulae in [2.4.3], [2.4.4] and [2.4.5] are indicated in Tab 10.

Table 10 : Efficiency of unpierced shells

Case	e
Seamless shells	1
Shells of class 1 vessels **(1)**	1
Shells of class 2 vessels (with partial radiographic examination of butt-joints)	0,85
Shells of class 2 vessels with actual thickness ≤ 15mm (without radiographic examination of butt-joints)	0,75
(1) In special cases the Society reserves the right to take a factor e < 1, depending on the welding procedure adopted for the welded joint.	

2.4.3 Cylindrical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of cylindrical shells is given by the following formula:

$$t = \frac{pD}{(2K - p)e}$$

where:

p : Design pressure, in MPa

D : Inside diameter of vessel, in mm

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

e : Efficiency of welded joint, the value of which is given in [2.4.2].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.4 Spherical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of spherical shells is given by the following formula:

$$t = \frac{pD}{(4K - p)e}$$

For the meaning of the symbols, see [2.4.3].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.5 Conical shells

a) The following formula applies to conical shells of thickness not exceeding 1/6 of the external diameter in way of the large end of the cone:

$$t = \frac{pD}{(2K - p)e \cdot \cos\varphi}$$

For the meaning of the symbols, see [2.4.3].

D is measured in way of the large end of the cone and φ is the angle of slope of the conical section of the shell to the pressure vessel axis (see Fig 1). When φ exceeds 75°, the shell thickness is to be taken as required for flat heads, see [2.7].

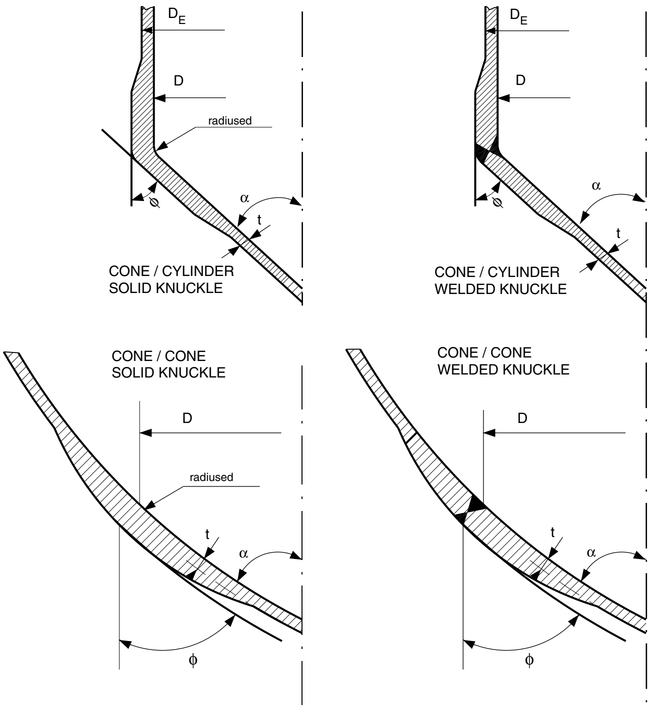
b) The minimum thickness of shells having thickness exceeding 1/6 of the external diameter in way of the large end of the cone is subject of special consideration.

c) Conical shells may be made of several ring sections of decreasing thickness. The minimum thickness of each section is to be obtained by the formula in a) using for D the maximum diameter of the considered section.

d) In general, the junction with a sharp angle between the conical shell and the cylindrical or other conical shell, having different angle of slope, is not allowed if the angle of the generating line of the shells to be assembled exceeds 30°.

e) The shell thickness in way of knuckles is subject of special consideration by the Society.

Figure 1 : Conic shells



2.4.6 Minimum thickness of shells

Irrespective of the value calculated by the formulae in [2.4.3], [2.4.4] or [2.4.5], the thickness t of shells is not to be less than one of the following values, as applicable:

- for pressure vessels: t = 3 + D/1500 mm
- for unpierced plates of boilers: t = 6,0 mm
- for boiler cylindrical tube plates: t = 9,5 mm.

No corrosion allowance needs to be added to the above values.

2.4.7 Corrosion allowance

The Society reserves the right to increase the corrosion allowance value in the case of vessels exposed to particular accelerating corrosion conditions. The Society may also consider the reduction of this factor where particular measures are taken to effectively reduce the corrosion rate of the vessel.

2.5 Dished heads subject to pressure on the concave (internal) side

2.5.1 Dished head for boiler headers

Dished heads for boiler headers are to be seamless.

2.5.2 Dished head profile

The following requirements are to be complied with for the determination of the profile of dished heads (see Fig 2 (a) and (b)).

a) Ellipsoidal heads:

$H \geq 0{,}2\ D$

where:

H : External depth of head, in mm, measured from the start of curvature at the base.

b) Torispherical heads:

$R_{IN} \leq D$

$r_{IN} \geq 0{,}1\ D$

$r_{IN} \geq 3\ t$

$H \geq 0{,}18\ D$

where:

R_{IN} : Internal radius of the spherical part, in mm

r_{IN} : Internal knuckle radius, in mm

H : External depth of head calculated by the following formula (see Fig 2 (b)):

$H = R_E - [(R_E - 0,5\ D) \cdot (R_E + 0,5\ D - 2\ r_E)]^{0,5}$

where:

R_E : External radius of the spherical part, in mm

r_E : External knuckle radius, in mm.

2.5.3 Required thickness of solid dished heads

a) The minimum thickness of solid (not pierced) hemispherical, torispherical, or ellipsoidal unstayed dished heads, subject to pressure on the concave (internal) side, is to be not less than the value t, in mm, calculated by the following formula:

$$t = \frac{pDC}{2Ke}$$

where:

C : Shape factor, obtained from the graph in Fig 3, as a function of H/D and t/D.

For other symbols, see [2.4.3].

b) The thickness obtained by the formula in item a) is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,75 mm. See also [2.4.7].

2.5.4 Composed torispherical heads

a) Torispherical heads may be constructed with welded elements of different thicknesses (see Fig 4).

b) Where a torispherical head is built in two sections, the thickness of the torispherical part is to be obtained by the formula in [2.5.3], while the thickness of the spherical part may be obtained by the formula in [2.4.4].

c) The spherical part may commence at a distance from the knuckle not less than:

$0,5 \cdot (R_{IN} \cdot t)^{0,5}$

where:

R_{IN} : Internal radius of the spherical part, in mm

t : Knuckle thickness, in mm.

2.5.5 Minimum thickness of dished heads

Irrespective of the values calculated in [2.5.2] and [2.5.3], the thickness t of dished heads is not to be less than:

- $3 + D_E / 1500$ mm for normal pressure vessels
- 6 mm for boiler pressure vessels.

No corrosion allowance needs to be added to the above values.

2.5.6 Connection of heads to cylindrical shells

The heads are to be provided, at their base, with a cylindrical skirt not less than 2t in length and with a thickness in no case less than the Rule thickness of a cylindrical shell of the same diameter and the same material, calculated by the formula given in [2.4.3] using the same efficiency factor e adopted for calculation of the head thickness. Fig 5 and Fig 6 show typical admissible attachments of dished ends to cylindrical shells.

In particular, hemispherical heads not provided with the above skirt are to be connected to the cylindrical shell if the latter is thicker than the head, as shown in Fig 5.

Other types of connections are subject to special consideration by the Society.

Figure 2 : Dished head profiles

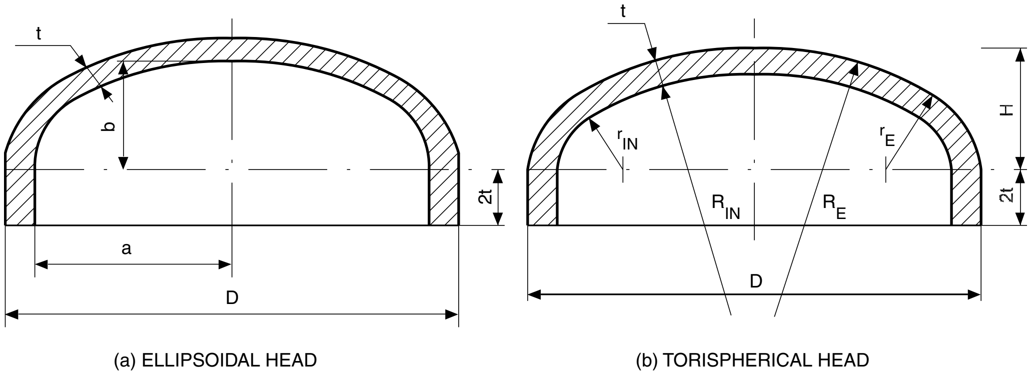


Figure 3 : Shape factor for dished heads

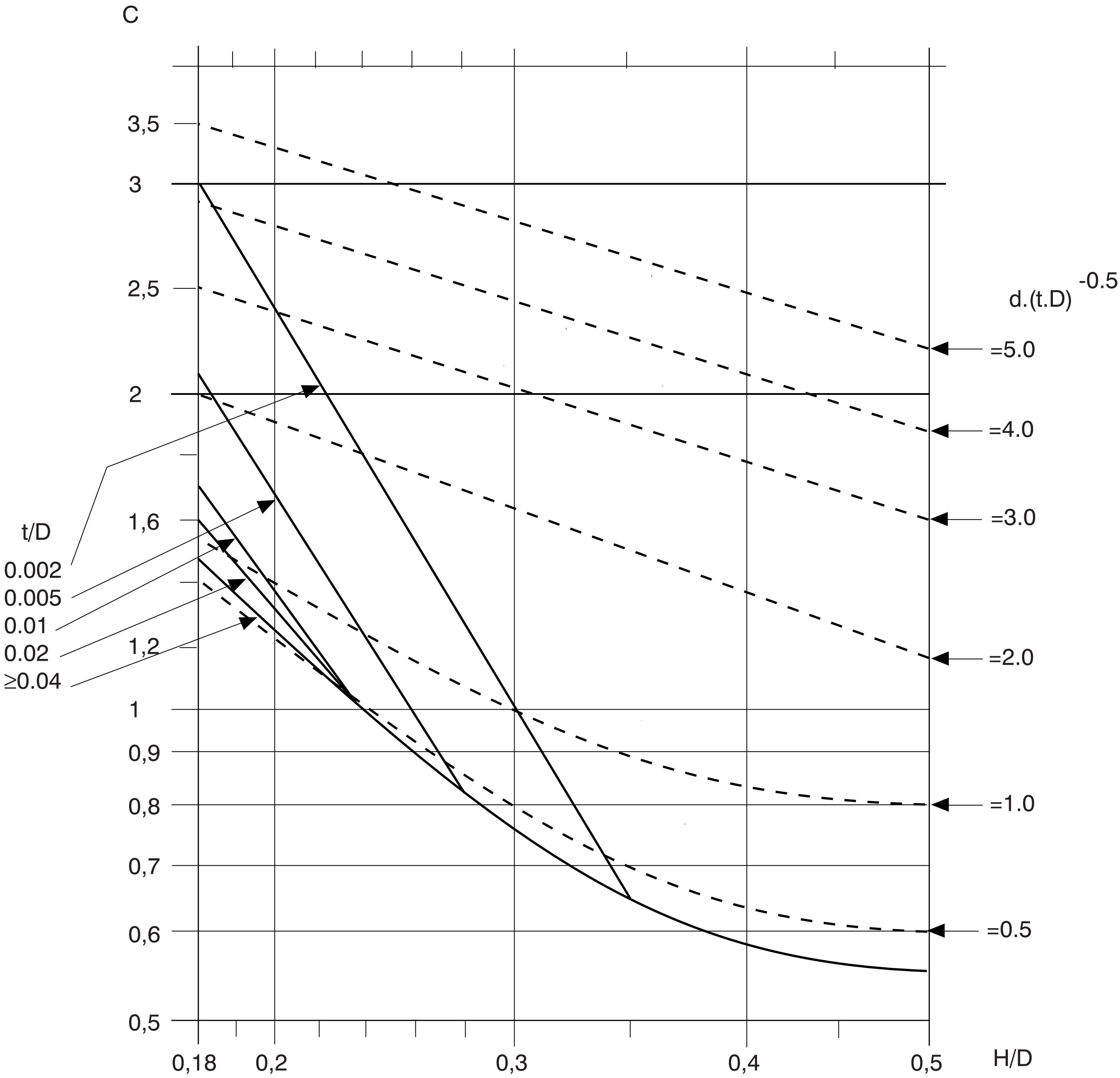


Figure 4 : Composed torispherical head

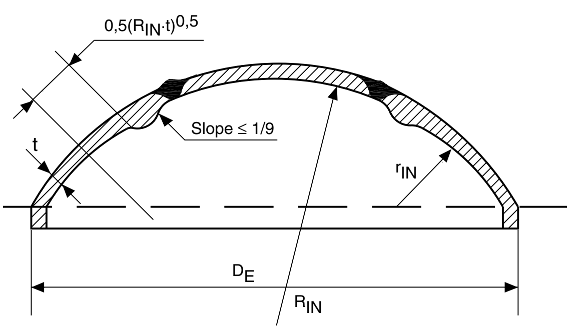
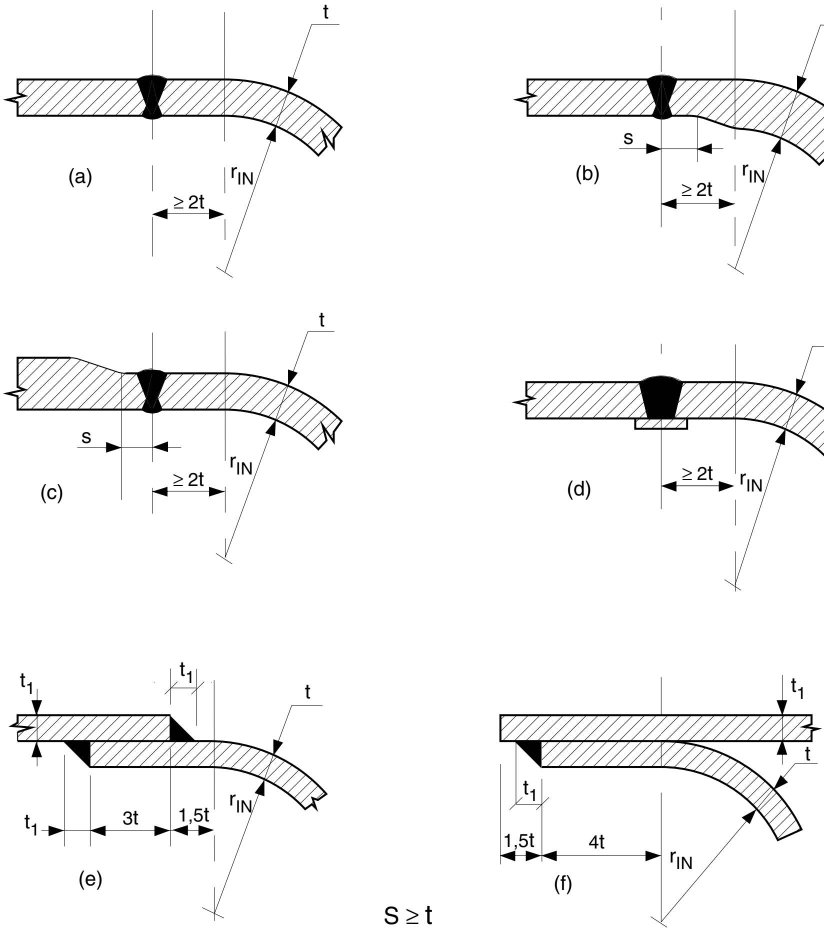
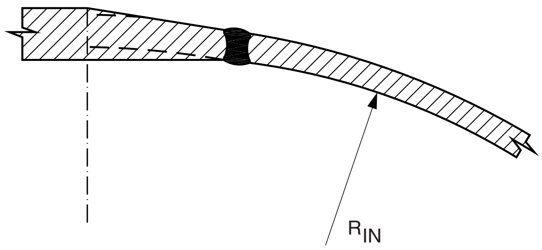


Figure 5 : Typical attachment of dished heads to cylindrical shells



Types shown in (a), (b) and (c) are acceptable for all pressure vessels.
Type shown in (d) is acceptable for class 2 and class 3 pressure vessels.
Types shown in (e) and (f) are acceptable for class 3 pressure vessels only.

Figure 6 : Connection of hemispherical head to the cylindrical shell



2.6 Dished heads subject to pressure on the convex (external) side

2.6.1 The calculation of the minimum thickness is to be performed according to a standard accepted by the Society.

In addition, the thickness of torispherical or ellipsoidal heads under external pressure is no to be less than 1,2 times the thickness required for a head of the same shape subject to internal pressure.

2.7 Flat heads

2.7.1 Unstayed flat head minimum thickness

a) The minimum thickness of unstayed flat heads is not to be less than the value t, in mm, calculated by the following formula:

$$t = D\left(\frac{100p}{CK}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

D : Diameter of the head, in mm. For circular section heads, the diameter D is to be measured as shown in Fig 7 and Fig 8 for various types of heads. For rectangular section heads, the equivalent value for D may be obtained from the following formula:

$$D = a\left[3{,}4 - 2{,}4\left(\frac{a}{b}\right)\right]^{0{,}5}$$

a and b being the smaller and larger side of the rectangle, respectively, in mm

C : The values given below, depending on the various types of heads shown in Fig 7 and Fig 8:

Fig 7(a) : C = 400 for circular heads

Fig 7(b) : C = 330 for circular heads

Fig 7(c) : C = 350 for circular heads

Fig 7(d) : C = 400 for circular heads and C = 250 for rectangular heads

Fig 7(e) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 7(f) : C = 350 for circular heads

Fig 7(g) : C = 300 for circular heads

Fig 7(h) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(i) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(j) : C = 200 for circular heads

Fig 8(k) : C = 330 for circular heads

Fig 8(l) : C = 300 for circular heads

Fig 8(m) : C = 300 for circular heads

Fig 8(n) : C = 400 for circular heads

Fig 8(o) : C = value obtained from the following formula, for circular heads:

$$C = \frac{100}{0{,}3 + \frac{1{,}9Fh}{pD^3}}$$

where:

h : Radial distance, in mm, from the pitch centre diameter of bolts to the circumference of diameter D, as shown in Fig 8(o)

F : Total bolt load, in N, to be taken as the greater of the following values F_1 and F_2:

$F_1 = 0{,}785\ D\ p\ (D + m\ b)$

$F_2 = 9{,}81\ y\ D\ b$

with:

b : Effective half contact width of the gasket, in mm, calculated as follows:

$b = 0{,}5\ N$ for $N \leq 13$ mm, and

$b = 1{,}8\ N^{0{,}5}$ for $N > 13$ mm

where N is the geometric contact width of the gasket, in mm, as indicated in Fig 8(o)

m, y : Adimensional coefficients whose values are given in Tab 11, depending on the type of gasket.

The adoption of one of the above-mentioned heads is subject to the Society's approval depending upon its use. Types of heads not shown in Fig 7 and Fig 8 are to be the subject of special consideration by the Society.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.7.2 Stayed flat head minimum thickness

For the minimum thickness of stayed flat heads, see [2.12.3].

Table 11 : Coefficients m and y

Type of gasket	m	y
Self-sealing, metal or rubber (e.g. O-ring)	0	0
Rubber with cotton fabric	10	0,88
Rubber with reinforcing fabric with or without metal wire:		
- 3 layers	18	4,85
- 2 layers	20	6,4
- 1 layers	22	8,2
Synthetic fibre with suitable binders:		
- 3,0 mm thick	16	3,5
- 1,5 mm thick	22	8,2
Organic fibre	14	2,4
Metal spiral lined with synthetic fibre:		
- carbon steel	20	6,4
- stainless steel	24	9,9
Synthetic fibre with plain metal lining:		
- copper	28	14,0
- iron	30	16,8
- stainless steel	30	20,0
Solid metal:		
- copper	38	28,7
- iron	44	39,8
- stainless steel	52	57,5

Figure 7 : Types of unstayed flat heads (1)

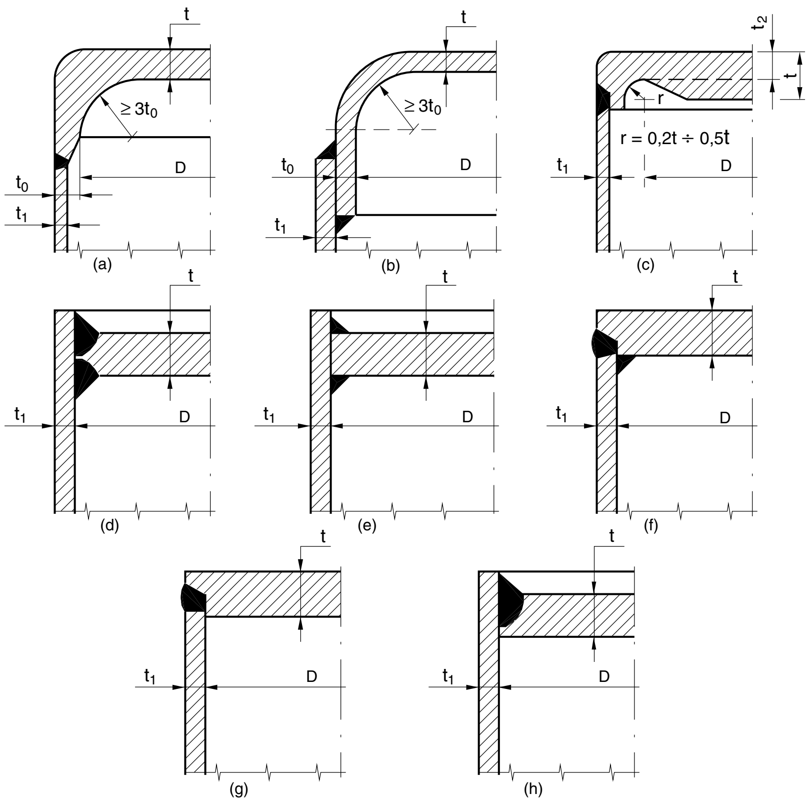
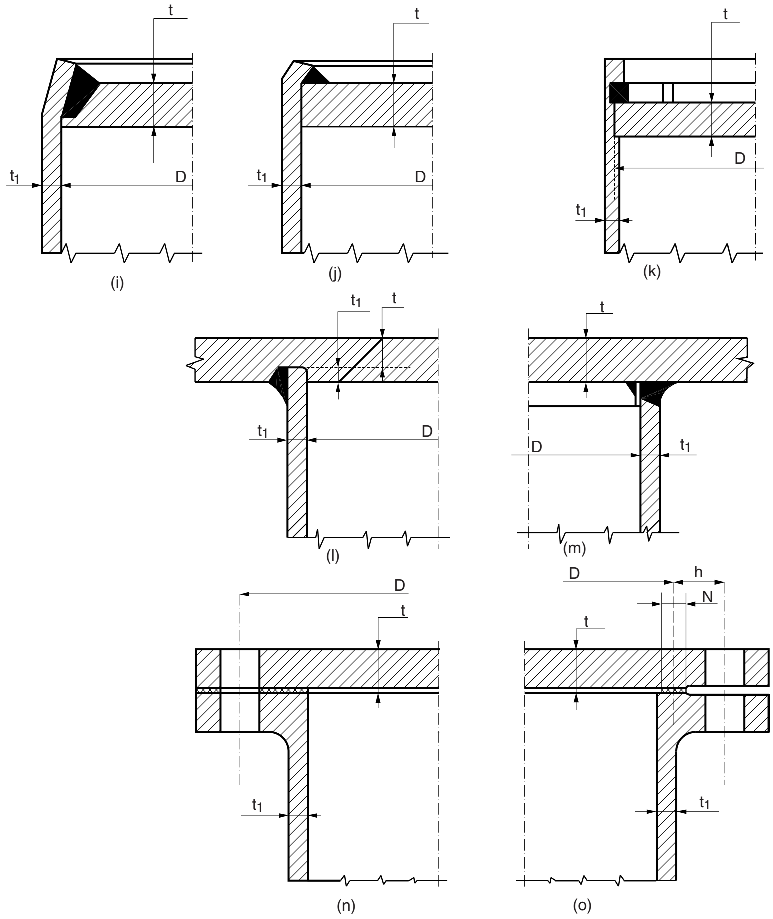


Figure 8 : Types of unstayed flat heads (2)



2.8 Openings and branches (nozzles)

2.8.1 Nozzles thickness

a) The thickness e_b, in mm, of nozzles attached to shells and headers of boilers is not to be less than:

$$e_b = \frac{d_E}{25} + 2{,}5$$

where d_E is the outside diameter of nozzle, in mm.

The thickness of the nozzle is, however, to be not less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not to be greater than the thickness of the shell to which it is connected.

b) The thickness of the nozzle attached to shells and headers of other pressure vessels is not to be less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not be greater than the thickness of the shell to which it is connected.

c) Where a branch is connected by screwing, the thickness of the nozzle is to be measured at the root of the thread.

2.8.2 Nozzle connection to vessel shell

a) In general, the axis of the nozzle is not to form an angle greater than 15° with the normal to the shell.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show some typical acceptable connections of nozzles to shells. Other types of connections are to be considered by the Society on a case by case basis.

2.8.3 Openings in shells

a) In general, the largest dimensions of the openings in shells are not to exceed:

- for shells up to 1500 mm in diameter D_E:

  1/2 D_E, but not more than 500 mm

- for shells over 1500 mm in diameter D_E:

  1/3 D_E, but not more than 1000 mm,

where D_E is the vessel external diameter, in mm.

Greater values may be considered by the Society on a case by case basis.

b) In general, in oval or elliptical openings the ratio major diameter/minor diameter is not to exceed 2.

2.8.4 Openings compensation in cylindrical shells

a) Compensation methods

For cylindrical shells with openings, the efficiency of the main body is to be satisfied by one of the following methods:

- by increasing the wall thickness of main body compared with that of the cylindrical shell without opening: see Fig 9
- by branches which have been provided with a wall thickness of that required on account of the internal pressure: see Fig 10 and Fig 11
- by reinforcing pads or rings analogous to increasing the wall thickness: see Fig 12 and Fig 13
- by a combination of previous reinforcement.

b) Definitions

Effective lengths ℓ_{rs} required for calculation of efficiency and of compensations is to be taken as:

$$\ell_{rs} = \min(\sqrt{Dt_a}, \ell_{s1})$$

where:

D : Outside diameter, in mm

t_a : Available thickness, in mm

ℓ_{s1} : Transition length, in mm, according to Fig 9 and Fig 10

c) Basic calculation

The required wall thickness without allowance of a cylindrical shell is determined with the following formula (see [2.4.3]):

$$t = \frac{pD}{(2K-p)e}$$

With the available thickness t_a, we obtain the available efficiency e_a and the maximum diameter d_{obmax} of an unreinforced opening when the average stress of the main body is equal to the permissible stress K:

$$e_a = \frac{pD_i}{(2K-p)t_a}$$

$$d_{obmax} = 2\left[\frac{\ell_{rs}}{e_a} - \ell_{rs}\right]$$

where:

D_i : Internal diameter of the main body, in mm

d) Isolated opening reinforcement

The reinforcement of isolated openings as indicated in Fig 9 to Fig 13 are to be in respect with:

$$\frac{A_p}{A_f} \leq \frac{K}{p} - 0,5$$

where:

K : Permissible stress in the shell, in N/mm^2

A_f : Total area of cross section (wall and branch and pad)

A_p : Total area under pressure p.

In Fig 9 to Fig 13, ℓ_{rs}, ℓ_{rb} and ℓ_{rbi} are effective lengths for calculation of efficiencies and compensation, equal to:

- for shell:

  $$\ell_{rs} = \min(\sqrt{(D+e_{rs})e_{rs}}, \ell_{s1})$$

- for external branch projection:

  $$\ell_{rb} = \min(\sqrt{(d_{ib}+e_{rb})e_{rb}}, \ell_{b1})$$

- for internal branch projection:

  $$\ell_{rbi} = \min(0,5\sqrt{(d_{ib}+e_{rb})e_{rb}}, \ell_{b2})$$

Figure 9 : Reinforcement by increasing the wall thickness of the main body with opening

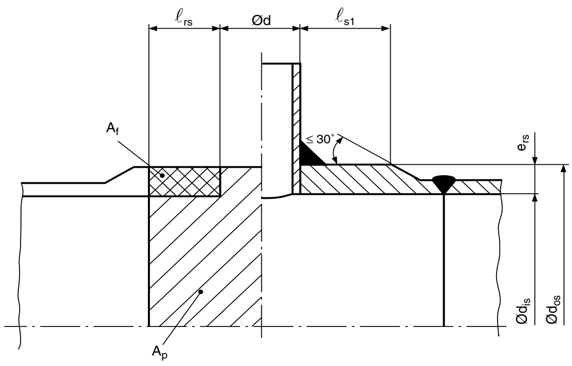


Figure 10 : Reinforcement by set-through and full penetration welded branch

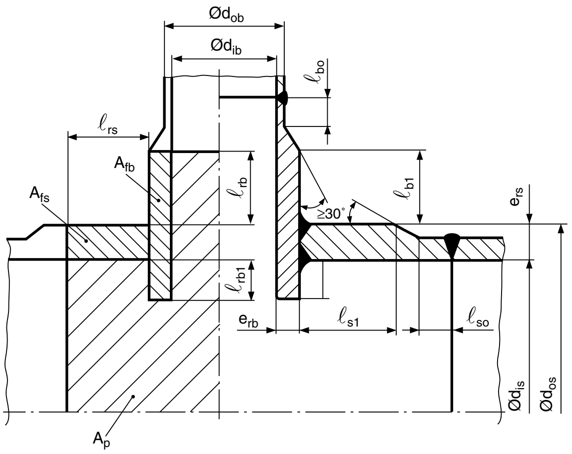


Figure 11 : Reinforcement by welded on branch

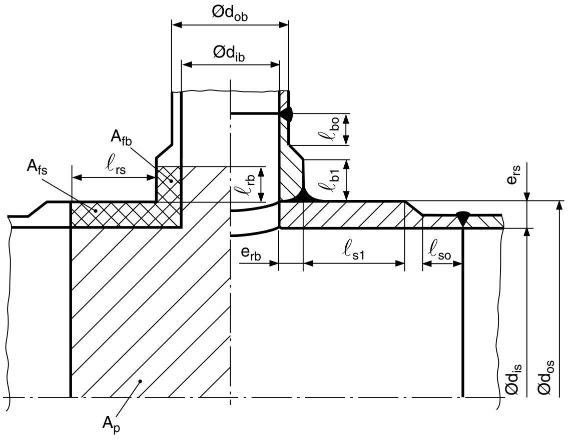
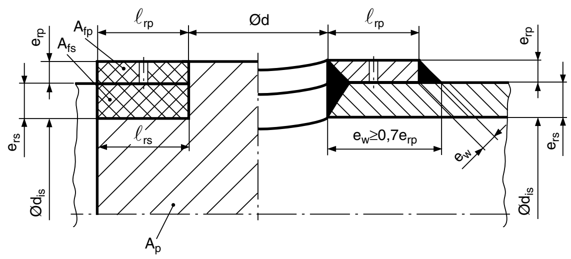


Figure 12 : Opening with reinforcing pad



e) Condition of isolated openings

- Full case

  Adjacent openings are to be treated as isolated openings if the centre distance P_ϕ, in accordance with Fig 16, is not less than:

$$\frac{\left(\frac{d_{ib1}}{2}+e_{rb1}\right)}{\cos\Psi_1}+\frac{\left(\frac{d_{ib2}}{2}+e_{rb2}\right)}{\cos\Psi_2}+2\sqrt{(d_{is}+e_{rs})e_{rs}}$$

  For variable definition see Fig 14 and Fig 15.

- Simplification
  - For openings without branch:

    $e_{rb} = 0$ and $\Psi = 0$
  - For openings with nozzles perpendicular to shell:

    The openings are to be treated as isolated openings if the centre distance P_ϕ in accordance with Fig 16 is not less than:

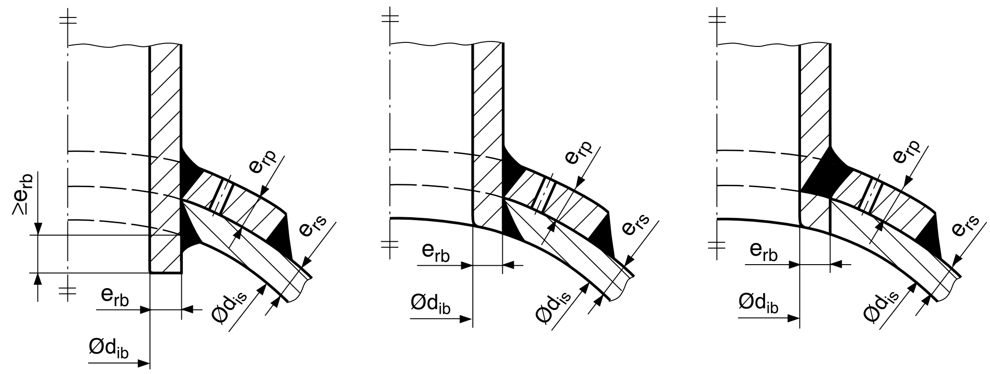
$$\left(\frac{d_{ib1}}{2}+e_{rb1}\right)+\left(\frac{d_{ib2}}{2}+e_{rb2}\right)+2\sqrt{(d_{is}+e_{rs})e_{rs}}$$

f) Adjacent openings

Where the condition of isolated openings is not fulfilled, the compensation is to be calculated, using Fig 16, as per the following formula:

$$\frac{A_p}{A_f}\le\frac{K}{p}-0,5$$

Figure 13 : Opening with reinforcing pad and full penetration branch



a) set through welded branch b) set in welded branch c) set on welded branch

Figure 14 : Angle definition for cylindrical shell with oblique branch

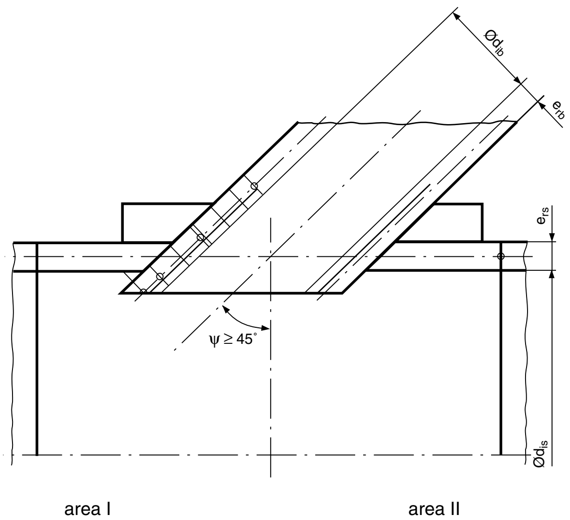


Figure 15 : Angle definition for cylindrical shell with non-radial branch

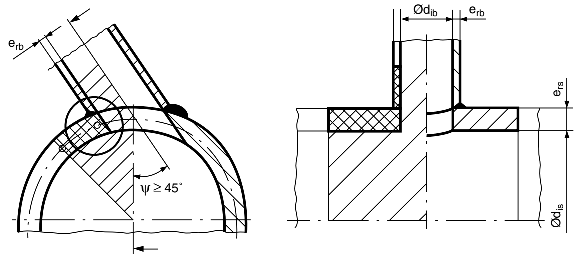
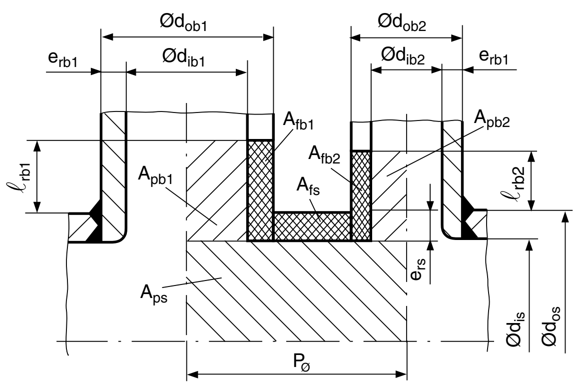
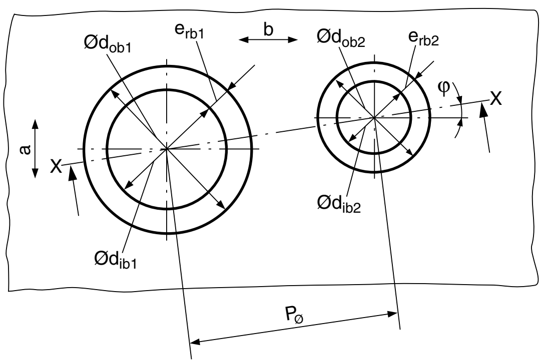


Figure 16 : Load diagram for cylindrical shell with adjacent branches

Section view X -X



Plan view



a : Circumferential direction

b : Longitudinal direction.

2.8.5 Openings in dished heads

a) The openings in dished heads may be circular, elliptical or oval.

b) The largest diameter of the non-compensated opening is not to exceed one half of the external diameter of the head.

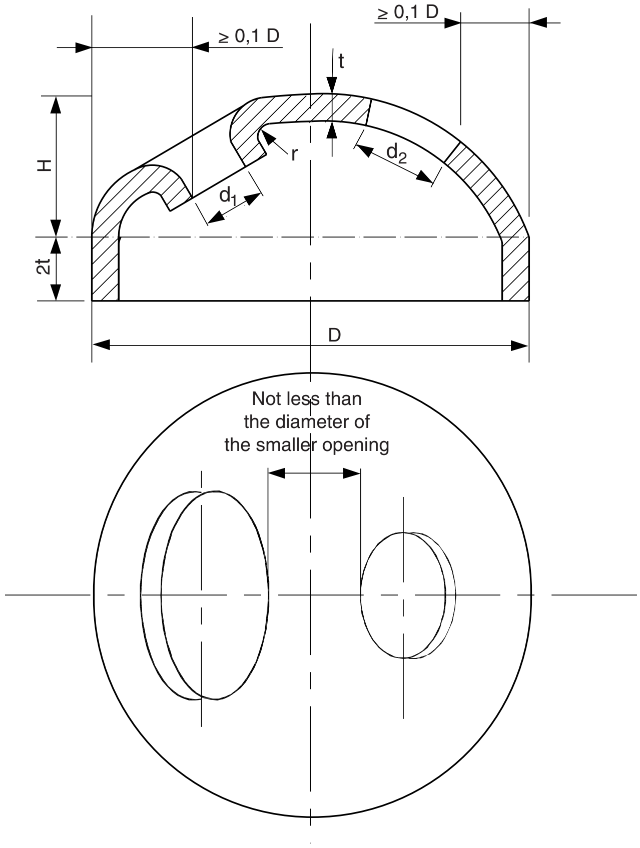
c) The opening is to be so situated that its projection, or its reinforcement projection in the case of compensated openings, is completely contained inside a circle having its centre at the centre of the head and a diameter of 0,8 D, D being the external diameter of the head (see Fig 17). However, a small reinforced opening for drainage may be accepted outside the indicated area.

d) In the case of non-compensated openings (for this purpose, flanged openings are also to be considered as non-compensated), the head thickness is not to be less than that calculated by the formula in [2.5.3] using the greatest of the shape factors C obtained from the graph in Fig 3 as a function of:

   H/D and t/D or H/D and $d \cdot (t \cdot D)^{-0,5}$,

   where d is the diameter of the largest non-compensated opening in the head, in mm. For oval and elliptical openings, d is the width of the opening in way of its major axis.

Figure 17 : Openings on dished heads



e) In all cases the diameter D of the head base, the head thickness t and the diameter d of the largest non-compensated opening are to be such as to meet the following requirements:
   - the position of non-compensated openings in the heads is to be as shown in Fig 17
   - for flanged openings, the radius r of the flanging (see Fig 17) is not to be less than 25 mm
   - the thickness of the flanged part may be less than the Rule thickness.

2.8.6 Opening compensation in dished heads

a) Where openings are cut in dished heads and the proposed thickness of the head is less than that calculated by the formula in [2.5.3], the openings are to be compensated.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show typical connections of nozzles and compensating rings.

c) The opening is considered sufficiently compensated when the head thickness t is not less than that calculated in accordance with [2.5.3] and using the shape-factor C obtained from the graph in Fig 3 using the value:

$$\left(d - \frac{A}{t}\right) \cdot (t \cdot D)^{-0,5}$$

instead of:

$$d \cdot (t \cdot D)^{-0,5}$$

where:

A : Area, in mm^2, of the total transverse section of the compensating parts

t : Actual thickness of the head, in mm, in the zone of the opening under consideration.

d) When A/t > d, the coefficient C is to be determined using the curve corresponding to the value:

$$d \cdot (t \cdot D)^{-0,5} = 0$$

e) If necessary, calculations are to be repeated.

2.8.7 Compensation criteria

In the evaluation of the area A, the following is also to be taken into consideration:

a) The material that may be considered for compensating an opening is that located around the opening up to a distance l from the edge of the opening. The distance l, in mm, is the lesser obtained from the following formulae:

$$l = 0,5\ d$$

$$l = (2 \cdot R_{IN} \cdot t)^{0,5}$$

where:

d : Diameter of the opening, in mm

R_{IN} : Internal radius of the spherical part, in mm, in the case of hemispherical or torispherical heads

In the case of ellipsoidal heads, R_{IN} is to be calculated by the following formula (see Fig 2 (a):

$$R_{IN} = \frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b}$$

where;

a : Half the major axis of the elliptical meridian section of the head, in mm

b : Half the minor axis of the above section, in mm

x : Distance between the centre of the hole and the rotation axis of the shell, in mm.

b) In the case of nozzles or pads welded in the hole, the section corresponding to the thickness in excess of that required is to be considered for the part which is subject to pressure and for a depth h, in mm, both on the external and internal sides of the head, not greater than:

$(d_B \cdot t_B)^{0,5}$

where d_B and t_B are the diameter of the opening and the thickness of the pad or nozzle, in mm, respectively.

c) The area of the welding connecting nozzle and pad reinforcements may be considered as a compensating section.

d) If the material of reinforcement pads, nozzles and collars has a permissible stress lower than that of the head material, the area A, to be taken for calculation of the coefficient C, is to be reduced proportionally.

2.8.8 Openings in flat end plates

The maximum diameter of an unreinforced opening in a flat end plate is to be determined from the equation:

$$d_{max} = 8 e_{rh}\left[1{,}5\frac{e_{rh}^2}{e_{ch}^2} - 1\right]$$

where:

e_{rh} : Actual thickness of the flat end, in mm

e_{ch} : Required calculated thickness of the flat end, in mm.

2.8.9 Opening compensation in flat end plate

Reinforcement of branch openings is to be achieved by taking account of locally disposed material, including the attachment welds, in excess of the minimum requirements for end plate and branch thickness as shown in Fig 18. The branch thickness is to be increased where required. Compensation is to be considered adequate when the compensating area Y is equal to or greater than the area X requiring compensation.

Area X is to be obtained by multiplying 25% of the inside radius of the branch by the thickness of the flat end plate, calculated for the part of the end plate under consideration.

Area Y is to be measured in a plane through the axis of the branch parallel to the surface of the flat end plate, and is to be calculated as follows:

a) For that part of the branch which projects outside the boiler, calculate the full sectional area of the branch up to a distance ℓ_b from the actual outer surface of the flat end plate and deduct from it the sectional area that the branch would have within the same distance if its thickness were calculated in accordance with equation given in [2.4.3]

Note 1: The compensating plate is required only in cases where area Y would otherwise be less than area X.

b) Add to it the full sectional area of that part of the branch that projects inside the boiler (if any) up to a distance ℓ_b from the inside surface of the flat end plate

c) Add to it the sectional area of the fillet welds

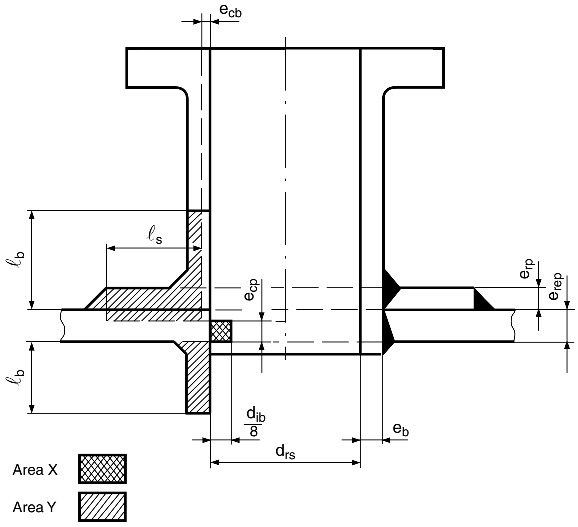
d) Add to it the area obtained by multiplying the difference between the actual flat end plate thickness and its thickness calculated for the part of the end plate under consideration by the length ℓ_s

e) Add to it the area of the compensating plate (if any) within the limits of reinforcement shown in Fig 18.

Where material having a lower allowable stress than that of the flat end plate is taken as compensation, its effective area is to be reduced in the ratio of the allowable stresses at the calculation temperature. No credit is to be taken for the additional strength of material having a higher allowable stress than that of the flat end plate

Welds attaching branches and compensating plates are to be capable of transmitting the full strength of the reinforcing area and all other loadings to which they may be subjected.

Figure 18 : Compensation for branch in flat end plate



e_{cp} : Thickness calculated in accordance with equation in [2.8.1] for the part under consideration

e_{cb} : Thickness calculated taking efficiency = 1

ℓ_b : The smaller of the two values:
$2,5\ e_{rep}$ and $(2,5\ e_b + e_{rp})$

ℓ_s : The greater of the two values:
$(e_{rep} + 75)$ and $(d_{ib} / 4)$

Area Y is not to be less than area X.

2.8.10 Covers

a) Circular, oval and elliptical inspection openings are to be provided with steel covers. Inspection openings with a diameter not exceeding 150 mm may be closed by blind flanges.

b) The thickness of the opening covers is not to be less than the value t, in mm, given by the following formula:

$$t = 1,22 \cdot a \cdot \left(\frac{pC}{K}\right)^{0,5}$$

where:

a : The minor axis of the oval or elliptical opening, measured at half width of gasket, in mm

b : The major axis of the oval or elliptical opening, measured at half width of the gasket, in mm

C : Coefficient in Tab 12 as a function of the ratio b/a of the axes of the oval or elliptical opening, as defined above. For intermediate values of the ratio b/a, the value of C is to be obtained by linear interpolation.

For circular openings the diameter d, in mm, is to be used in the above formula instead of a.

c) The thickness obtained by the formula in item a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm for classification purpose. See also [2.4.7].

2.9 Regular pattern openings - Tube holes

2.9.1 Definition

Openings may be considered as regular pattern openings when not less than three non isolated openings are disposed in regularly staggered rows in longitudinal or circular direction of a shell.

In such a case, instead of a direct calculation of the compensation of openings, the thickness of the shell could be calculated by application of applicable formulae given in [2.4], [2.5] with a reduced efficiency e as indicated in [2.9.2] and [2.9.3].

This requirement apply for pressure vessels and for boiler.

2.9.2 Efficiency factor of tube holes in cylindrical tube plates

The efficiency factor e of pipe holes in cylindrical shells pierced by tube holes is to be determined by direct calculation or by another suitable method accepted by the Society. In the case of cylindrical holes of constant diameter and radial axis, the efficiency factor e may be determined by the following formula (see Fig 19):

$$e = \frac{1}{\frac{s}{s-d} \cdot (1 - (0,5 \cdot \sin^2\alpha)) + m \cdot \sin 2\alpha}$$

where:

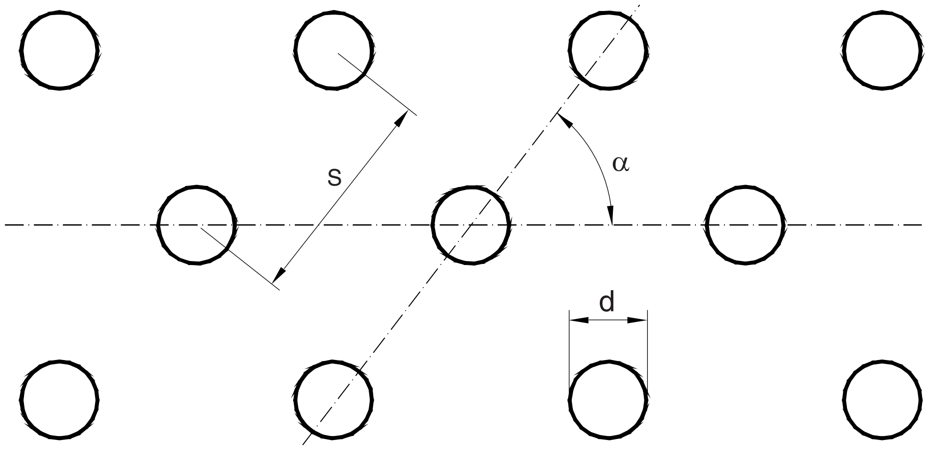
Table 12 : Coefficient C for oval or elliptical covers

b/a	1,00	1,05	1,10	1,15	1,20	1,25	1,30	1,40	1,50	1,60
C	0,206	0,220	0,235	0,247	0,259	0,271	0,282	0,302	0,321	0,333
b/a	1,70	1,80	1,90	2,00	2,50	3,00	3,50	4,00	4,50	5,00
C	0,344	0,356	0,368	0,379	0,406	0,433	0,449	0,465	0,473	0,480

Table 13 : Coefficient m

d/s	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80
m	0,137	0,175	0,220	0,274	0,342	0,438	0,560	0,740	1,010	1,420	2,060

Figure 19 : Hole pattern in cylindrical shells



s : Pitch of the hole row considered, in mm

d : Diameter of holes, in mm. The hole diameter d may be reduced by the amount Y/e_{cp} where Y is the compensating area, in mm², of nozzle and welds and e_{cp} the calculated unpierced shell thickness, see [2.8.9] and Fig 18

α : Angle between the axis of hole row considered and the axis of the cylinder (α = 0° if the hole row is parallel to the cylinder generating line; α = 90° for circumferential hole row)

m : Coefficient depending upon the ratio d/s, as obtained from Tab 13. For intermediate values of d/s, the value of m is to be obtained by linear interpolation.

The value of e actually used is to be the smallest calculated value for either longitudinal, diagonal or circumferential rows of holes.

2.9.3 Welded shells with tube holes and efficiency factor of different hole patterns

Where shells have welding butts and/or different groups of hole patterns, the value to be assumed for the efficiency e in the formulae is the minimum of the values calculated separately for each type of welding (as per [2.4.2]) and for each configuration of holes (as per [2.9.1]).

2.9.4 Rectangular section headers

a) For seamless type headers of rectangular section design, the wall thickness t, in mm, in way of corner fillets and the thickness t_1, in mm, of any drilled wall is not to be less than those given by the following formulae, as appropriate (see Fig 20):

$$t = \left(\frac{100pM_1}{K}\right)^{0,5}$$

$$t_1 = \left(\frac{100pM_2}{eK}\right)^{0,5}$$

where (see also Fig 20):

t : Wall thickness at the corners, in mm

t_1 : Thickness of drilled wall, in mm

p : Design pressure, in MPa

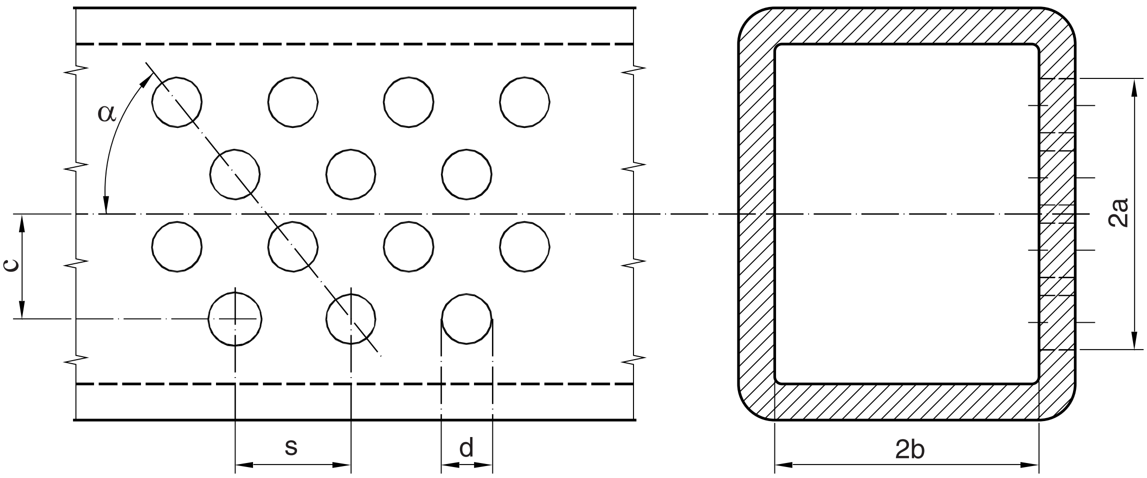
K : Permissible stress, in N/mm², obtained as specified in [2.3]

a : Internal half width of the header, in a direction parallel to the wall under consideration, in mm

b : Internal half width of the header, in a direction normal to the wall under consideration, in mm

c : Distance between the axis of the hole row considered and the centreline of the header wall, in mm

Figure 20 : Rectangular section headers



e : Efficiency factor of holes in the wall, determined by the following formulae:

$$e = \frac{s-d}{s} \quad \text{for } d < a$$

$$e = \frac{s-0{,}67d}{s} \quad \text{for } a \le d < 1{,}3a$$

$$e = \frac{s-0{,}33d}{s} \quad \text{for } d \ge 1{,}3a$$

where:

s : Pitch of the holes, in mm, of the longitudinal or diagonal row under consideration. For a staggered pattern of holes the pitch of the diagonal row is to be considered

d : Diameter of the holes, in mm

M_1 : Coefficient to be calculated by the following formula:

$$M_1 = \frac{a^2+b^2-ab}{50}$$

M_2 : Coefficient (to be taken always positive) to be calculated by one of the following formulae, as appropriate:

- For a non-staggered pattern of holes:

$$M_2 = \frac{b^2-\frac{1}{2}a^2-ab+\frac{3}{2}c^2}{50}$$

- For a staggered pattern of holes:

$$M_2 = \frac{b^2-\frac{1}{2}a^2-ab}{50}\cos\alpha$$

where α is the angle between the axis of the diagonal row of the holes under consideration and the axis of the header, in the case of a staggered pattern of holes.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1,5 mm. See also [2.4.7].

2.10 Water tubes, superheaters and economiser tubes of boilers

2.10.1

a) The thickness of tubes of evaporating parts, economisers and superheaters exposed to gases which are subject to internal pressure is not to be less than the value t given by the following formula:

$$t = \frac{pd}{2K+p}+0{,}3$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

d : Outside diameter of tube, in mm.

However, irrespective of the value calculated by the formulae in item a), the thickness t of tubes is not to be less than the values given in Tab 14.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in item a) is to be increased by 12,5% to take into account the manufacturing tolerance. For bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the formula.

c) Whenever abnormal corrosion and erosion may occur during service, the corrosion constant of 0,3 in the formula may be increased to the satisfaction of the Society.

d) The thickness of tubes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes (see Ch 1, Sec 10, [14]).

2.11 Additional requirements for fired pressure vessels

2.11.1 Insulation for headers and combustion chambers

Those parts of headers and/or combustion chambers which are not protected by tubes and are exposed to radiant heat or to high temperature gases are to be covered by suitable insulating material.

2.11.2 Connections of tubes to drums and tube plates

Tubes are to be adequately secured to drums and/or tube plates by expansion, welding or other appropriate procedure.

a) Where the tubes are secured by expanding or equivalent process, the height of the shoulder bearing the tube, measured parallel to the tube axis, is to be at least 1/5 of the hole diameter, but not less than 9 mm for tubes normal to the tube plate or 13 mm for tubes angled to the tube plate. The tubes ends are not to project over the other face of the tube plate more than 6 mm.

b) The tube ends intended to be expanded are to be partially annealed when the tubes have not been annealed by the manufacturer.

2.12 Additional requirements for vertical boilers and fire tube boilers

2.12.1 General

The scantlings of the shells of vertical boilers and fire tube boilers are to be determined in accordance with [2.4].

2.12.2 Ends of vertical boilers

a) The minimum thickness of the dished ends forming the upper part of vertical boilers and subject to pressure on their concave face is to be determined in accordance with [2.5].

b) When the end is supported in its centre by an uptake, the minimum thickness t, in mm, is to be calculated with the following formula:

$$t = 0{,}77 \cdot \frac{pR_I}{K}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

R_I : Radius of curvature at the centre of the end measured internally. R_I is not to exceed the external diameter of the shell.

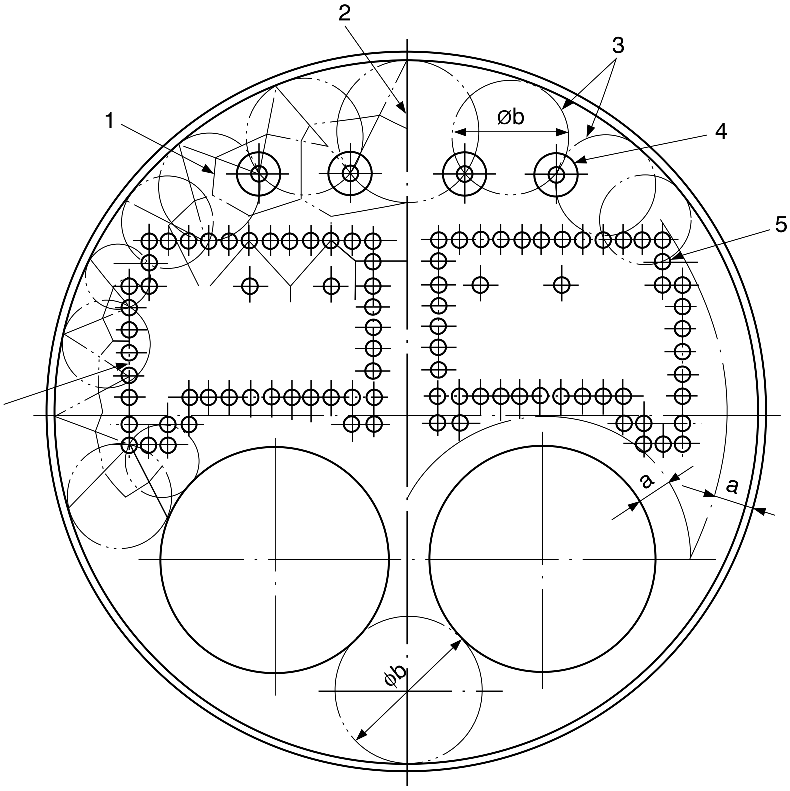
c) The thickness obtained by the formula in item b) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,7 mm. See also [2.4.7].

d) For ends supported by an uptake at their centre, the corner radius measured internally is not to be less than 4 times the end thickness or 65 mm, whichever is the lesser and the inside radius of curvature on the flange to uptake is not to be less than twice the end thickness or 25 mm, whichever is the lesser.

Table 14 : Minimum thickness of water tubes

Outside diameter, in mm	Minimum thickness in mm of tubes subject to internal pressure of cylindrical boilers and water tube boilers having the feed water system	
	Closed type, if equipped with suitable devices for reducing the oxygen concentration in the water	Open type, not equipped with suitable devices for reducing the oxygen concentration in the water
< 38	1,8	2,9
38 - 48,3	2,0	2,9
51 - 63,5	2,4	2,9
70	2,6	3,2
76,1 - 88,9	2,9	3,2
101,6 - 127	3,6	–

Figure 21 :



Key:

1 : Boundaries of areas supported by individual stays

2 : To establish the area supported by bar stays or stay tubes in boundary rows, the boundary of the loaded area is to terminate at the centre of the associated main circle

3 : Main circles, diameter b

4 : Bar stays

5 : Stay tubes

6 : Termination of boundary areas where stay tubes are situated in the boundary rows only.

2.12.3 Supported flat head

a) Breathing space

- Stays are to give breathing space around the furnace tube connections and tube nests and equally divide the unstayed areas. Breathing space between furnace tube and tube nests are to be a minimum of 50 mm or 5% of the shell outside diameter, whichever is the larger, but need not be more than 100 mm.
- Breathing space between furnace tube and shell depends on the thickness of the plate of the type of end and of the dimensions of the boiler but is to be not less than 50 mm or, for bowling hoop furnaces tubes, not less than 75 mm.

b) The thickness of stayed flat heads, or of heads supported by flanges, is not to be less than the value t, in mm, given by the following formula:

$$t = D\left[\frac{100p}{CC_1K(1+C_2B^2)}\right]^{0,5}$$

where:

B : Ratio of the thickness of the large washer or doubler, where fitted, to the thickness of the plate:

$B = t_1 / t$

The value of B is to be taken between 0,67 and 1

K : Permissible stress, in N/mm², obtained as specified in [2.3]

C : C = 1 when the plate is not exposed to flame

C = 0,88 when the plate is exposed to flame

C_1 : C_1 = 462 when the plate is supported by welded stays

C_1 = 704 for plates supported by flanges or equivalent

C_2 : C_2 = 0 when no doublers are fitted

C_2 = 0,85 when a complete doubling plate is fitted, adequately joined to the base plate.

The value of D is to be in accordance with the following provisions:

- In the parts of the flat heads between the stays:

  D is the diameter, in mm, of the largest circle which can be drawn through the centre of at least three stays without enclosing any other stay, where the stays are not evenly spaced (see Fig 21), or

  $D = (a^2 + b^2)^{0,5}$ where the stays are evenly spaced, considering the most unfavourable condition

  where:

  a : Distance between two adjacent rows of stays, in mm

  b : Pitch of stays in the same row, in mm.

- In the parts of the flat heads between the stays and the boundaries, where flat heads are generally supported by flanges or shapes, or connected to other parts of the boiler:

  D is the diameter, in mm, of the largest circle which can be drawn through not less than three points of support (stay centres or points of tangency of the circle with the contour line). To this end, the contour of the part under consideration is to be drawn at the beginning of the flanging or connection curve if its inside radius does not exceed 2,5 times the thickness of the plate, or, where such radius is greater, at the above-mentioned distance (of 2,5 times the thickness of the plate) from the ideal intersection with other surfaces (see Fig 21).

c) When applying the formulae for calculation of thickness of heads covered by this sub-article, the position of plates in the most unfavourable condition is to be considered.

d) Where various types of supports are provided, the value of C_1 should be the arithmetic mean of the values of C_1 appropriate to each type of support.

e) The thickness obtained by the formulae in a), is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.12.4 Flat tube plates

a) Flat tube plates in tube bundles

The thickness of the parts of flat tube plates contained in the tube bundle and supported by stay tubes is not to be less than the value t, in mm, given by the following formula:

$$t = s\left(\frac{p}{2,8K}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

s : Pitch of stay tubes, taken as the greatest mean pitch of the stay tubes supporting a quadrilateral portion of the plate, in mm.

Moreover the spacing of tube holes (diameter d) is to be such that the minimum width, in mm, of any ligament between the tube holes is to be not less than:

- for expanded tubes:

  (0,125 d + 12,5) mm

- for welded tubes:
  - for gas entry temperatures greater than 800°C:

    (0,125 d + 9) mm, but need not exceed 15 mm
  - for gas entry temperatures less than or equal to 800°C:

    (0,125 d + 7) mm, but need not exceed 15 mm.

Moreover the calculated thickness of tube plates is to be not less than the following:

- 12 mm where the tubes are expanded into the tube plate when the diameter of the tube hole does not exceed 50 mm, or 14 mm when the diameter of the tube hole is greater than 50 mm, or
- 6 mm where the tubes are attached to the tube plate by welding only.

b) Flat tube plates of combustion chamber in vertical boilers

Where tube plates contained in the tube bundle are simultaneously subject to compression due to the pressure in the combustion chamber, their thickness, as well as complying with the requirements in item a) is not to be less than the value t, in mm, given by the following formula:

$$t = \frac{p l s_1}{1,78(s_1 - d)K}$$

where:

l : Depth of the combustion chamber, in mm

s_1 : Horizontal pitch of tubes, in mm

d : Inside diameter of plain tubes, in mm.

For the meaning of other symbols, see item a).

c) Tube plates outside tube bundles

For those parts of tube plates which are outside the tube bundle, the formula in [2.13.3] is to be applied, using the following coefficients C_1 and C_2:

$C_1 = 390$

$C_2 = 0,55$

Doublers are only permitted where the tube plate does not form part of a combustion chamber.

d) Tube plates not supported by stays

Flat tube plates which are not supported by stay tubes (e.g. in heat exchangers), are subject of special consideration by the Society (see also [2.14]).

e) Stay and stay tube scantling

- The diameter of solid stays of circular cross-section is not to be less than the value d calculated by the following formula:

$$d = \left(\frac{pA}{K}\right)^{0,5}$$

where:

d : Minimum diameter, in mm, of the stay throughout its length

A : Area supported by the stay, in mm²

K : $K = R_m / 7$

R_m : Minimum ultimate tensile strength of the stay material, in N/mm².

The cross section of tube stays is to be equivalent to that of a solid stay supporting the same area, whose diameter is calculated by the above formula.

Stays which are not perpendicular to the supported surface are to be of an adequately increased diameter depending on the component of the force normal to the plate.

- Where articulated stays are used, articulation details are to be designed assuming a safety factor for articulated elements not less than 5 with respect to the value of R_m and a wear allowance of 2 mm.

The articulation is to be of the fork type and the clearance of the pin in respect of the holes is not to exceed 1,5 mm. The pin is to bear against the jaws of the fork and its cross-sectional area is not to be less than 80% of the cross-sectional area of the stay. The width of material around the holes is not to be less than 13 mm.

- Where stays are flanged for joining to the plate, the thickness of the flange is not to be less than one half the diameter of the stay.
- For welded connections of stays to tube plates, see Fig 37.

f) Stay and stay tubes construction

- In general, doublers are not to be fitted in plates exposed to flame.
- As far as possible, stays are to be fitted perpendicularly to the supported surface.
- Long stays in double front boilers and, in general, stays exceeding 5 m in length, are to be supported at mid-length.
- Where the ends of stay tubes are of increased thickness, the excess material is to be obtained by forging and not by depositing material by means of welding.
- After forging, the ends of stay tubes are to be stress relieved.

g) Gusset stays

Tube plate may be supported by gussets stays with full penetration welds to plate and shell.

The general shape and the scantling are to be in accordance with a standard accepted by the Society.

h) Girders

Where tops of combustion chambers, or similar structures, are supported by girders of rectangular section associated with stays, the thickness of the single girder or the aggregate thickness of all girders, at mid-length, is not to be less than the value t determined by the appropriate formula below, depending upon the number of stays.

- In case of an odd number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+1}{n}$$

- In case of an even number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+2}{n+1}$$

where:

p : Design pressure, in MPa

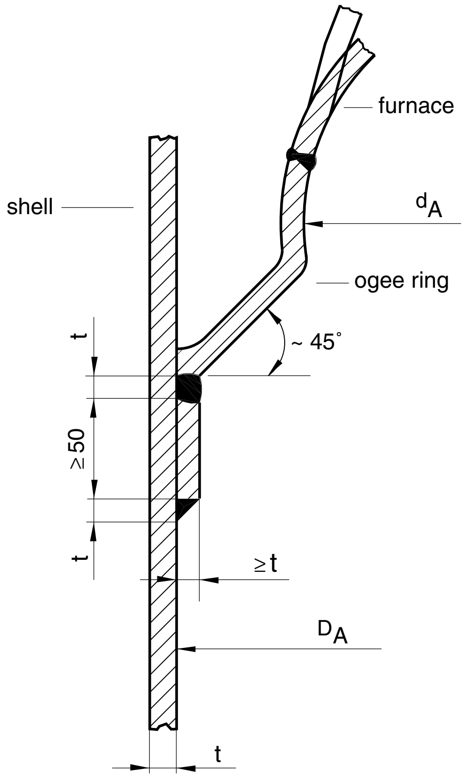
a : Depth of the girder plate at mid-length, in mm

L : Length of girder between supports, in mm

s : Pitch of stays, in mm

n : Number of stays on the girder

Figure 22 : Ogee ring



l : Distance between centres of girders, in mm

R_m : Minimum ultimate tensile strength of the material used for the plates, in N/mm².

The above formulae refer to the normal arrangement where:

- The stays are regularly distributed over the length L.
- The distance from the supports of the outer stays does not exceed the uniform pitch s.
- When the tops of the combustion chambers are connected to the sides with curved parts with an external radius less than 0,5 l, the distance of end girders from the inner part of the side surface does not exceed l.
- When the curvature radius mentioned under item just above exceeds 0,5 l, the distance of the end girders from the beginning of the connection does not exceed 0,5 l.

In other cases a direct calculation is to be made using a safety factor not less than 5, with respect to the minimum value of the tensile strength R_m.

i) Ogee rings

The thickness of ogee rings connecting the furnaces to the shell in vertical auxiliary boilers (see Fig 22), where the latter support the weight of the water above the furnace, is not to be less than the value t, in mm, given by the following formula:

$$t = [1{,}02 \cdot 10^{-3} \cdot pD_A \cdot (D_A - d_A)]^{0{,}5} + 1$$

where:

p : Design pressure, in MPa

D_A : Inside diameter of boiler shell, in mm

d_A : Inside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

2.12.5 Fire tubes

a) The thickness of fire tubes subject to external pressure in cylindrical boilers is not to be less than the value t, in mm, calculated by the following formula:

$$t = \frac{pd}{0{,}15 R_m} + 1{,}8$$

where:

p : Design pressure, in MPa

d : Outside diameter of tube, in mm

R_m : Minimum ultimate tensile strength of the tube material, in N/mm².

The minimum acceptable thickness is given in Tab 15.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in a) is to be increased by 12,5% to take into account the manufacturing tolerance. In the case of bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the above formula.

c) Whenever abnormal corrosion and erosion may occur during service the corrosion constant of 1,8 in the formula may be increased to the satisfaction of the Society.

Table 15 : Minimum thickness of fire tubes

Nominal outside diameter	Lowest nominal thickness t
d ≤ 88,9	3,00
88,9 < d ≤ 114,3	3,15
114,3 < d ≤139,7	3,50
139,7 < d ≤168,3	3,99

2.12.6 Furnaces general points

a) Thermal design of furnace tubes.

The heat input for a given furnace tube inside diameter is not to exceed a value compatible with the chosen design temperature. Burners with a fixed firing rate are not to be used for heat inputs exceeding 1 MW per furnace tube.

b) The minimum thickness of furnaces is to be calculated for elastic buckling and plastic deformation in accordance with the requirements of a Standard for pressure vessels subject to external pressure accepted by the Society.

c) However, the minimum thicknesses of furnaces and cylindrical ends of combustion chambers of fire tube boilers are to be not less than the value t given by the appropriate formulae in [2.12.7], [2.12.8] and [2.12.9].

d) The thickness of furnaces is not to be less than 8 mm for plain furnace and 10 mm for corrugated furnace and the stays are to be spaced such that the thickness does not exceed 22 mm.

e) All the thicknesses obtained for furnaces by the formulae in [2.12.7], [2.12.8], [2.12.9] and [2.12.4] are "net" thicknesses, as they do not include any corrosion allowance. The thicknesses obtained by the above formulae are to be increased by 1 mm. See also [2.4.7].

2.12.7 Plain furnace tubes

a) Plain furnace tube

The minimum thickness t of plain cylindrical furnaces is to be not less than the greater value, in mm, obtained from the following formulae:

$$t = \frac{B}{2}\left[1 + \sqrt{1 + \frac{0,12D \cdot u}{(1 + 5D/L)B}}\right]$$

$$t = D^{0,6}[(LS_2p)/(2,6E)]^{0,4}$$

where:

$$B = \frac{pDS_1}{2R_{S,MIN,T}(1 + 5D/L)}$$

S_1 : Safety factor, equal to 2,5

L : Unstayed length of furnace, in mm

u : Departure from circularity, in %, equal to:

$$u = \frac{2(D_{max} - D_{min})}{D_{max} + D_{min}} \times 100$$

u is to be taken as 1,5% for plain furnace tubes

S_2 : Safety factor for buckling, equal to:

- 3 for u ≤1,5%
- 4 for 1,5% < u ≤ 2%

E : Elastic modulus, in MPa, at design temperature T, in °C, and equal to:

$E = 208800 - 93,4 \cdot T$

b) Stiffeners

Stiffeners welded to furnaces tubes according to a standard accepted by the Society may be considered as providing effective stiffening (reduction of L in upper formulae).

2.12.8 Corrugated furnace tubes

The minimum thickness of corrugated furnace tubes, in mm, is to be determined by:

$$t = \frac{pD_E}{0,26R_m}$$

where:

D_E : External diameter of the furnace, in mm, measured at the bottom of the corrugation.

This formula apply for Fox and Morisson type furnaces tubes. The scantling of furnaces of other types and the use of stiffeners are to be especially considered by the Society.

2.12.9 Hemispherical furnaces

The minimum thickness t, in mm, of hemispherical furnaces is not to be less than the value given by the following equation:

$$t = \frac{pD_E}{120}$$

2.13 Bottles containing pressurised gases

2.13.1 General

a) The following requirements apply to bottles intended to contain pressurised and/or liquefied gases at ambient temperature, made by seamless manufacturing processes.

b) In general, such bottles are to have an outside diameter not exceeding 420 mm, a length not exceeding 2000 mm and capacity not exceeding 150 litres (see also [3.4.1]).

c) For bottles exceeding the above capacity and dimensions, the following requirements may be applied at the discretion of the Society.

2.13.2 Cylindrical shell

The wall thickness of the cylindrical shell is not to be less than the value t, in mm, determined by the following formula:

$$t = \frac{p_H D_E}{2K + p_H}$$

where:

p_H : Hydrostatic test pressure, in MPa. This pressure is to be taken as 1,5 times the setting pressure of the safety valves with the following exceptions:

- 25 MPa for CO_2 bottles
- for refrigerants, the value of hydrostatic test pressure is given in Pt E, Ch 11, Sec 3

D_E : Outside diameter of tube, in mm

$K = R_{S,MIN} / 1,3$

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\ 0,2}$), at the ambient temperature, in N/mm². In no case is the value $R_{S,MIN}$ to exceed:

- 0,75 R_m for normalised steels
- 0,90 R_m for quenched and tempered steels.

2.13.3 Dished heads

Dished ends are to comply with the following requirements:

a) Hemispherical ends: the thickness of the ends is to be not less than the thickness calculated for spherical shells in accordance with [2.4.4]

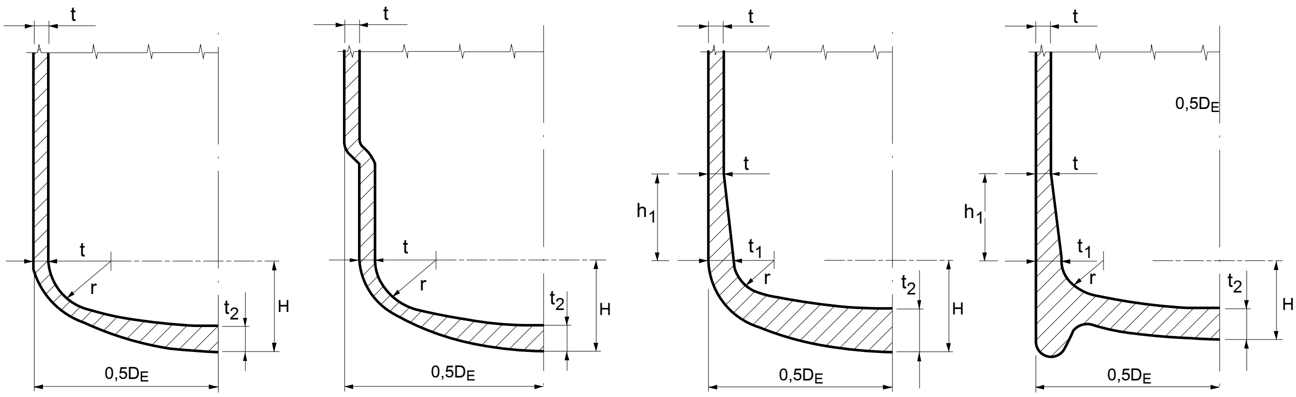
b) Convex ends: see Fig 23

c) Concave base ends: see Fig 24

d) Ends with openings: see Fig 25

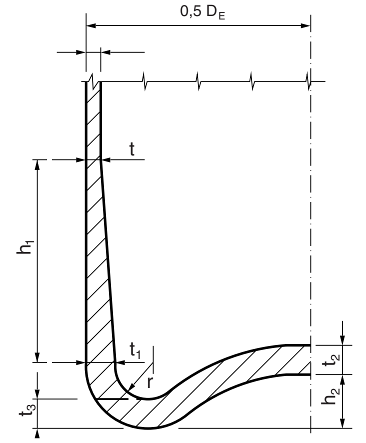
e) Other types of ends are to be specially considered by the Society.

Figure 23 : Dished convex ends



$H/D_E \geq 0,20$ $r \geq 0,075D_E$ $t_1 \geq 1,25\ t$ $t_2 \geq 1,5\ t$ $h_1 \geq 6\ t$

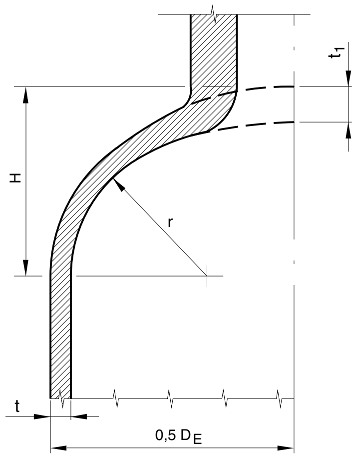
Figure 24 : Dished concave ends



$t_1 \geq 1,7\ t$ $t_2 > 2\ t$ $t_3 \geq 2\ t$

$h_1 \geq 6\ t$ $h_2 \geq 0,12\ D_E$ $r \geq 0,075\ D_E$

Figure 25 : Heads with openings



$0,25 \leq H/D_E \leq 0,5$ $t_1 \geq 1,5t$ $r \geq 0,35D_E$

2.14 Heat exchangers

2.14.1 Scantlings

a) Vessels are to be designed in accordance with the applicable requirements stated in [2.4] and [2.5].

b) Tubes are to be designed in accordance with [2.10.1].

c) Tube plates are to be designed in accordance with a standard accepted by the Society.

2.14.2 Thermal oil heat exchangers

The provisions of [2.14.1] apply also to thermal oil heat exchangers. However, irrespective of the thickness obtained by the formula in [2.10.1], the tube thickness of oil fired and exhaust fired thermal oil heaters is to be not less than the values indicated in Tab 16.

Table 16 : Minimum thickness of thermal oil heat exchanger tubes

Outside diameter, in mm	Minimum thickness, in mm, of tubes subject to internal pressure of oil fired and exhaust fired thermal oil heaters
< 63,5	2,4
70 - 89	2,9
> 89	3,6

3 Design and construction - Equipment

3.1 All pressure vessels

3.1.1 Drainage

a) Each air pressure vessel is to be fitted with a drainage device allowing the evacuation of any oil or water accumulated in the vessel.

b) Drainage devices are also to be fitted on other vessels, in particular steam vessels, in which condensation water is likely to accumulate.

3.2 Boilers and steam generators

3.2.1 Safety valve arrangement

a) Every steam boiler and every steam generator with a total heating surface of 50 m^2 and above is to be provided with not less than two spring loaded safety valves of adequate capacity. For steam boilers and steam generators having heating surface less than 50 m^2, only one safety valve need be fitted.

b) Where a superheater is an integral part of the boiler, at least one safety valve is to be located on the steam drum and at least one at the superheater outlet. The valves fitted at the superheater outlet may be considered as part of the boiler safety valves required in item a), provided that their capacity does not account for more than 25% of the total capacity required in [3.2.2], unless specially considered by the Society.

c) Where fitted, superheaters which may be shut-off from the boiler are to be provided with at least one safety valve; such valve(s) cannot be considered as part of the boiler safety valves required in item a).

d) In the case of boilers fitted with a separate steam accumulator, safety valves may be fitted on the accumulator if no shut-off is provided between it and the boiler and if the connecting pipe is of a size sufficient to allow the whole steam production to pass through, without increasing the boiler pressure more than 10% above the design pressure.

3.2.2 Relieving capacity of safety valves

a) The relieving capacity of each safety valve Q, in kg/h, is to be determined by the appropriate formula below in order that:

$Q \geq W$

- saturated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1,05)}{100}$$

- superheated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1,05)}{100} \times \sqrt{\frac{v}{v_S}}$$

where:

W : Maximum steam production, in kg/h, as defined by the maximum power of the heating equipment; otherwise the value of W is to be based on evaporating capacities (referring to evaporating surfaces of the boiler concerned) less than the following:

- 14 kg/(m^2·h) for exhaust gas heated boilers
- 29 kg/(m^2·h) for oil fired boilers
- 60 kg/(m^2·h) for water walls of oil fired boilers

A : Aggregate area, in mm^2, of the orifices in way of the seat of the valve, deducting the obstructions corresponding to the guides and the conformation of the valve in full lift position

p : Maximum working pressure of the boiler or other steam generator, in MPa. For superheated steam safety valves, P is to be the pressure at the superheater outlet

C : Coefficient with the following values:

- C = 4,8 for ordinary safety valves, i.e. where the valve lift is at least 1/24 of the internal diameter of the seat
- C = 10 for high lift safety valves, i.e. where the valve lift is at least 1/12 of the internal diameter of the seat
- C = 20 for full lift safety valves, i.e. where the valve lift is at least 1/4 of the internal diameter of the valve

Higher values of coefficient C may be admitted for safety valves of approved type and having undergone, in the presence of the Surveyor or according to a procedure considered as equivalent by the Society, capacity tests with conditions of pressure and temperature comparable to those of the plant considered. In such a case, coefficient C is to be, as a rule, taken as 90% of the resulting value from the capacity test

v : Specific volume of saturated steam at the pressure corresponding to the superheater outlet

v_S : Specific volume of superheated steam at the temperature corresponding to the superheater outlet.

b) When the safety valves are fitted at the superheater outlet. Their relieving capacity is to be such that, during the discharge of safety valves, a sufficient quantity of steam is circulated through the superheater to avoid damage.

c) The orifice diameter in way of the safety valves seat is not to be less than 40 mm. Where only one safety valve need be fitted, the orifice minimum diameter is not to be less than 50 mm. Valves of large relieving capacity with 15 mm minimum diameter may be accepted for boilers with steam production not exceeding 2000 kg/h.

d) Independently of the above requirements, the aggregate capacity of the safety valves is to be such as to discharge all the steam that can be generated without causing a transient pressure rise of more than 10% over the design pressure.

3.2.3 Miscellaneous safety valve requirements

a) Safety valves operated by pilot valves

The arrangement on the superheater of large relieving capacity safety valves, operated by pilot valves fitted in the saturated steam drum, is to be specially considered by the Society.

b) Safety valve setting

- safety valves are to be set under steam in the presence of the Surveyor to a pressure not higher than 1,03 times the design pressure
- safety valves are to be so constructed that their setting may not be increased in service and their spring may not be expelled in the event of failure. In addition, safety valves are to be provided with simple means of lifting the plug from its seat from a safe position in the boiler or engine room
- where safety valves are provided with means for regulating their relieving capacity, they are to be so fitted that their setting cannot be modified when the valves are removed for surveys.

c) Safety valve fitting on boiler

- the safety valves of a boiler are to be directly connected to the boiler and separated from other valve bodies
- where it is not possible to fit the safety valves directly on the superheater headers, they are to be mounted on a strong nozzle fitted as close as practicable to the superheater outlet. The cross-sectional area for passage of steam through restricted orifices of the nozzles is not to be less than 1/2 the aggregate area of the valves, calculated with the formulae of [2.3.2] when $C \leq 10$, and not less than the aggregate area of the valves when $C > 10$
- safety valve bodies are to be fitted with drain pipes of a diameter not less than 20 mm for double valves, and not less than 12 mm for single valves, leading to the bilge or to the hot well. Valves or cocks are not to be fitted on drain pipes.

d) Exhaust pipes

- the minimum cross-sectional area of the exhaust pipes of safety valves which have not been experimentally tested is not to be less than C times the aggregate area A
- the cross-sectional area of the exhaust manifold of safety valves is to be not less than the sum of the areas of the individual exhaust pipes connected to it
- silencers fitted on exhaust manifolds are to have a free passage area not less than that of the manifolds
- the strength of exhaust manifolds and pipes and associated silencers is to be such that they can withstand the maximum pressure to which they may be subjected, which is to be assumed not less than 1/4 of the safety valve setting pressure
- in the case that the discharges from two or more valves are led to the same exhaust manifold, provision is to be made to avoid the back pressure from the valve which is discharging influencing the other valves
- exhaust manifolds are to be led to the open and are to be adequately supported and fitted with suitable expansion joints or other means so that their weight does not place an unacceptable load on the safety valve bodies.

e) Steam generator heated by steam

Steam heated steam generators are also to be protected against possible damage resulting from failure of the heating coils. In this case, the area of safety valves calculated as stated in [3.2.2] may need to be increased to the satisfaction of the Society, unless suitable devices limiting the flow of steam in the heating coils are provided.

3.2.4 Other requirements

Access arrangement

a) Boilers are to be provided with openings in sufficient number and size to permit internal examination, cleaning and maintenance operations. In general, all pressure vessels which are part of a boiler with inside diameter exceeding 1200 mm, and those with inside diameter exceeding 800 mm and length exceeding 2000 mm, are to be provided with access manholes.

b) Manholes are to be provided in suitable locations in the shells, headers, domes, and steam and water drums, as applicable. The "net" (actual hole) dimension of elliptical or similar manholes is to be not less than 300mm x 400mm. The "net" diameter of circular manholes (actual hole) cannot be less than 400 mm. The edges of manholes are to be adequately strengthened to provide compensation for vessel openings in accordance with [2.8.4], [2.8.6] and [2.8.9], as applicable.

c) In pressure vessels which are part of a boiler and are not covered by the requirement in item a) above, or where an access manhole cannot be fitted, at least the following openings are to be provided, as far as practicable:

- head holes: minimum dimensions: 220mm x 320mm (320 mm diameter if circular)
- handholes: minimum dimensions: 87mm x 103mm
- sight holes: minimum diameter: 50 mm.

d) Sight holes may only be provided when the arrangement of manholes, head holes, or handholes is impracticable.

e) Covers for manholes and other openings are to be made of ductile steel, dished or welded steel plates or other approved design. Grey cast iron may be used only for small openings, such as handholes and sight holes, provided the design pressure p does not exceed 1 MPa and the design temperature T does not exceed 220°C.

f) Covers are to be of self-closing internal type. Small opening covers of other type may be accepted by the Society on a case by case basis.

g) Covers of the internal type are to have a spigot passing through the opening. The clearance between the spigot and the edge of the opening is to be uniform for the whole periphery of the opening and is not to exceed 1,5 mm.

h) Closing devices of internal type covers, having dimensions not exceeding 180mm x 230mm, may be fitted with a single fastening bolt or stud. Larger closing devices are to be fitted with at least two bolts or studs.

i) Covers are to be designed so as to prevent the dislocation of the required gasket by the internal pressure. Only continuous ring gaskets may be used for packing.

Fittings

a) In general, cocks and valves are to be designed in accordance with the requirements in Ch 1, Sec 10, [2.7.2].

b) Cocks, valves and other fittings are to be connected directly or as close as possible to the boiler shell.

c) Cocks and valves for boilers are to be arranged in such a way that it can be easily seen when they are open or closed and so that their closing is obtained by a clockwise rotation of the actuating mechanism.

Boiler burners

Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

Allowable water levels

a) In general, for water tube boilers the lowest permissible water level is just above the top row of tubes when the water is cold. Where the boiler is designed not to have fully submerged tubes, when the water is cold, the lowest allowable level indicated by the manufacturer is to be indicated on the drawings and submitted to the Society for consideration.

b) For fire tube boilers with combustion chamber integral with the boiler, the minimum allowable level is to be at least 50 mm above the highest part of the combustion chamber.

c) For vertical fire tube boilers the minimum allowable level is 1/2 of the length of the tubes above the lower tube sheet.

Steam outlets

a) Each boiler steam outlet, if not serving safety valves, integral superheaters and other appliances which are to have permanent steam supply during boiler operation, is to be fitted with an isolating valve secured either directly to the boiler shell or to a standpipe of substantial thickness, as short as possible, and secured directly to the boiler shell.

b) The number of auxiliary steam outlets is to be reduced to a minimum for each boiler.

c) Where several boilers supply steam to common mains, the arrangement of valves is to be such that it is possible to positively isolate each boiler for inspection and maintenance. In addition, for water tube boilers, non-return devices are to be fitted on the steam outlets of each boiler.

d) Where steam is used for essential auxiliaries (such as whistles, steam operated steering gears, steam operated electric generators, etc.) and when several boilers are fitted on board, it is to be possible to supply steam to these auxiliaries with any one of these boilers out of operation.

e) Each steam stop valve exceeding 150 mm nominal diameter is to be fitted with a bypass valve.

Feed check valves

a) Each fired boiler supplying steam to essential services is to be fitted with at least two feed check valves connected to two separate feed lines. For unfired steam generators a single feed check valve may be allowed.

b) Feed check valves are to be secured directly to the boiler or to an integral economiser. Water inlets are to be separated. Where, however, feed check valves are secured to an economiser, a single water inlet may be allowed provided that each feed line can be isolated without stopping the supply of feed water to the boiler.

c) Where the economisers may be bypassed and cut off from the boiler, they are to be fitted with pressure-limiting type valves, unless the arrangement is such that excessive pressure cannot occur in the economiser when cut off.

d) Feed check valves are to be fitted with control devices operable from the stokehold floor or from another appropriate location. In addition, for water tube boilers, at least one of the feed check valves is to be arranged so as to permit automatic control of the water level in the boiler.

e) Provision is to be made to prevent the feed water from getting in direct contact with the heated surfaces inside the boiler and to reduce, as far as possible and necessary, the thermal stresses in the walls.

Drains

Each superheater, whether or not integral with the boiler, is to be fitted with cocks or valves so arranged that it is possible to drain it completely.

Water sample

a) Every boiler is to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

b) For this purpose, boilers are to be fitted with at least one water sample cock or valve. This device is not to be connected to the water level standpipes.

c) Suitable inlets for water additives are to be provided in each boiler.

Marking of boilers

a) Each boiler is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
   - the design pressure
   - the design temperature
   - the test pressure and the date of the test.

b) Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.

c) For lagged vessels, these markings are also to appear on a similar plate fitted above the lagging.

3.3 Thermal oil heaters and thermal oil installation

3.3.1 General

a) The following requirements apply to thermal oil heaters in which organic liquids (thermal oils) are heated by oil fired burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.

b) Thermal oils are only to be used within the limits set by the manufacturer.

c) Means are to be provided for manual operation. During manual operation, the automated functioning of at least the temperature control device on the thermal oil side as well as the flow monitoring is to be maintained.

d) Means are to be provided to take samples of thermal oil.

3.3.2 Thermal oil heater design

a) Heaters are to be so constructed that neither the surfaces nor the thermal oil becomes excessively heated at any point. The flow of the thermal oil is to be ensured by forced circulation.

b) The surfaces which come into contact with the thermal oil are to be designed for the design pressure, subject to the minimum pressure of 1 MPa.

c) Copper and copper alloys are not permitted.

d) Heaters heated by exhaust gas are to be provided with inspection openings at the exhaust gas intake and outlet.

e) Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber. The opening for the burner may be considered as an inspection opening, provided its size is sufficient for this purpose.

f) Heaters are to be fitted with means enabling them to be completely drained.

g) Thermal oil heaters heated by exhaust gas are to be fitted with a permanent system for extinguishing and cooling in the event of fire, for instance a pressure water spraying system.

3.3.3 Safety valves of thermal oil heaters

Each heater is to be equipped with at least one safety valve having a discharge capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During discharge the pressure may not increase above 10% over the design pressure.

3.3.4 Pressure vessels of thermal oil heaters

The design pressure of all vessels which are part of a thermal oil system, including those open to the atmosphere, is to be taken not less than 0,2 MPa.

3.3.5 Equipment of the expansion, storage and drain tanks

For the equipment to be installed on expansion, storage and drain tanks, see Ch 1, Sec 10, [13].

3.3.6 Marking

Each thermal oil heater and other pressure vessels which are part of a thermal oil installation are to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):

- Heaters
  - maximum allowable heating power
  - design pressure
  - maximum allowable discharge temperature
  - minimum flow rate
  - liquid capacity
- Vessels
  - design pressure
  - design temperature
  - capacity.

3.4 Special types of pressure vessels

3.4.1 Seamless pressure vessels (bottles)

Each bottle is to be marked with the following information:

- name or trade name of the manufacturer
- serial number
- type of gas
- capacity
- test pressure
- empty weight
- test stamp.

3.4.2 Steam condensers

a) The water chambers and steam spaces are to be fitted with doors for inspection and cleaning.

b) Where necessary, suitable diaphragms are to be fitted for supporting tubes.

c) Condenser tubes are to be removable.

d) High speed steam flow, where present, is to be prevented from directly striking the tubes by means of suitable baffles.

e) Suitable precautions are to be taken in order to avoid corrosion on the circulating water side and to provide an efficient grounding.

3.5 Other pressure vessels

3.5.1 Safety valves arrangement

a) General
   - Pressure vessels which are part of a system are to be provided with safety valves, or equivalent devices, if they are liable to be isolated from the system safety devices. This provision is also to be made in all cases in which the vessel pressure can rise, for any reason, above the design pressure.
   - In particular, air pressure vessels which can be isolated from the safety valves ensuring their protection in normal service are to be fitted with another safety device, such as a rupture disc or a fusible plug, in order to ensure their discharge in case of fire. This device is to discharge to the open.
   - Safety devices ensuring protection of pressure vessels in normal service are to be rated to operate before the pressure exceeds the maximum working pressure by more than 5%
   - where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

b) Heat exchangers

Special attention is to be paid to the protection against overpressure of vessels, such as heat exchangers, which have parts that are designed for a pressure which is below that to which they might be subjected in the case of rupture of the tubular bundles or coils contained therein and that have been designed for a higher pressure.

3.5.2 Other requirements

a) Access arrangement

The access requirements for boilers stated in [3.2.4] are also applicable for other pressure vessels.

b) Corrosion protection

Vessels and equipment containing media that might lead to accelerated corrosion are to be suitably protected.

c) Marking

- Each pressure vessel is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
  - the design pressure
  - the design temperature
  - the test pressure and the date of the test.
- Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.
- For smaller pressure vessels the indication of the design pressure only may be sufficient.

4 Design and construction - Fabrication and welding

4.1 General

4.1.1 Base materials

a) These requirements apply to boilers and pressure vessels made of steel of weldable quality.

b) Fabrication and welding of vessels made of other materials are to be the subject of special consideration.

4.1.2 Welding

a) Weldings are to be performed in accordance with welding procedures approved by the Society.

b) Manual and semi-automatic welding is to be performed by welders qualified by the Society.

c) The conditions under which the welding procedures, welding equipment and welders operate are to correspond to those specified in the relevant approvals or qualifications.

d) Both ordinary and special electric arc welding processes are covered in the following requirements.

4.1.3 Cutting of plates

a) Plates are to be cut by flame cutting, mechanical machining or a combination of both processes. For plates having a thickness less than 25 mm, cold shearing is admitted provided that the sheared edge is removed by machining or grinding for a distance of at least one quarter of the plate thickness with a minimum of 3 mm.

b) For flame cutting of alloy steel plates, preheating is to be carried out if necessary.

c) The edges of cut plates are to be examined for laminations, cracks or any other defect detrimental to their use.

4.1.4 Forming of plates

a) The forming processes are to be such as not to impair the quality of the material. The Society reserves the right to require the execution of tests to demonstrate the suitability of the processes adopted. Forming by hammering is not allowed.

b) Unless otherwise justified, cold formed shells are to undergo an appropriate heat treatment if the ratio of internal diameter after forming to plate thickness is less than 20. This heat treatment may be carried out after welding.

c) Before or after welding, hot formed plates are to be normalised or subjected to another treatment suitable for their steel grade, if hot forming has not been carried out within an adequate temperature range.

d) Plates which have been previously butt-welded may be formed under the following conditions:

- Hot forming

  After forming, the welded joints are to be subjected to X-ray examination or equivalent. In addition, mechanical tests of a sample weld subjected to the same heat treatment are to be carried out.

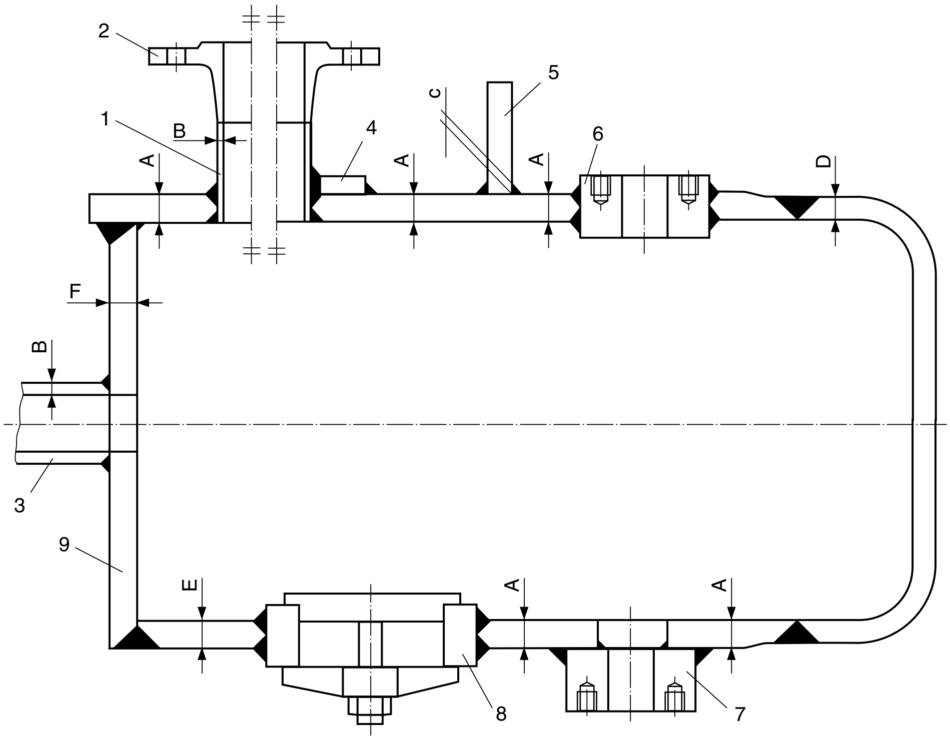
- Cold forming

  Cold forming is only allowed for plates having a thickness not exceeding:

  - 20 mm for steels having minimum ultimate tensile strength R_m between 360 N/mm² and 410 N/mm²
  - 15 mm for steels having R_m between 460 N/mm² and 510 N/mm² as well as for steels 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.

  Cold forming is not allowed for steels 1Cr0,5Mo and 2,25Cr1Mo.
- Weld reinforcements are to be carefully ground smooth prior to forming.
- A proper heat treatment is to be carried out after forming, if the ratio of internal diameter to thickness is less than 36, for steels: 460 N/mm², 510 N/mm², 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.
- After forming, the joints are to be subjected to X-ray examination or equivalent and to a magnetic particle or liquid penetrant test.
- Refer to Fig 26 for definition of thickness to be taken in account.

Figure 26 : Example of acceptable joints and thickness to be considered for forming and post-weld heat treatment



Key

1 : Nozzle (set in); **2** : Flange; **3** : Nozzle (set on); **4** : Reinforcing plate; **5** : Non-pressure part;

6 : Pad (set in); **7** : Pad (set on); **8** : Manhole frame; **9** : Flat plate.

4.2 Welding design

4.2.1 Main welded joints

a) All joints of class 1 and 2 pressure parts of boilers and pressure vessels are to be butt-welded, with the exception of welding connecting flat heads or tube sheets to shells, for which partial penetration welds or fillet welds may be accepted.

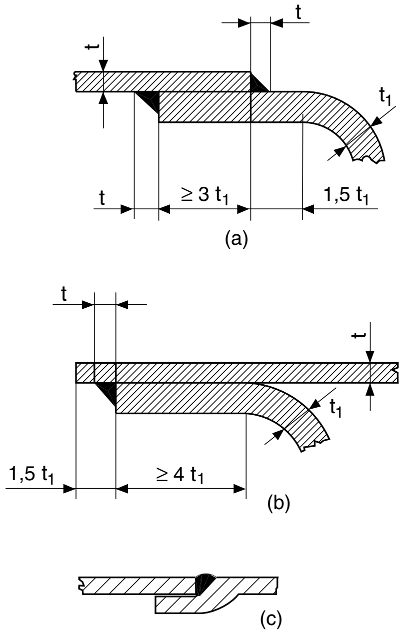
   Fig 26 show examples of acceptable welding for class 1 and 2 pressure vessels.

b) Joints of class 3 pressure vessels are also subject to the requirement in a), however connection of dished heads to shells by lap welds may be accepted. Fig 27 shows some acceptable details of circumferential lap welds for class 3 pressure vessels.

4.2.2 Shell longitudinal and circumferential welds

Longitudinal and circumferential joints are to be welded from both sides of the plate. Welding from one side may be allowed only when there is evidence that the welding process permits a complete penetration and a sound weld root. If a backing strip is used, it is to be removed after welding and prior to any non-destructive examination. However, the backing strip may be retained in circumferential joints of class 2 vessels, having a thickness not exceeding 15 mm, and of class 3 vessels, provided that the material of the backing strip is such as not to adversely affect the weld.

Figure 27 : Example of acceptable lap-joints



Details (b) and (c) may be used only for pressure vessels having internal diameter less than 600mm.

4.2.3 Plates of unequal thickness

a) If plates of unequal thickness are butt-welded and the difference between thicknesses is more than 3 mm, the thicker plate is to be smoothly tapered for a length equal to at least four times the offset, including the width of the weld. For longitudinal joints the tapering is to be made symmetrically on both sides of the plate in order to obtain alignment of middle lines.

b) If the joint is to undergo radiographic examination, the thickness of the thicker plate is to be reduced to that of the thinner plate next to the joint and for a length of at least 30 mm.

4.2.4 Dished heads

a) For connection of a hemispherical end with a cylindrical shell, the joint is to be arranged in a plane parallel to that of the largest circle perpendicular to the axis of the shell and at such a distance from this plane that the tapering of the shell made as indicated in [2.5.6] is wholly in the hemisphere.

b) For torispherical ends made of parts assembled by welding, no welded joint is normally admitted along a parallel in the knuckle nor at a distance less than 50 mm from the beginning of the knuckle.

4.2.5 Welding location

The location of main welded joints is to be chosen so that these joints are not submitted to appreciable bending stresses.

4.2.6 Accessories and nozzles

a) Attachment of accessories by welds crossing main welds or located near such welds is to be avoided; where this is impracticable, welds for attachment of accessories are to completely cross the main welds rather than stop abruptly on or near them.

b) Openings crossing main joints or located near main joints are also to be avoided as far as possible.

c) Doubling plates for attachment of accessories such as fixing lugs or supports are to be of sufficient size to ensure an adequate distribution of loads on pressure parts; such doubling plates are to have well rounded corners. Attachment of accessories such as ladders and platforms directly on the walls of vessels such that they restrain their free contraction or expansion is to be avoided.

d) Welded connections of nozzles and other fittings, either with or without local compensation, are to be of a suitable type, size and preparation in accordance with the approved plans.

4.2.7 Connections of stays to tube plates

a) Where stays are welded, the cross-sectional area of the weld is to be at least 1,25 times the cross-section of the stay.

b) The cross-sectional area of the end welding of welded stay tubes is to be not less than 1,25 times the cross-sectional area of the stay tube.

4.2.8 Type of weldings

Fig 28, Fig 29, Fig 30, Fig 31, Fig 32, Fig 33, Fig 34, Fig 35, Fig 36 and Fig 37 indicate the type and size of weldings of typical pressure vessel connections. Any alternative type of welding or size is to be the subject of special consideration by the Society.

Figure 28 : Types of joints for unstayed flat heads (1)

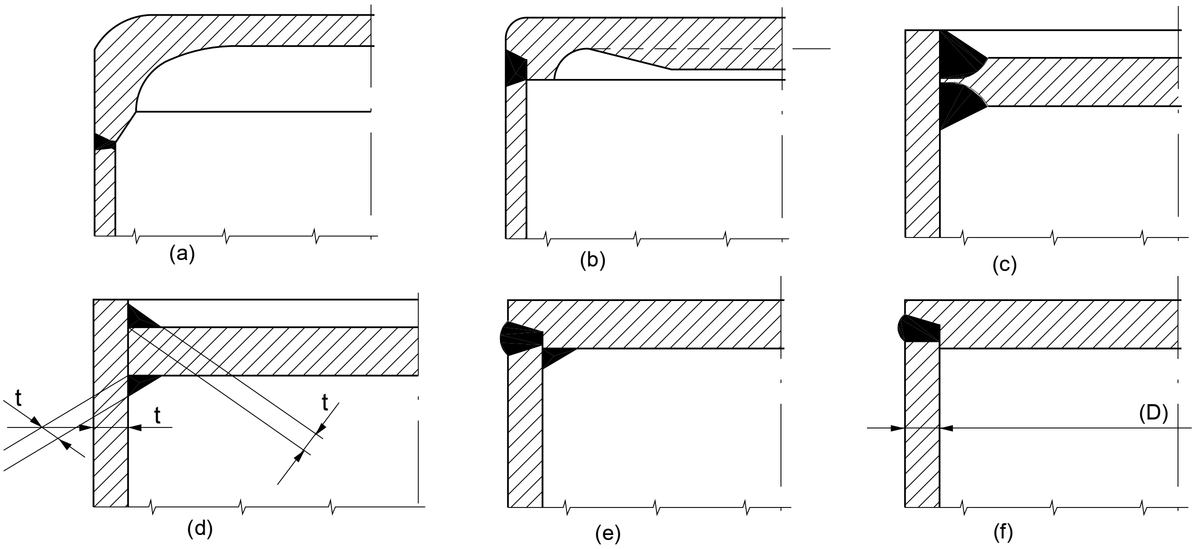


Figure 29 : Types of joints for unstayed flat heads (2)

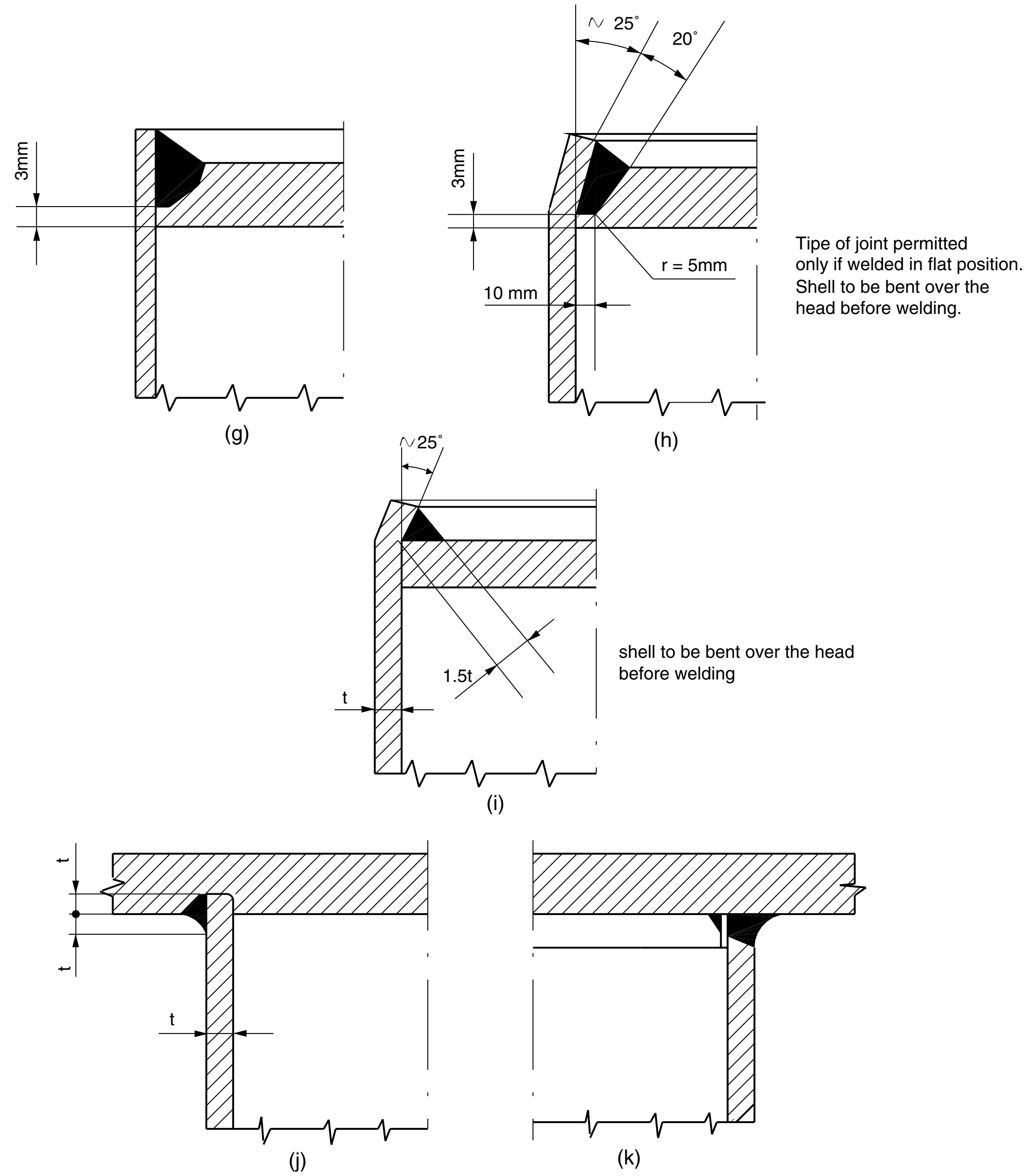


Figure 30 : Types of joints for nozzles and reinforced rings (1)

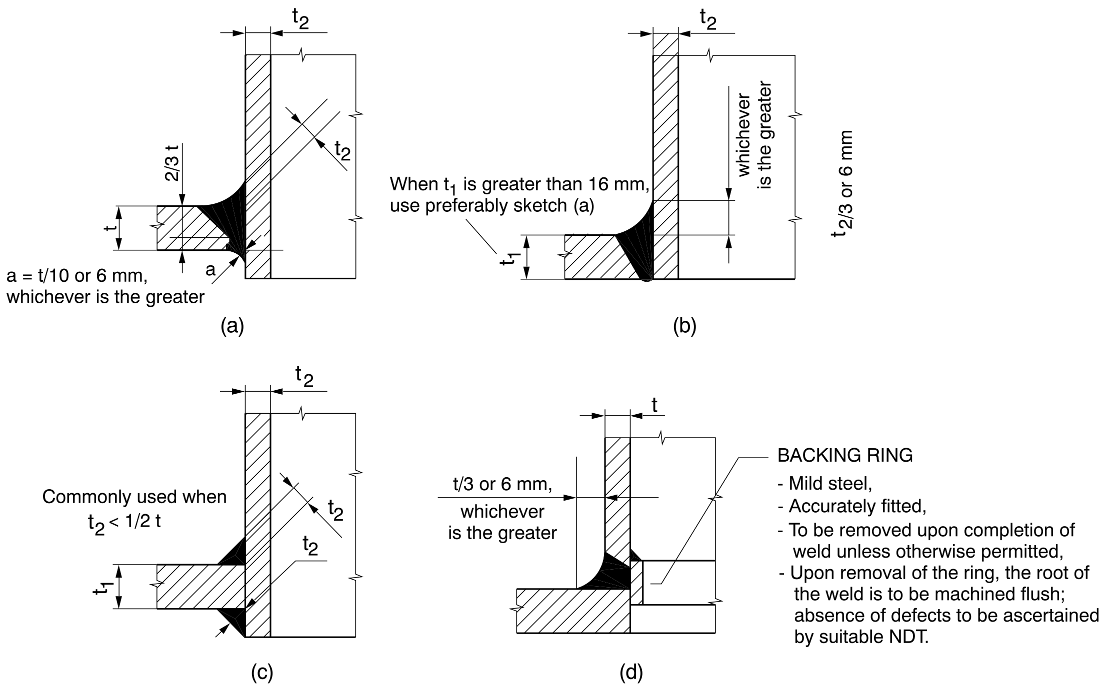


Figure 31 : Types of joints for nozzles and reinforcing rings (2)

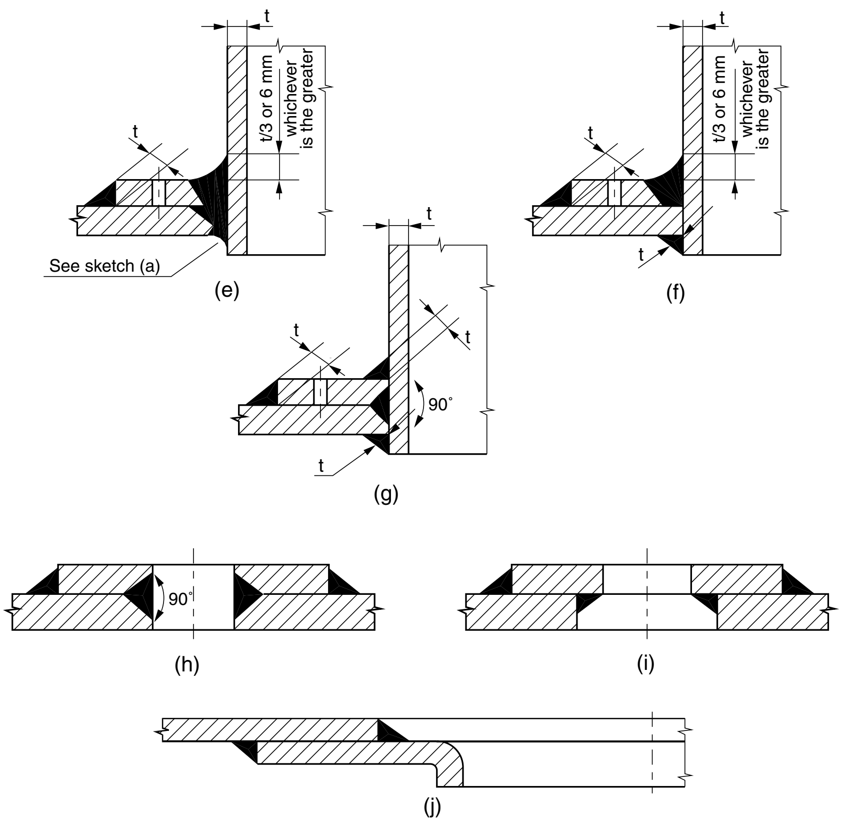


Figure 32 : Types of joints for nozzles and reinforcing rings (3)

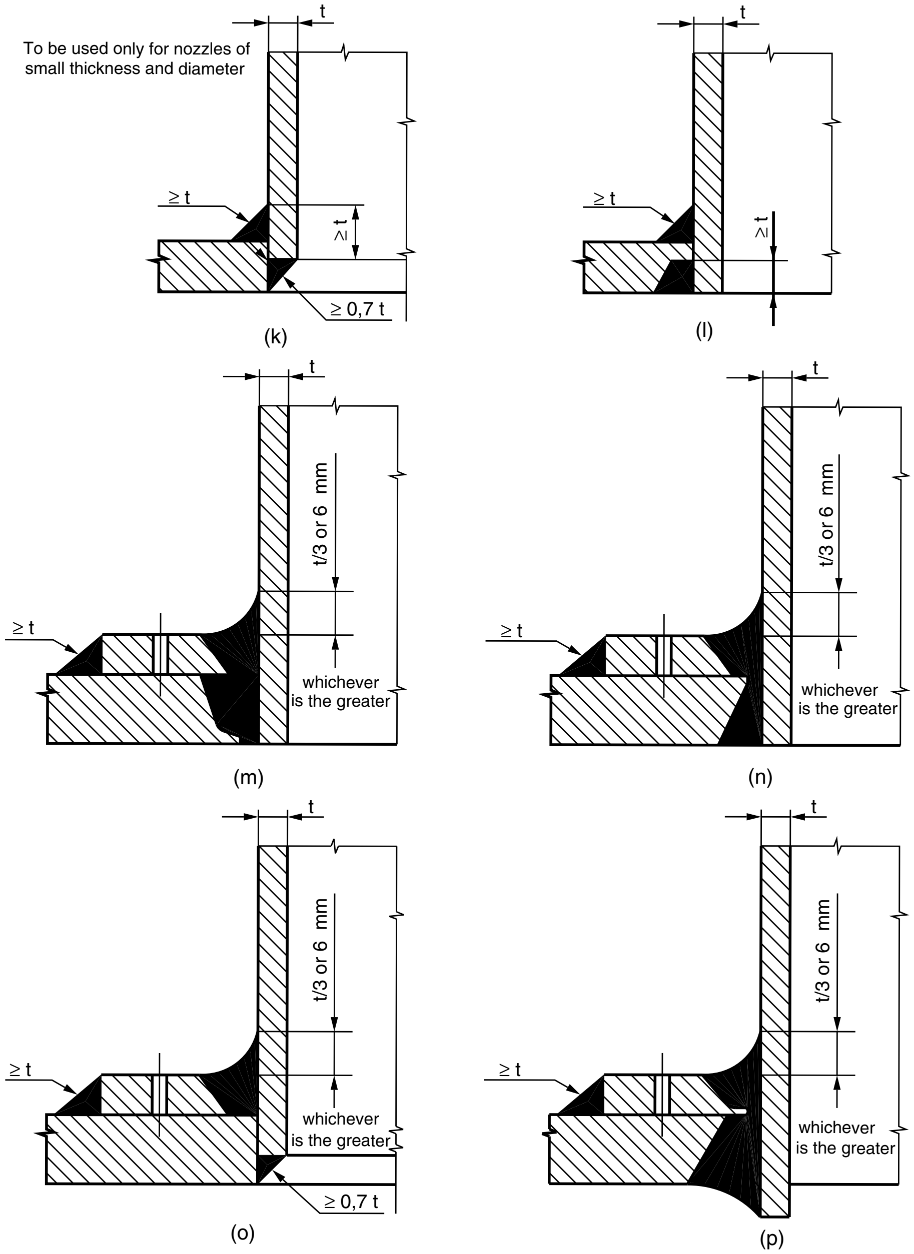
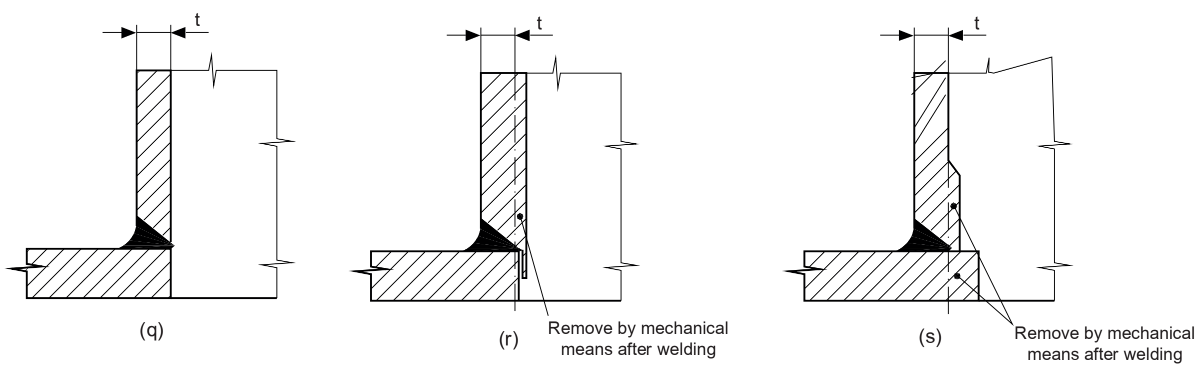


Figure 33 : Types of joints for nozzles (4)



Note: Where preparations of Fig 33 are carried out, the shell is to be carefully inspected to ascertain the absence of lamination.

Figure 34 : Types of joints for flanges to nozzles

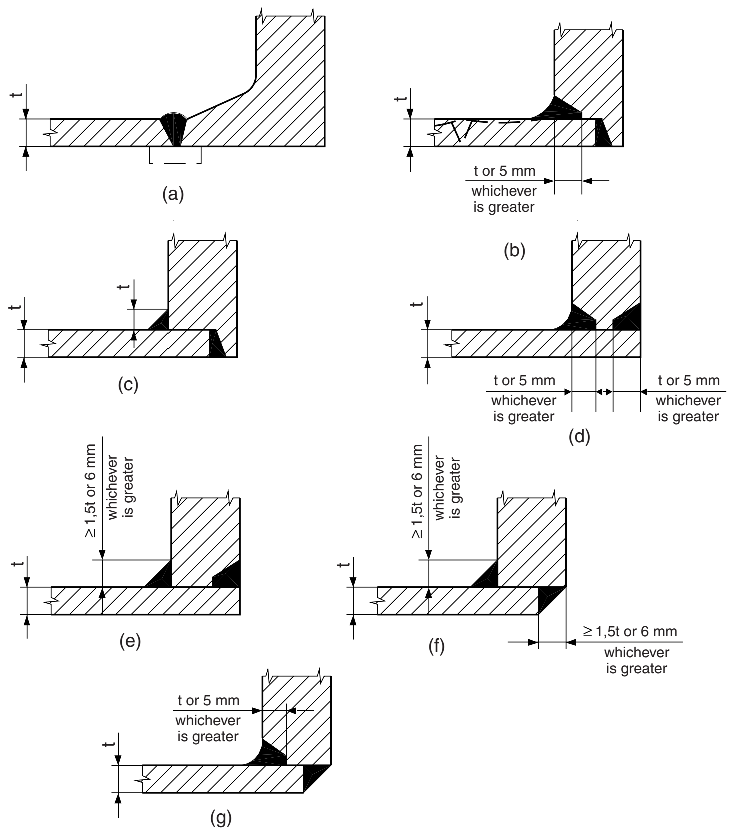


Figure 35 : Types of joints for tubesheets to shell (1)

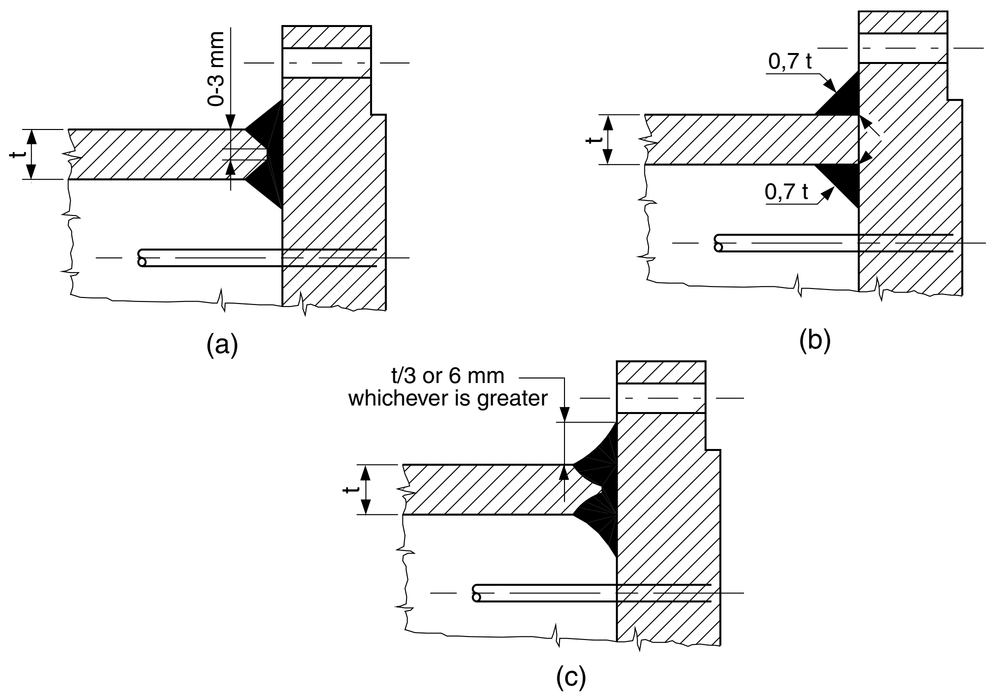


Figure 36 : Types of joints for tubesheets to shells (2)

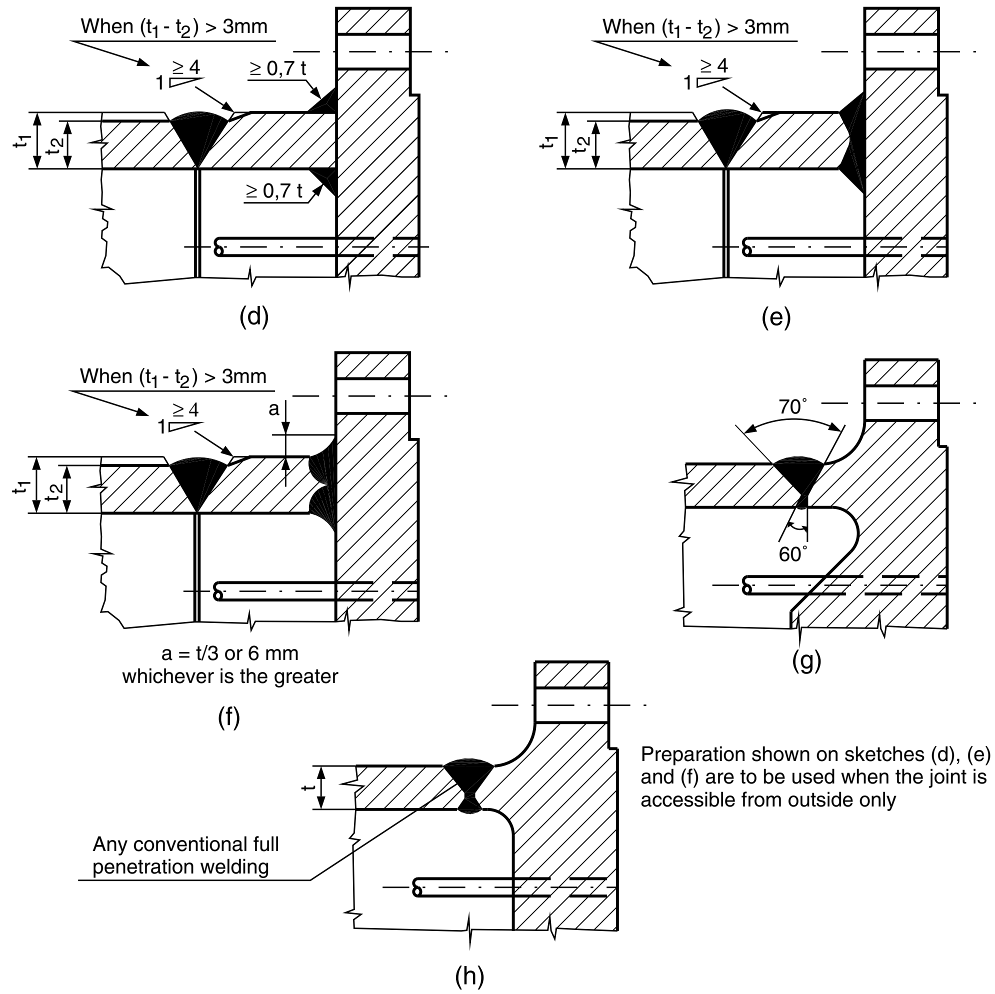
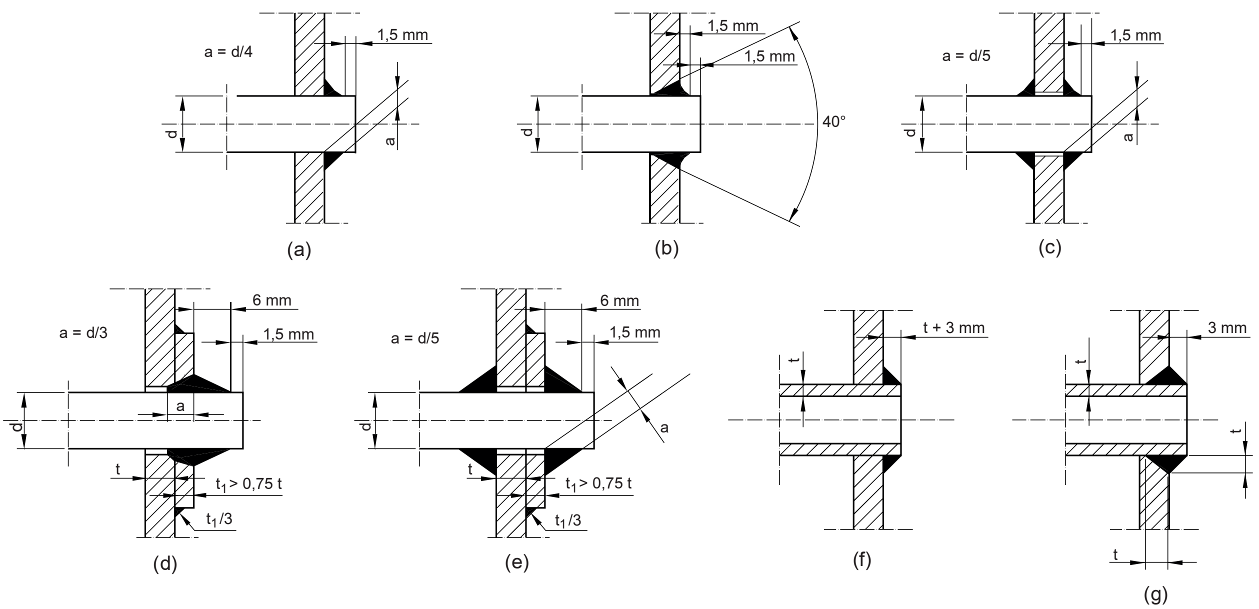


Figure 37 : Type of joints for stays and stay tubes



4.3 Miscellaneous requirements for fabrication and welding

4.3.1 Welding position

a) As far as possible, welding is to be carried out in the downhand horizontal position and arrangements are to be foreseen so that this can be applied in the case of circumferential joints.

b) When welding cannot be performed in this position, tests for qualification of the welding process and the welders are to take account thereof.

4.3.2 Cleaning of parts to be welded

a) Parts to be welded are, for a distance of at least 25 mm from the welding edges, to be carefully cleaned in order to remove any foreign matter such as rust, scale, oil, grease and paint.

b) If the weld metal is to be deposited on a previously welded surface, all slag or oxide is to be removed to prevent inclusions.

4.3.3 Protection against adverse weather conditions

a) Welding of pressure vessels is to be done in a sheltered position free from draughts and protected from cold and rain.

b) Unless special justification is provided, no welding is to be performed if the temperature of the base metal is less than 0°C.

4.3.4 Interruption in welding

If, for any reason, welding is stopped, care is to be taken on restarting to obtain a complete fusion.

4.3.5 Backing weld

When a backing weld is foreseen, it is to be carried out after suitable chiseling or chipping at the root of the first weld, unless the welding process applied does not call for such an operation.

4.3.6 Appearance of welded joints

a) Welded joints are to have a smooth surface without under-thickness; their connection with the plate surface is to be gradual without undercutting or similar defects.

b) The weld reinforcement of butt welds, on each side of the plate, is not to exceed the following thickness:
   - 2,5 mm for plates having a thickness not exceeding 12 mm
   - 3 mm for plates having a thickness greater than 12 mm but less than 25 mm
   - 5 mm for plates having a thickness at least equal to 25 mm.

4.4 Preparation of parts to be welded

4.4.1 Preparation of edges for welding

a) Grooves and other preparations of edges for welding are to be made by machining, chipping or grinding. Flame cutting may also be used provided that the zones damaged by this operation are removed by machining, chipping or grinding. For alloy steel plates, preheating is to be provided, if needed, for flame cutting.

b) Edges prepared are to be carefully examined to check that there are no defects detrimental to welding.

4.4.2 Abutting of parts to be welded

a) Abutting of parts to be welded is to be such that surface misalignment of plates does not exceed:
   - 10% of the thickness of the plate with a maximum of 3 mm for longitudinal joints
   - 10% of the thickness of the plate plus 1 mm with a maximum of 4 mm for circumferential joints.

b) For longitudinal joints, middle lines are to be in alignment within 10% of the thickness of the thinner plate with a maximum of 3 mm.

c) Plates to be welded are to be suitably retained in position in order to limit deformation during welding. The arrangements are to be such as to avoid modification of the relative position of parts to be welded and misalignment, after welding, exceeding the limits indicated above.

d) Temporary welds for abutting are to be carried out so that there is no risk of damage to vessel shells. Such welds are to be carefully removed after welding of the vessel and before any heat treatment. Non-destructive testing of the corresponding zones of the shell may be required by the Surveyor if considered necessary.

e) Accessories such as doubling plates, brackets and stiffeners are to be suitable for the surface to which they are to be attached.

4.5 Tolerances after construction

4.5.1 General

The sizes and shape of vessels are to be checked after welding for compliance with the design taking into account the tolerances given below. The Society reserves the right to stipulate smaller values for these tolerances for vessels subjected to special loads.

Any defect in shape is to be gradual and there is to be no flat area in way of welded joints.

Measurements are to be taken on the surface of the parent plate and not on the weld or other raised part.

4.5.2 Straightness

The straightness of cylindrical shells is to be such that their deviation from the straight line does not exceed 0,6% of their length, with a maximum of 15 mm for each 5 m of length.

4.5.3 Out-of-roundness

a) Out-of-roundness of cylindrical shells is to be measured either when set up on end or when laid flat on their sides; in the second case, measures of diameters are to be repeated after turning the shell through 90° about its axis and out-of-roundness is to be calculated from the average of the two measures of each diameter.

b) For any transverse section, the difference between the maximum and minimum diameters is not to exceed 1% of the nominal diameter D with a maximum of:

   (D + 1250) / 200, D being expressed in mm.

   For large pressure vessels, this limit may be increased by a maximum of 0,2% of the internal diameter of the vessel. Any possible out-of-roundness within the above limit is to be gradual and there are to be no localised deformations in way of the welded joints.

4.5.4 Irregularities

Irregularities in profile of cylindrical shells, checked by a 20° gauge, are not to exceed 5% of the thickness of the plate plus 3 mm. This value may be increased by 25% if the length of the irregularity does not exceed one quarter of the distance between two circumferential seams, with a maximum of 1 mm.

4.6 Preheating

4.6.1

a) Preheating, to be effectively maintained during the welding operation, may be required by the Society when deemed necessary in relation to a number of circumstances, such as the type of steel, thickness of the base material, welding procedure and technique, type of restraint, and heat treatment after welding, if any.

b) The preheating temperature is to be determined accordingly. However, a preheating temperature of approximately 150°C is required for 0,5Mo or 1Cr0,5Mo type steel, and approximately 250°C for 2,25Cr1Mo type steel.

c) These requirements also apply to welding of nozzles, fittings, steam pipes and other pipes subject to severe conditions.

4.7 Post-weld heat treatment

4.7.1 General

a) When post-weld heat treatment of a vessel is to be carried out, such treatment is to consist of:
   - heating the vessel slowly and uniformly up to a temperature suitable for the grade of steel
   - maintaining this temperature for a duration determined in relation to the actual thickness t_A of the vessel and the grade of steel
   - slowly cooling the vessel in the furnace down to a temperature not exceeding 400°C, with subsequent cooling allowed out of the furnace in still air.

b) As far as possible, vessels are to be heat treated in a single operation. However, when the sizes of the vessels are such that heat treatment requires several operations, care is to be taken such that all the parts of the vessels undergo heat treatment in a satisfactory manner. In particular, a cylindrical vessel of great length may be treated in sections in a furnace if the overlap of the heated sections is at least 1500 mm and if parts outside the furnace are lagged to limit the temperature gradient to an acceptable value.

4.7.2 Thermal stress relieving

Upon completion of all welding, including connections of nozzles, doublers and fittings, pressure vessels of classes 1 and 2, boilers and associated parts are to be subjected to an effective stress relieving heat treatment in the following cases:

- pressure vessels of classes 1 and 2 containing fluids at a temperature not less than the ambient temperature, where the thickness exceeds that indicated in Tab 17
- boilers and steam generators for thicknesses higher than 20 mm or, depending upon the type of steel, for lower thicknesses as required for class 1 pressure vessels.

Applications at temperatures less than the ambient temperature and/or steels other than those indicated above are to be the subject of special consideration by the Society.

Stress relieving heat treatment is not to be required when the minimum temperature of the fluid is at least 30°C higher than the KV-notch impact test temperature specified for the steel; this difference in temperature is also to be complied with for welded joints (both in heat-affected zones and in weld metal).

Pressure vessels and pipes of class 3 and associated parts are not required to be stress relieved, except in specific cases.

Table 17 : Thermal stress relieving

Grade	Thickness (mm) above which post-weld heat treatment is required	
	Boilers	Unfired pressure vessels
R_m = 360 N/mm² Grade HA R_m = 410 N/mm² Grade HA	14,5	14,5
R_m = 360 N/mm² Grade HB R_m = 410 N/mm² Grade HB	20	30
R_m = 360 N/mm² Grade HD R_m = 410 N/mm² Grade HD	20	38
R_m = 460 N/mm² Grade HB R_m = 510 N/mm² Grade HB	20	25
R_m = 460 N/mm² Grade HD R_m = 510 N/mm² Grade HD	20	35
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	20	20
1Cr 0,5Mo 2,25Cr 1Mo	ALL	ALL

4.7.3 Heat treatment procedure

The temperature of the furnace at the time of introduction of the vessel is not to exceed 400°C.

a) The heating rate above 400°C is not to exceed:
- 220°C per hour if the maximum thickness is not more than 25 mm, or
- $(5500 / t_A)$°C per hour, with a minimum of 55°C per hour, if the maximum thickness t_A , in mm, is more than 25 mm

b) The cooling rate in the furnace is not to exceed:
- –280°C per hour if the maximum thickness is not more than 25 mm, or
- $-(7000 / t_A)$°C per hour, with a minimum of –55°C per hour, if the maximum thickness t_A , in mm, is more than 25 mm.

Unless specially justified, heat treatment temperatures and duration for maintaining these temperatures are to comply with the values in Tab 18.

Table 18 : Heat treatment procedure

Grade	Temperatures	Time per 25 mm of maximum thickness	Minimum time
Carbon steels	580-620°C	1 hour	1 hour
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	620-660°C	1 hour	1 hour
1Cr 0,5Mo	620-660°C	1hour	2 hours
2,25Cr 1Mo	600-750°C **(1)**	2 hours	2 hours
(1) The temperature is to be chosen, with a tolerance of ± 20°C, in this temperature range in order to obtain the required mechanical characteristics			

4.7.4 Alternatives

When, for special reasons, heat treatment is carried out in conditions other than those given in [4.7.2], all details regarding the proposed treatment are to be submitted to the Society, which reserves the right to require tests or further investigations in order to verify the efficiency of such treatment.

4.7.5 Execution of heat treatment

Furnaces for heat treatments are to be fitted with adequate means for controlling and recording temperature; temperatures are to be measured on the vessel itself. The atmosphere in the furnaces is to be controlled in order to avoid abnormal oxidation of the vessel.

4.7.6 Treatment of test plates

Test plates are normally to be heated at the same time and in the same furnace as the vessel.

When separate heat treatment of test plates cannot be avoided, all precautions are to be taken such that this treatment is carried out in the same way as for the vessel, specifically with regard to the heating rate, the maximum temperature, the duration for maintaining this temperature and the cooling conditions.

4.7.7 Welding after heat treatment

a) Normally, welding after heat treatment is only allowed if:
   - the throat of welding fillets does not exceed 10 mm
   - the largest dimension of openings in the vessel for the accessories concerned does not exceed 50 mm.

b) Any welding of branches, doubling plates and other accessories on boilers and pressure vessels after heat treatment is to be submitted for special examination by the Society.

4.8 Welding samples

4.8.1 Test plates for welded joints

a) Test plates of sufficient size, made of the same grade of steel as the shell plates, are to be fitted at each end of the longitudinal joints of each vessel so that the weld in the test plates is the continuation of these welded joints. There is to be no gap when passing from the deposited metal of the joint to the deposited metal of the test plate.

b) No test plate is required for circumferential joints if these joints are made with the same process as longitudinal joints. Where this is not the case, or if there are only circumferential joints, at least one test plate is to be welded separately using the same welding process as for the circumferential joints, at the same time and with the same welding materials.

c) Test plates are to be stiffened in order to reduce as far as possible warping during welding. The plates are to be straightened prior to their heat treatment which is to be carried out in the same conditions as for the corresponding vessel (see also [4.7.6]).

d) After radiographic examination, the following test pieces are to be taken from the test plates:
   - one test piece for tensile test on welded joint
   - two test pieces for bend test, one direct and one reverse
   - three test pieces for impact test
   - one test piece for macrographic examination.

4.8.2 Mechanical tests of test plates

a) The tensile strength on welded joint is not to be less than the minimum specified tensile strength of the plate.

b) The bend test pieces are to be bent through an angle of 180° over a former of 4 times the thickness of the test piece. There is to be no crack or defect on the outer surface of the test piece exceeding in length 1,5 mm transversely or 3 mm longitudinally. Premature failure at the edges of the test piece is not to lead to rejection. As an alternative, the test pieces may be bent through an angle of 120° over a former of 3 times the thickness of the test piece.

c) The impact energy measured at 0°C is not to be less than the values given in NR216 Materials and Welding for the steel grade concerned.

d) The test piece for macrographic examination is to permit the examination of a complete transverse section of the weld. This examination is to demonstrate good penetration without lack of fusion, large inclusions and similar defects. In case of doubt, a micrographic examination of the doubtful zone may be required.

4.8.3 Re-tests

a) If one of the test pieces yields unsatisfactory results, two similar test pieces are to be taken from another test plate.

b) If the results for these new test pieces are satisfactory and if it is proved that the previous results were due to local or accidental defects, the results of the re-tests may be accepted.

4.9 Specific requirements for class 1 vessels

4.9.1 General

The following requirements apply to class 1 pressure vessels, as well as to pressure vessels of other classes, whose scantlings have been determined using an efficiency of welded joint e greater than 0,90.

4.9.2 Non-destructive tests

a) All longitudinal and circumferential joints of class 1 vessels are to be subject of 100% radiographic or equivalent examination with the following exceptions:
   - for pressure vessels or parts designed to withstand external pressures only, at the Society’s discretion, the extent may be reduced up to approximately 30% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.
   - for vessels not intended to contain toxic or dangerous matters, made of carbon steels having thickness below 20 mm when the joints are welded by approved automatic processes at the Society’s discretion, the extent may be reduced up to

approximately 10% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.

- for circumferential joints having an external diameter not exceeding 175 mm, at the Society's discretion, the extent may be reduced up to approximately 10% of the total length of the joints.

b) Fillet welds for parts such as doubling plates, branches or stiffeners are to undergo a spot magnetic particle test for at least 10% of their length. If magnetic particle tests cannot be used, it is to be replaced by liquid penetrant test.

c) Welds for which non destructive tests reveal unacceptable defects, such as cracks or areas of incomplete fusion, are to be rewelded and are then to undergo a new non destructive examination

4.9.3 Number of test samples

a) During production, at least one test plate for each 20 m of length (or fraction) of longitudinal weldings is to be tested as per [4.8.2].

b) During production, at least one test plate for each 30 m of length (or fraction) of circumferential welding is to be tested as per [4.8.2].

c) When several vessels made of plates of the same grade of steel, with thicknesses varying by not more than 5 mm, are welded successively, only one test plate may be accepted per each 20 m of length of longitudinal joints (or fraction) and per each 30 m of circumferential welding (or fraction) provided that the welders and the welding process are the same. The thickness of the test plates is to be the greatest thickness used for these vessels.

4.10 Specific requirements for class 2 vessels

4.10.1 General

For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

4.10.2 Non-destructive tests

All longitudinal and circumferential joints of class 2 vessels are to be subjected to radiographic or equivalent examination to an extent of 10% of each weld length. This examination is to cover all the junctions between welds.

This extension may be increased at the Society's discretion depending on the actual thickness of the welded plates.

For actual thickness ≤ 15 mm, this examination can be omitted. In this case, the value of the efficiency should be as indicated in Tab 10.

4.10.3 Number of test samples

In general, the same requirements of [4.9.3] apply also to class 2 pressure vessels. However, test plates are required for each 50 m of longitudinal and circumferential weldings (or fraction).

4.11 Specific requirements for class 3 vessels

4.11.1 For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1]. Heat treatment, mechanical tests and non-destructive tests are not required for welded joints of other class 3 vessels.

5 Design and construction - Control and monitoring

5.1 Boiler control and monitoring system

5.1.1 Local control and monitoring

Means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. The functional condition of the fuel, feed water and steam systems and the boiler operational status are to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.1.2 Emergency shut-off

Means are to be provided to shut down boiler forced draft or induced draft fans and fuel oil service pumps from outside the space where they are located, in the event that a fire in that space makes their local shut-off impossible.

5.1.3 Water level indicators

a) Each boiler is to be fitted with at least two separate means for indicating the water level. One of these means is to be a level indicator with transparent element. The other may be either an additional level indicator with transparent element or an equivalent device. Level indicators are to be of an approved type.

b) The transparent element of level indicators is to be made of glass, mica or other appropriate material.

c) Level indicators are to be located so that the water level is readily visible at all times. The lower part of the transparent element is not to be below the safety water level defined by the builder.

d) Level indicators are to be fitted either with normally closed isolating cocks, operable from a position free from any danger in case of rupture of the transparent element or with self-closing valves restricting the steam release in case of rupture of this element.

5.1.4 Water level indicators - Special requirements for water tube boilers

a) For water tube boilers having an athwarships steam drum more than 4 m in length, a level indicator is to be fitted at each end of the drum.

b) Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level audible and visual alarm (see also Tab 20).

5.1.5 Water level indicators - Special requirements for fire tube boilers (vertical and cylindrical boilers)

a) For cylindrical boilers, the two water level indicators mentioned in [5.1.3] are to be distributed at each end of the boiler; i.e. double front cylindrical boilers are to have two level indicators on each front.

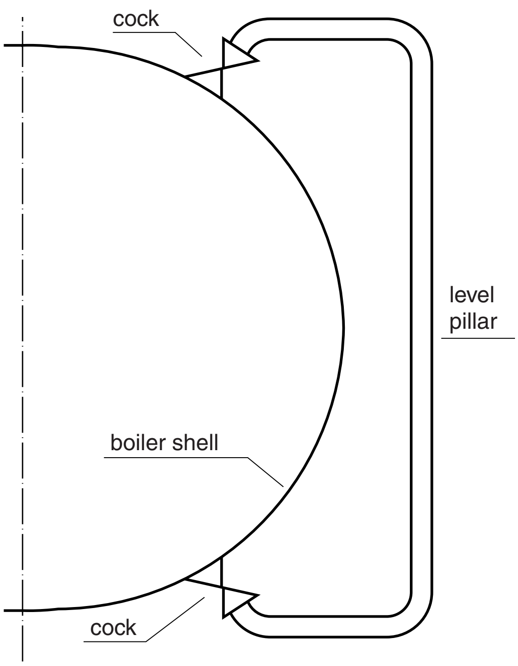
b) A system of at least two suitably located and remote controlled gauge-cocks may be considered as the equivalent device mentioned in [5.1.3] for cylindrical boilers having a design pressure lower than 1 MPa, for cylindrical boilers having a diameter lower than 2 m and for vertical boilers having height lower than 2,3 m. Gauge-cocks are to be fixed directly on the boiler shell.

c) Where level indicators are not fixed directly on the boiler shell, but on level pillars, the internal diameter of such pillars is not to be less than the value d_N given in Tab 19. Level pillars are to be either fixed directly on the boiler shell or connected to the boiler by pipes fitted with cocks secured directly to the boiler shell. The internal diameter of these pipes d_C is not to be less than the values given in Tab 19. The upper part of these pipes is to be arranged so that there is no bend where condense water can accumulate. These pipes are not to pass through smoke boxes or uptakes unless they are located inside metallic ducts having internal diameter exceeding by not less than 100 mm the external diameter of the pipes. Fig 38 shows the sketch of a level pillar arrangement.

Table 19 : Minimum internal diameters d_N and d_C

Internal diameter of the boiler	d_N (mm)	d_C (mm)
D > 3 m	60	38
2,30 m ≤ D ≤ 3 m	50	32
D < 2,30 m	45	26

Figure 38 : Level pillar arrangement



5.1.6 Pressure control devices

a) Each boiler is to be fitted with a steam pressure gauge so arranged that its indications are easily visible from the stokehold floor. A steam pressure gauge is also to be provided for superheaters which can be shut off from the boiler they serve.

b) Pressure gauges are to be graduated in units of effective pressure and are to include a prominent legible mark for the pressure that is not to be exceeded in normal service.

c) Each pressure gauge is to be fitted with an isolating cock.

d) Double front boilers are to have a steam pressure gauge arranged in each front.

5.1.7 Temperature control devices

Each boiler fitted with a superheater is to have an indicator or recorder for the steam temperature at the superheater outlet.

5.1.8 Automatic shut-off of oil fired propulsion and auxiliary boilers

a) Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

b) A low water condition is to automatically shut off the fuel supply to the burners. The shut-off is to operate before the water level reaches a level so low as to affect the safety of the boiler and no longer be visible in the gauge glass. Means are to be provided to minimise the risk of shut-off provoked by the effect of roll and pitch and/or transients. This shut-off system need not be installed in auxiliary boilers which are under local supervision and are not intended for automatic operation.

c) Forced draft failure is to automatically shut off the fuel supply to the burners.

d) Loss of boiler control power is to automatically shut off the fuel supply to the burners.

5.1.9 Alarms

Any actuation of the fuel-oil shut-off listed in [5.1.8] is to operate a visual and audible alarm.

5.1.10 Additional requirements for boilers fitted with automatic control systems

a) The flame scanner required in [5.1.8], item a) is to operate within 6 seconds from the flame failure.

b) A timed boiler purge with all air registers open is to be initiated manually or automatically when boilers are fitted with an automatic ignition system. The purge time is based on a minimum of 4 air changes of the combustion chamber and furnace passes. Forced draft fans are to be operating and air registers and dampers are to be open before the purge time commences.

c) Means are to be provided to bypass the flame scanner control system temporarily during a trial-for-ignition for a period of 15 seconds from the time the fuel reaches the burners. Except for this trial-for-ignition period, no means are to be provided to bypass one or more of the burner flame scanner systems unless the boiler is locally controlled.

d) Where boilers are fitted with an automatic ignition system, and where residual fuel oil is used, means are to be provided for lighting of burners with igniters lighting properly heated residual fuel oil. In the case of flame failure, the burner is to be brought back into automatic service only in the low-firing position.

e) An alarm is to be activated whenever a burner operates outside the limit conditions stated by the manufacturer.

f) Immediately after normal shutdown, an automatic purge of the boiler equal to the volume and duration of the pre-purge is to occur. Following automatic fuel valve shut-off, the air flow to the boiler is not to automatically increase; post-purge in such cases is to be carried out under manual control.

g) Propulsion and auxiliary boilers associated with propulsion machinery intended for centralised, unattended operations are to comply with the requirements of Part C, Chapter 3.

5.2 Pressure vessel instrumentation

5.2.1

a) Pressure vessels are to be fitted with the necessary devices for checking pressure, temperature and level, where it is deemed necessary.

b) In particular, each air pressure vessel is to be fitted with a local manometer.

5.3 Thermal oil heater control and monitoring

5.3.1 Local control and monitoring

Suitable means to effectively operate, control and monitor the operation of oil fired thermal oil heaters and their associated auxiliaries are to be provided locally. The functional condition of the fuel, thermal oil circulation, forced draft and flue gas systems is to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.3.2 Flow control and monitoring

a) A flow indicator of the thermal oil is to be provided.

b) The flow detection is to be representative of the flow in each heated element.

c) The flow detection is not to be based on a measurement of the pressure-drop through the heating element.

d) Oil fired or exhaust gas heaters are to be provided with a flow monitor limit-switch. If the flow rate falls below a minimum value the firing system is to be switched off and interlocked.

5.3.3 Manual control

During manual operation, the automated functioning of at least the temperature control device on the thermal oil side as well as the flow monitoring is to be maintained.

5.3.4 Leakage monitoring

Oil tanks are to be equipped with a leakage detector which, when actuated, shuts down and interlocks the thermal oil firing system. If the oil fired heater is on stand-by, the starting of the burner is to be blocked if the leakage detector is actuated.

5.4 Control and monitoring requirements

5.4.1 Tab 20, Tab 21, Tab 22 and Tab 23 summarise the control and monitoring requirements for main propulsion boilers, auxiliary boilers, oil fired thermal oil heaters and exhaust gas thermal oil heaters and incinerators, respectively.

Table 20 : Main propulsion boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil							
• Fuel oil delivery pressure or flow	L						
• Fuel oil temperature after heater or viscosity fault	L+H	local					
• Master fuel oil valve position (open / close)		local					
• Fuel oil input burner valve position (open / close)		local					
Combustion							
• Flame failure of each burner	X						
• Failure of atomizing fluid	X					5	
• Boiler casing and economizer outlet smoke temperature (in order to detect possible fire out-break)	H						
	HH			X			
Air							
• Air register position		local					
General steam							
• Superheated steam pressure	L+H	local					
					X		
• Superheated steam temperature	H	local					
• Lifting of safety valve (or equivalent: high pressure alarm for instance)	X						
• Water level inside the drum of each boiler	L+H	local**(1)**					
	LL			X			
					X		
(1) Duplication of level indicator is required							

Table 21 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Water level	L+H	local					
	LL			X			
Circulation stopped (when forced circulation boiler)	X			X			
Fuel oil temperature or viscosity **(2)**	L+H	local					
Flame failure	X			X			
Temperature in boiler casing (Fire)	H						
Steam pressure	H**(1)**	local		X			
(1) When the automatic control does not cover the entire load range from zero load **(2)** Where heavy fuel is used							

Table 22 : Thermal oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Thermal fluid temperature heater outlet	H	local		X**(1)**			
Thermal fluid pressure pump discharge	H	local		X			
Thermal fluid flow through heating element	L LL	local		 X**(1)**			
Expansion tank level	L LL	local		 X**(2)**			
Expansion tank temperature	H						
Forced draft fan stopped	X			X			
Heavy fuel oil temperature or viscosity	H+L	local					
Burner flame failure	X			X			
Flue gas temperature heater outlet	H HH			 X**(2)**			
(1) Shut-off of heat input only **(2)** Stop of fluid flow and shut-off of heat input							

Table 23 : Incinerators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Flame failure	X			X			
Furnace temperature	H			X			
Exhaust gas temperature	H						
Fuel oil pressure		local					
Fuel oil temperature or viscosity **(1)**	H+L	local					
(1) Where heavy fuel is used							

6 Arrangement and installation

6.1 Foundations

6.1.1 For boilers and pressure vessels bolting down to their foundations, see Ch 1, Sec 1, [3.3.1]. Where necessary, they are also to be secured to the adjacent hull structures by suitable ties.

Where chocks are required to be fitted between the boilers and their foundations, they are to be of cast iron or steel.

6.2 Boilers

6.2.1 Thermal expansion

Means are to be provided to compensate thermal expansion of boilers.

6.2.2 Minimum distance of boilers from vertical bulkheads and fuel tanks

a) The distance between boilers and vertical bulkheads is to be not less than the minimum distance necessary to provide access for inspection and maintenance of the structure adjacent to the boiler.

b) In addition to the requirement in a), the distance of boilers from fuel oil tanks is to be such as to prevent the possibility that the temperature of the tank bulkhead may approach the flash point of the oil.

c) In any event, the distance between a boiler and a vertical bulkhead is not to be less than 450 mm.

6.2.3 Minimum distance of boilers from double bottom

a) Where double bottoms in way of boilers may be used to carry fuel oil, the distance between the top of the double bottom and the lower metal parts of the boilers is not to be less than:
- 600 mm, for cylindrical boilers
- 750 mm, for water tube boilers.

b) The minimum distance of vertical tube boilers from double bottoms not intended to carry oil may be 200 mm.

6.2.4 Minimum distance of boilers from ceilings

a) A space sufficient for adequate heat dissipation is to be provided on the top of boilers.

b) Oil tanks are not permitted to be installed in spaces above boilers.

6.2.5 Installation of boilers on engine room flats

Where boilers are installed on an engine room flat and are not separated from the remaining space by means of a watertight bulkhead, a coaming of at least 200 mm in height is to be provided on the flat. The area surrounded by the coaming may be drained into the bilge.

6.2.6 Drip trays and gutterways

Boilers are to be fitted with drip trays and gutterways in way of burners so arranged as to prevent spilling of oil into the bilge.

6.2.7 Hot surfaces

Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7.1].

6.2.8 Registers fitted in the smoke stacks of oil fired boilers

Where registers are fitted in smoke stacks, they are not to obstruct more than two thirds of the cross-sectional area of gas passage when closed. In addition, they are to be provided with means for locking them in open position when the boiler is in operation and for indicating their position and degree of opening.

6.3 Pressure vessels

6.3.1 Safety devices on multiple pressure vessels

Where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

6.4 Thermal oil heaters

6.4.1 In general, the requirements of [6.2] for boilers are also applicable to thermal oil heaters.

7 Material test, workshop inspection and testing, certification

7.1 Material testing

7.1.1 General

Materials, including welding consumables, for the constructions of boilers and pressure vessels are to be certified by the material manufacturer in accordance with the appropriate material specification.

7.1.2 Boilers, other steam generators, and oil fired and exhaust gas thermal oil heaters

In addition to the requirement in [7.1.1], testing of materials intended for the construction of pressure parts of boilers, other steam generators, oil fired thermal oil heaters and exhaust gas thermal oil heaters is to be witnessed by the Surveyor.

7.1.3 Class 1 pressure vessels and heat exchangers

In addition to the requirement in [7.1.1], testing of materials intended for the construction of class 1 pressure parts of pressure vessels and heat exchangers is to be witnessed by the Surveyor.

This requirement may be waived at the Society’s discretion for mass produced small pressure vessels (such as accumulators for valve controls, gas bottles, etc.).

7.2 Workshop inspections

7.2.1 Boilers and individually produced class 1 and 2 pressure vessels

The construction, fitting and testing of boilers and individually produced class 1 and 2 pressure vessels are to be attended by the Surveyor, at the builder's facility.

7.2.2 Mass produced pressure vessels

Construction of mass produced pressure vessels which are type approved by the Society need not be attended by the Surveyor.

7.3 Hydrostatic tests

7.3.1 General

Hydrostatic tests of all class 1, 2 and 3 pressure vessels are to be witnessed by the Surveyor with the exception of mass produced pressure vessels which are built under the conditions stated in [7.2.2].

7.3.2 Testing pressure

a) Upon completion, pressure parts of boilers and pressure vessels are to be subjected to a hydraulic test under a pressure p_t defined below as a function of the design pressure p:
   - $p_t = 1,5\ p$ where $p \le 4$ MPa
   - $p_t = 1,4\ p + 0,4$ where 4 MPa $< p \le 25$ Mpa
   - $P_t = p + 10,4$ where $p > 25$ MPa

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

c) If the design temperature exceeds 300°C, the test pressure p_t is to be as determined by the following formula:

$$p_t = 1,5 \cdot \frac{K_{100}}{K} \cdot p$$

where:

p : Design pressure, in MPa

K_{100} : Permissible stress at 100°C, in N/mm²

K : Permissible stress at the design temperature, in N/mm².

d) Consideration is to be given to the reduction of the test pressure below the values stated above where it is necessary to avoid excessive stress. In any event, the general membrane stress is not to exceed 90% of the yield stress at the test temperature.

e) Economisers which cannot be shut off from the boiler in any working condition are to be submitted to a hydraulic test under the same conditions as the boilers.

f) Economisers which can be shut off from the boiler are to be submitted to a hydraulic test at a pressure determined as a function of their actual design pressure p.

7.3.3 Hydraulic test of boiler and pressure vessel accessories

a) Boilers and pressure vessel accessories are to be tested at a pressure p_t which is not less than 1,5 times the design pressure p of the vessels to which they are attached.

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

7.3.4 Hydraulic test procedure

a) The hydraulic test specified in [7.3.1] is to be carried out after all openings have been cut out and after execution of all welding work and of the heat treatment, if any. The vessel to be tested is to be presented without lagging, paint or any other lining and the pressure is to be maintained long enough for the Surveyor to proceed with a complete examination.

b) Hydraulic tests of boilers are to be carried out either after installation on board, or at the manufacturer's plant. Where a boiler is hydrotested before installation on board, the Surveyor may, if deemed necessary, request to proceed with a second hydraulic test on board under a pressure at least equal to 1,1 p. For this test, the boiler may be fitted with its lagging. However, the Surveyor may require this lagging to be partially or entirely removed as necessary.

c) For water tube boilers, the hydraulic test may also be carried out separately for different parts of the boiler upon their completion and after heat treatment. For drums and headers, this test may be carried out before drilling the tube holes, but after welding of all appendices and heat treatment. When all parts of the boiler have been separately tested and following assembly the boiler is to undergo a hydraulic test under a pressure of 1,25 p.

7.3.5 Hydraulic tests of condensers

Condensers are to be subjected to a hydrostatic test at the following test pressures:

- Steam space: 0,1 MPa
- Water space: maximum pressure which may be developed by the pump with closed discharge valve increased by 0,07 MPa. However, the test pressure is not to be less than 0,2 MPa. When the characteristics of the pump are not known, the hydrostatic test is to be carried out at a pressure not less than 0,35 MPa.

7.4 Certification

7.4.1 Certification of boilers and individually produced pressure vessels

Boilers and individually produced pressure vessels of classes 1, 2 and 3 are to be certified by the Society in accordance with the procedures stated in Part A.

7.4.2 Mass produced pressure vessels

Small mass produced pressure vessels of classes 1, 2 and 3 may be accepted provided they are type approved by the Society in accordance with the procedures stated in Part A.

Table 24 : Pressure vessel certification

Class	Drawing / Calculation		Material testing		Hydraulic test	
	Manufacturer	The Society	Manufacturer	The Society	Manufacturer	The Society
1	X	review	X	witness + workshop inspection	X	witness
2	X	review	X	review	X	witness
3	X	–	X	review	X	witness

Note 1:
Certificates of the Manufacturer and the Society to be issued for all cases for pressure vessels covered by the Rules of the Society.

Section 4 Steam Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Auxiliary turbines driving generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with those of Part C, Chapter 2.

1.2 Documentation to be submitted

1.2.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans and data listed in Tab 1 are to be submitted.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of the types of materials employed.

Table 1 : Documents to be submitted

No	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Rotors and discs, revolving and stationary blades for each turbine
3	A	Fastening details of revolving and stationary blades
4	A	Casings
5	A	Schematic diagram of control and safety devices
6	I	General specification of the turbine, including an operation and instruction manual
7	I	Maximum power and corresponding maximum rotational speed, and the values of pressure and temperature at each stage
8	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, when the service temperature exceeds 400°C, the fatigue strength, the corrosion resistance and the heat treatments
9	I	Distribution box
10	A	Strength calculations of rotors, discs and blades and blade vibration calculations
11	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding conditions, heat treatments and non-destructive examinations after welding

(1) A = to be submitted for approval
I = to be submitted for information.

2 Design and construction

2.1 Materials

2.1.1 Rotating components

a) Rotors, shafts and discs of turbines are to be of forged steel. In general, the forgings are to have minimum tensile strength R_m within the limits in Tab 2.

b) Rotors of small turbines may be built of special cast steels.

c) Turbine blades are to be built of corrosion-resistant materials.

Table 2 : Limits of R_m

STEEL	R_m limits (N/mm^2)
Carbon and carbon-manganese steel	$400 < R_m < 600$
Alloy steels for rotors	$500 < R_m < 800$
Alloy steels for discs and other forgings	$500 < R_m < 1000$

2.1.2 Static components

The casings and diaphragms of turbines are to be built of forged or cast steels capable of withstanding the pressures and temperatures to which they are subjected. Cast iron may be used for temperatures up to 300°C.

2.2 Design and constructional details

2.2.1 Rotors and stators

a) All components of turbines are to be free from defects and are to be built and installed with tolerances and clearances such as to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Particular care is to be devoted to preventing condensation water from accumulating in the blade spaces of the casings. Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easy to operate.

c) When labyrinth packings are used, the steam supply pipes to the sealing system are to be so arranged that condensed steam may not enter the turbine.

d) Particular attention is to be paid to the connection of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of section of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.2.2 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from adjacent hot parts.

b) Lubricating oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped may also be required, at the discretion of the Society.

2.2.3 Turning gear

a) Main propulsion turbines are to be equipped with turning gear for both directions of rotation. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of turning gear is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the turbine cannot be started up when the turning gear is engaged.

2.2.4 Astern power for main propulsion

a) The main propulsion turbine is to have sufficient power for running astern. The astern power is considered to be sufficient if it is able to attain astern revolutions equivalent to at least 70% of the rated ahead revolutions for a period of at least 30 minutes.

b) For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

c) During astern running, the main condenser and the ahead turbines are not to be excessively overheated.

2.2.5 Interlock

The simultaneous admission of steam to the ahead and astern turbines is to be prevented by interlocks. Brief overlapping of the ahead and astern valves during manoeuvring may be permitted.

2.2.6 Turbine exhaust

a) Sentinel valves or other equivalent means are to be provided at the exhaust end of all turbines. The valve discharge outlets are to be clearly visible and suitably guarded, as necessary.

b) Where, in auxiliary steam turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valve are designed, means to relieve the excess pressure are to be provided.

2.2.7 Water accumulation prevention

a) Non-return valves or other approved means are to be fitted in bled steam connections to prevent steam and water returning into the turbines.

b) Bends are to be avoided in steam piping in which water may accumulate.

2.2.8 Steam strainers

Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

2.2.9 Emergency arrangements

a) In single screw ships fitted with compound main turbine installations the arrangements are to be such as to enable safe navigation when the steam led to any one of the turbines is cut off. For this purpose the steam may be led direct to the low pressure (L.P.) turbine and either the high pressure (H.P.) or medium pressure (M.P.) turbine can exhaust direct to the condenser.

b) Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam do not exceed those which the turbine and condenser can safely withstand.

c) Ships classed for unrestricted service and fitted with a steam turbine propulsion plant and only one main boiler are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

2.3 Welded fabrication

2.3.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable when the plans are submitted to the Society for approval. Requirements relative to fabrication, welding, heat treatments, examinations, testing and acceptance will be stipulated on a case by case basis.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures and using approved consumables.

2.4 Control, monitoring and shut-off devices

2.4.1 Governors

a) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or electrical transmission systems are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed given in [2.4.2].

b) The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load may not exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed.

2.4.2 Overspeed devices

a) Each main and auxiliary turbine is to be provided with an overspeed protective device to prevent the rotational speed from exceeding the maximum rotational by more than 15%. The device is to be actuated by the turbine shaft.

b) Where two or more steam turbines are coupled to the same gear wheel, the Society may accept the fitting of only one overspeed device for all the coupled turbines.

c) For turbines driving electric generators, the overspeed protective device mentioned in a) is also to be fitted with a means for manual tripping.

d) Where exhaust steam from auxiliary systems is led to the main turbine, provision is to be made to cut off the steam automatically when the overspeed protective device is activated.

2.4.3 Rotor axial displacement

A quick-closing valve is to be provided which automatically shuts off the steam supply in the event of axial displacement of the rotor beyond the permissible limits stated by the manufacturer. The device controlling the valve is to be actuated by the turbine shaft.

2.4.4 Bearing lubrication failure

a) Main ahead turbines are to be provided with a quick-closing valve which automatically shuts off the steam supply in the event of a dangerous reduction in oil pressure in the bearing lubricating system.

b) This arrangement is to be such as to ensure the admission of steam to the astern turbine for braking purposes.

2.4.5 Shut-off arrangement

a) Arrangements are to be provided for shutting off the steam to the main turbines by a suitable hand trip device controlling the steam admission valve situated at the control platform and at the turbine itself.

b) Hand tripping for auxiliary turbines is to be arranged in the proximity of the turbine overspeed protective device.

c) The hand trip device is any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

d) The quick-closing valves are also to be manually operable at the turbine and from the control platform.

e) Re-setting of the quick-closing valve device may be effected only at the turbine or from the control platform with the control valves in the closed position.

f) Where the valves are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, at the Society's discretion, a hand-operated pump may be accepted as a standby pump.

g) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

h) A quick-closing device is to be provided which automatically shuts off the steam supply in the event of an increase in pressure or water level in the condenser beyond the permissible limits.

2.4.6 Summary Tables

Tab 3 and Tab 4 summarise the minimum control and monitoring requirements for main propulsion and auxiliary turbines, respectively.

Table 3 : Main propulsion turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Main turbine speed		local					
	H			X			
					X		
• Main turbine axial displacement	X	local		X			
• Main turbine vibration	H	local					
Lubricating oil							
• Supply pressure		local					
	L			X(2)			
• Level of gravity tank	L(1)	local					
(1) Sensor to be located near the normal level **(2)** This is not to prevent astern operation for braking							

Table 4 : Auxiliary turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Overspeed	H	local		X			
Rotor displacement	X	local		X			
Vibration	H	local					
Lubricating oil supply pressure	L			X			
Lubricating oil level in gravity tank	L						

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Jointing of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine casings are to be fitted in such a way as to minimise the thrust loads and moments.

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1 Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet.

3.6 Circulating water system

3.6.1 The circulating water system with vacuum ejectors is to be so arranged that water may not enter the low pressure turbines.

3.7 Gratings

3.7.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.8 Drains

3.8.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.9 Instruments

3.9.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts.

This check is to be performed to the Surveyor’s satisfaction at the time of installation.

4 Material tests, workshop inspection and testing, certification

4.1 Material tests

4.1.1 Parts to be tested

The materials for the construction of the parts listed in Tab 5 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

Table 5 : Material and non-destructive tests

Turbine component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	sample
Stationary parts (castings and plates for casings)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

4.1.2 Special auxiliary turbines

In the case of auxiliary turbines with a steam inlet temperature of up to 250°C, the extent of the tests stated in Tab 5 may be limited to the disc and shaft materials.

4.2 Inspections and testing during construction

4.2.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of the Surveyor during the construction of all turbines which are indicated in [1.1.1].

- material tests, as required (see [4.1])
- welded fabrication (see [4.2.2])
- non-destructive examination of turbine blades (see [4.2.3])
- hydrostatic tests (see [4.2.4])
- safety valves (see [4.2.5])
- thermal stability test of rotor (see [4.2.6])
- rotor balancing and overspeed test (see [4.2.7] and [4.2.8])
- shop trials (see [4.2.9]).

4.2.2 Welded fabrication

Welded fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.2.3 Turbine blades

When turbine blades are calculated using a permissible stress $K > R_m/4$, all turbine rotor blades are to be checked by dye penetrants or other equivalent method.

4.2.4 Hydrostatic tests

a) Turbine and nozzle casings are to be subjected to a hydrostatic test at the greater of the following test pressures:

b) 1,5 times the working pressure

c) 1,5 times the starting pressure

d) However, the test pressure is not to be less than 0,2 N/mm^2.

e) The turbine casings may be temporarily subdivided by diaphragms in order to obtain different pressure values for the various stages, if necessary.

f) Where it is not possible to perform hydrostatic tests, the manufacturer may submit to the Society, for consideration, alternative proposals for testing the integrity of turbine casings and the absence of defects therein.

g) For the bodies of quick-closing, safety, manoeuvring and control valves, the test pressure is to be 1,5 times the maximum allowable working pressure of the boiler (approval pressure). The sealing efficiency of these valves when closed is to be tested at 1,1 times the working pressure.

h) Intermediate coolers and heat exchangers are to be subjected to a hydrostatic test at 1,5 times the working pressure.

i) Pressure piping, valves and other fittings are to be subjected to hydrostatic tests in compliance with the normal requirements for these items.

4.2.5 Safety valves

All valves required in [2.4] are to be tested at their setting pressure in the presence of the Surveyor, as specified by the turbine manufacturer.

4.2.6 Thermal stability test of rotors

Solid forged and welded rotors of propulsion turbines are to be subjected to a thermal stability test where the service temperature exceeds 400°C. This test is to be carried out after heat treatment and rough machining or at a later stage of fabrication, in accordance with a procedure approved by the Society.

4.2.7 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.2.8 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above values of overspeed and that rotors are free from defects, as verified by means of non-destructive tests.

4.2.9 Shop trials

Where turbines are subjected to a trial run at the factory, the satisfactory functioning of the control, safety and monitoring equipment is to be verified during the trial run. Such verification is in any event to take place not later than the commissioning of the plant aboard ship.

In general, propulsion steam turbines are to be subjected to a works trial under steam but without load, up to the service rotational speed, as far as possible. In the course of the works trials, the overspeed devices for both main and auxiliary turbines are to be set.

4.3 Certification

4.3.1 Turbines required to be certified

For turbines required to be certified as per [1.1.1], Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 4 and for works trials as per [4.2.1]. Provided the manufacturer has a quality assurance system accepted by the Society, a reduced number of inspections and tests in the presence of the Surveyor may be agreed.

4.3.2 Turbines not required to be certified

For turbines not required to be certified as per [1.1.1], manufacturer's certificates including details of tests and inspections carried out at the shop are to be submitted. The acceptance of these turbines is, however, subject to their satisfactory performance during dock and sea trials.

4.3.3 Type approved turbines

For mass produced turbines which are requested to be type approved by the Society, the tests and trials on a prototype are to be carried out in the presence of the Surveyor as stated in [4.3.1]. The minimum required attendance of the Surveyor at the production tests and trials will be agreed between the manufacturer and the Society on a case by case basis.

Section 5 Gas Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Turbines for auxiliary generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with the applicable requirements of Part C, Chapter 2 of the Rules.

1.1.3 Type approval

Turbines intended for propulsion and essential services are to be type approved by the Society. Other procedures agreed with the Owner will be considered on a case by case basis.

1.2 Definition of rated power

1.2.1 For the definition of rated power, refer to ISO 2314 standard.

Table 1 : Documents to be submitted

No	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Detailed drawings of rotors, casings, blades, combustion chambers and heat exchangers **(2)**
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, the fatigue strength, the corrosion resistance and the heat treatments **(2)**
4	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding procedures and sequences, heat treatments and non-destructive examinations after welding **(2)**
5	I	General specification of the turbine, including instruction manual, description of structures and specification of the properties of fuel and lubricating oil to be used
6	I	Details of operating conditions, including the pressure and temperature curves in the turbine and compressor at the rated power and corresponding rotational speeds, and details of permissible temporary operation beyond the values for the rated power
7	A	Diagrammatic layout of the fuel system, including control and safety devices, and of the lubricating oil system
8	A	Cooling system layout, if applicable
9	I	Where applicable, background information on previous operating experience in similar applications
10	I	Maintenance and overhaul procedures
11	A	Stress and temperature analysis in blades, rotors and combustion chamber **(2)**
12	A	Life time calculation of hot and high stress parts **(2)**
13	A	Blade and rotor vibration analysis **(2)**
14	A	Details of automatic safety devices together with failure mode and effect analysis (FMEA) **(2)**

(1) A = to be submitted for approval
I = to be submitted for information.

(2) As an alternative, the Society may, on a case by case basis, consider reviewing a number of selected packages relative to important and critical parts of the turbine, where all the design, construction, inspection, testing and acceptance criteria used by the manufacturer are clearly described, provided the Quality Assurance system of the manufacturer is approved and certified by the Society.

1.3 Documentation to be submitted

1.3.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans listed in Tab 1 are to be submitted.

The listed constructional plans are to be complete with all dimensions and are to contain full indication of the types of materials used.

2 Design and construction

2.1 General

2.1.1 Operating conditions

Attention is to be paid to the specific operating conditions of the turbine (e.g. continuous operation at low load) which may be imposed by the ship specification.

2.1.2 Availability of propulsion turbines

In accordance with Ch 1, Sec 1, [2.1.2], propulsion turbines are to remain operational as required to fulfil the machinery availability requirements stated in Part D for the service notation of the ship and with the requirements of Part E, Chapter 3 when the ship is to be assigned an **AVM** additional class notation. Where propulsion turbines are to remain operational in flooding conditions, the turbines' enclosures may be used for this purpose.

2.2 Materials

2.2.1 Approved materials

a) Gas turbine materials are to fulfil the requirements imposed by the operating conditions of the individual components. In the choice of materials, account is to be taken of effects such as creep, thermal fatigue, oxidation and corrosion to which individual components are subject when in service. Evidence of the suitability of the materials is to be supplied to the Society in the form of details of their chemical and mechanical properties and of the heat treatment applied. Where composite materials are used, their method of manufacture is to be described.

b) Turbine blades are to be built of corrosion and heat-resistant materials.

2.3 Stress analyses

2.3.1 Calculation

a) The manufacturer is to submit the results of calculation of the stresses on each rotor under the most severe service conditions.

b) Fatigue analysis on each rotor, taking into account the stress concentrations, is also to be submitted.

c) The results of previous in-service experience on similar applications may be considered by the Society as an alternative to items a) and b) above.

The calculations and analyses (see also [1.3.1]) are to be carried out in accordance with criteria agreed by the Society. Data on the design service life and test results used to substantiate calculation assumptions are also to be provided.

2.3.2 Vibrations

The range of service speeds is not to give rise to unacceptable bending vibrations or to vibrations affecting the entire installation. Calculations of the critical speeds including details of their basic assumptions are to be submitted.

2.4 Design and constructional details

2.4.1 Rotors and stators

a) All components of turbines and compressors are to be free from defects and are to be built and installed with tolerances and clearances in order to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easily operated.

c) Suitable protective devices are to be provided in order to prevent heat, noise or possible failure of rotating parts from causing injury to personnel. If, to this end, the whole gas turbine is enclosed in a protective covering, the covering is to be adequately ventilated inside.

d) Particular attention is to be paid to the connection in the casings of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of sections of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.4.2 Access and inspection openings

a) Access to the combustion chambers is to be ensured. Means are to be provided to inspect the burner cans or combustion chamber without having to remove the gas generator.

b) Inspection openings are to be provided to allow the gas turbine flow path air to be inspected with special equipment, e.g. a bore-scope or similar, without the need for dismantling.

2.4.3 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.

b) Lubricating oil or fuel oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped are to be provided, if necessary to prevent bearing cooking.

d) Roller bearings are to be identifiable and are to have a life adequate for their intended purpose. In any event, their life cannot be less than 40000 hours.

2.4.4 Turning gear

a) Main propulsion turbines are to be equipped with turning gear or a starter for cranking. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of the turning gear or starter is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

2.4.5 Cooling

The turbines and their external exhaust system are to be suitably insulated or cooled to avoid excessive outside temperature.

2.4.6 Air supply

a) The air intake ducting is to be equipped to prevent extraneous substances from entering the compressor and turbine.

b) Measures are to be taken to control the salinity of the combustion air, to meet the manufacturer's specification.

c) Cleaning equipment is to be provided to remove deposits from compressors and turbines.

d) Means are to be provided to prevent the formation of ice in the air intake.

2.4.7 Turbine exhaust arrangement

a) The gas exhaust arrangement is to be designed in such a way as to prevent the entrance of gases into the compressor.

b) Silencers or other equivalent arrangements are to be provided in the gas exhaust, to limit the airborne noise at one metre distance from the turbine to not more than 110 dB (A) in unmanned machinery spaces and not more than 90 dB (A) in manned spaces.

2.4.8 Multi-turbine installations

Multi-turbine installations are to have separate air inlets and exhaust systems to prevent recirculation through the idle turbine.

2.4.9 Fuel

a) Where the turbine is designed to burn non-distillate fuels, a fuel treatment system is to be provided to remove, as far as practicable, the corrosive constituents of the fuel or to inhibit their action in accordance with the manufacturer's specification.

b) Suitable means are to be provided to remove the deposits resulting from the burning of the fuel while avoiding abrasive or corrosive action, if applicable.

2.4.10 Start-up equipment

a) Gas turbines are to be fitted with start-up equipment enabling them to be started up from the "shutdown" condition.

b) Provisions are to be made so that any dangerous accumulation of liquid or gaseous fuel inside the turbines is thoroughly removed before any attempt at starting or restarting.

c) Starting devices are to be so arranged that firing operation is discontinued and the main fuel valve is closed within a pre-determined time when ignition is failed.

d) The minimum number of starts is to be such as to satisfy the requirements of Ch 1, Sec 2, [3.1].

e) The arrangement is to be such as to grant redundancy of sources of energy for turbine starting.

2.4.11 Astern power

For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running maximum power is to be such as not to cause any overloading of the propulsion machinery.

2.4.12 Emergency operation

a) In installations with more than one propeller and connected shafting and more than one turbine, the failure of any gas turbine unit connected to a shafting line is not to affect the continued, independent operation of the remaining units.

b) In installations with only one propeller and connected shafting, driven by two or more main turbines, care is to be taken to ensure that, in the event of one of the turbines failing, the others are able to continue operation independently.

c) Ships classed for unrestricted service and fitted with only one propeller and connected shafting driven by a gas turbine are to be provided with means to ensure emergency propulsion in the event of failure of the main turbine.

2.5 Welded fabrication

2.5.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable by the Society in the plans submitted for approval.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures using approved consumables.

2.6 Control, monitoring and shut-off devices

2.6.1 Control and monitoring arrangement

For each main propulsion system, the associated control and monitoring equipment is to be grouped together at each location from which the turbine may be controlled.

2.6.2 Governors and speed control system

a) Propulsion turbines which may be operated in no-load conditions are to be fitted with a control system capable of limiting the speed to a value not exceeding 10% of the maximum continuous speed or another figure proposed by the manufacturer.

b) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or an electrical transmission system are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

c) In addition to the speed governor, turbines are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

d) The speed increase of turbines driving electric generators -except those for electrical propeller drive- resulting from a change from full load to no-load is not to exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed. Alternative requirements may be considered by the Society on a case by case basis based on the actual turbine design and arrangement.

2.6.3 Monitoring system

The main operating parameters (pressure, temperature, rpm, etc.) are to be adequately monitored and displayed at the control console.

2.6.4 Emergency shut-off

a) An emergency push-button shut-off device is to be provided at the control console.

b) Any shut-off device provided in pursuance of the above is to shut off the fuel supply as near the burners as possible.

2.6.5 Quick-closing devices

a) Gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least where required by Tab 2, unless the FMEA proves otherwise.

b) Re-setting of the quick-closing device may be effected only at the turbine or from the control platform with the fuel supply control valve in the closed position.

c) When the devices are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, a hand-operated pump may be accepted as a standby pump.

d) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

2.6.6 Automatic temperature controls

The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions within the normal operating range of the main gas turbine:

a) lubricating oil supply and discharge

b) fuel oil supply (or, alternatively, automatic control of fuel oil viscosity)

c) exhaust gas in specific locations of the flow gas path as determined by the manufacturer.

2.6.7 Indicators, alarm and shutdown

Tab 2 indicates the minimum control, monitoring and shutdown requirements for main propulsion and auxiliary turbines. Alarms can be added or omitted, taking into account the result of FMEA.

Table 2 : Main propulsion and auxiliary turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Control system failure	X						
• Automatic starting failure	X						
Mechanical monitoring of gas turbine							
• Speed		local					
					X		
	H			X			
• Rotor axial displacement (not applicable to roller bearing)		local					
	H			X			
• Vibration	H **(1)**	local					
• Performed number of cycle of rotating part	H						
Gas generator monitoring							
• Flame and ignition failure	X			X			
• Fuel oil supply pressure	L	local					
• Fuel oil supply temperature	H	local					
• Cooling medium temperature	H	local					
• Exhaust gas temperature or gas temperature in specific locations of flow gas path		local					
	H **(1)**			X			
• Pressure at compressor inlet		local					
	L **(1)**			X			
Lubricating oil							
• Turbine supply pressure		local					
	L **(1)**			X			
• Reduction gear supply pressure		local					
	L **(1)**			X			
• Differential pressure across lubricating oil filter	H	local					
• Bearing or lubricating oil (discharge) temperature	H	local					

(1) Alarm to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Joints of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine and compressor casings are to be fitted in such a way as to minimise the thrust loads and moments. If flexible hoses are used for this purpose, they are to comply with the requirements in Ch 1, Sec 10, [2.6].

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1

a) Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

b) When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

c) Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet. Such indicators are to be fitted in an easily visible position. This requirement does not apply to turbines fitted with roller bearings.

3.6 Gratings

3.6.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.7 Drains

3.7.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.8 Instruments

3.8.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts, when necessary.

At the time of installation on board, this check is to be performed in the presence and to the satisfaction of the Surveyor.

4 Material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Every new turbine type intended for installation on board ships is to undergo a type test whose program will be agreed on a case by case basis with the Society and the Owner.

4.2 Material tests

4.2.1 The materials for the construction of the parts listed in Tab 3 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 3 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

4.3 Inspections and testing during construction

4.3.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of a Surveyor during the construction of all turbines which are indicated in [1.1.1]. For on-board trials see Ch 1, Sec 16, [3.4].

- Material tests as required (see [4.2])
- Welding fabrication (see [4.3.2])
- Hydrostatic tests (see [4.3.3])
- Rotor balancing and overspeed test (see [4.3.4], [4.3.5])
- Shop trials (see [4.3.6]).

Table 3 : Material and non-destructive tests

Turbine component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (compressors and turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	all
Stationary parts (castings for casings intended for a temperature exceeding 230°C and plates for casings intended for a temperature exceeding 370°C or pressure exceeding 4 Mpa)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

4.3.2 Welding fabrication

Welding fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.3.3 Hydrostatic tests

Finished casing parts and heat exchangers are to be subjected to hydrostatic testing at 1,5 times the maximum permissible working pressure. If it is demonstrated by other means that the strength of casing parts is sufficient, a tightness test at 1,1 times the maximum permissible working pressure may be accepted by the Society. Where the hydrostatic test cannot be performed, alternative methods for verifying the integrity of the casings may be agreed between the manufacturer and the Society on a case by case basis.

4.3.4 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.3.5 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above overspeed values and that rotors are free from defects, as verified by means of non-destructive tests.

4.3.6 Shop trials

For shop trials, see Ch 1, Sec 2, [4.5], as far as applicable.

4.4 Certification

4.4.1 Type approval certificate and its validity

Subject to the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the turbine manufacturer a "Type Approval Certificate" valid for all turbines of the same type.

4.4.2 Testing certification

a) Turbines admitted to an alternative inspection scheme

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 3 and tests and trials listed in [4.3.1]. However, the shop trials are to be witnesses by a Surveyor.

b) Turbines not admitted to an alternative inspection scheme.

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 3 and for works trials as per [4.3.3], [4.3.4] and [4.3.6].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for the other items listed in Tab 3 and for trials described in [4.3.2], [4.3.5].

Section 6 Gearing

1 General

1.1 Application

1.1.1 Unless otherwise specified, the requirements of this Section apply to:

- reduction and/or reverse gears intended for propulsion plants with a transmitted power of 220 kW and above
- other reduction and step-up gears with a transmitted power of 110 kW and above.

The provisions of Article [2] apply only to cylindrical involute spur or helical gears with external or internal teeth.

The provisions of Article [3] apply only to bevel gears (straight or oblique teeth). Application of other specific methods for the design of bevel gears could be taken into consideration by the Society.

Additional requirements for gears fitted to ships having an ice notation are given in NR467, Part F, Chapter 8.

1.2 Documentation to be submitted

1.2.1 Documents

Before starting construction, all plans, specifications and calculations listed in Tab 1 are to be submitted to the Society.

1.2.2 Data

The data listed in Tab 2 or Tab 3 and in Tab 4 are to be submitted with the documents required in [1.2.1].

Table 1 : Documents to be submitted for gearing

No.	A / I **(2)**	Description of the document **(1)**
1	A	Constructional drawings of shafts and flanges
2	A	Constructional drawings of pinions and wheels, including: a) specification and details of hardening procedure: • core and surface mechanical characteristics • diagram of the depth of the hardened layer as a function of hardness values b) specification and details of the finishing procedure: • finishing method of tooth flanks (hobbing, shaving, lapping, grinding, shot-peening) • surface roughness for tooth flank and root fillet • tooth flank corrections (helix modification, crowning, tip-relief, end-relief), if any • flank tolerance class according to ISO 1328-1:2013
3	A	Shrinkage calculation for shrunk-on pinions, wheels rims and/or hubs with indication of the minimum and maximum shrinkage allowances
4	I	Calculation of load capacity of the gears
5	A / I **(3)**	Constructional drawings of casings
6	A	Functional diagram of the lubricating system, with indication of the: • specified grade of lubricating oil • expected oil temperature in service • kinematic viscosity of the oil
7	A	Functional diagram of control, monitoring and safety systems
8	I	Longitudinal and transverse cross-sectional assembly of the gearing, with indication of the type of clutch
9	I	Data form for calculation of gears**(4)**
10	I	Detailed justification of material quality used for gearing calculation (ML, MQ, or ME according to ISO 6336-5)

(1) Constructional drawings are to be accompanied by the specification of the materials employed including the chemical composition, heat treatment and mechanical properties and, where applicable, the welding details, welding procedure and stress relieving procedure.
(2) Submission of the drawings may be requested:
A = to be submitted for approval
I = to be submitted for information.
(3) "A" for welded casing, "I" otherwise
(4) The forms are given in Tab 2, Tab 3 and Tab 4.

Table 2 : Data to be submitted for cylindrical gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
a			mm	Operating centre distance
b_B			mm	Common face width (for double helix gear, width of one helix)
A			–	Flank tolerance class according to ISO 1328-1:2013
b_S			mm	Web thickness
s_R			mm	Rim thickness
$R_{m,rim}$			N/mm²	Ultimate tensile strength of the rim material
B			mm	Total face width of double helix gears, including gap
d_s			mm	Shrinkage diameter
m_n			mm	Normal module
α_n			deg or rad	Normal pressure angle at reference cylinder
β			deg or rad	Helix angle at reference cylinder
x			–	Addendum modification coefficient
z			–	Number of teeth
P			kW	Transmitted power
n			rpm	Rotational speed
d_a			mm	Tip diameter
ρ_{a0}			mm	Tip radius of the tool
h_{fp}			mm	Basic rack dedendum
HRC			–	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm²	Minimum yield strength of the shaft material
ν_{40}			mm²/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			$N^{1/2}$/mm	Elasticity factor

Table 3 : Data to be submitted for bevel gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
A			–	Flank tolerance class according to ISO 1328-1:2013
s_R			mm	Rim thickness
d_s			mm	Shrinkage diameter
b			mm	Common face width (for double helix gear width of one helix)
m_{mn}			mm	Mean normal module
α_n			deg or rad	Normal pressure angle
β_m			deg or rad	Mean helix angle
z			–	Actual number of teeth
δ			deg or rad	Pitch angle
x_h			–	Addendum modification coefficient
x_s			–	Thickness modification coefficient
h_{aP}			mm	Addendum of the basic rack tooth profile
h_{fP}			mm	Dedendum of the basic rack tooth profile
ρ_{a0}			mm	Cutter edge radius
r_{c0}			mm	Cutter radius
P			kW	Transmitted power
n			rpm	Rotational speed
HRC			–	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm^2	Minimum yield strength of the shaft material
ν_{40}			mm^2/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			$N^{1/2}/mm$	Elasticity factor

Table 4 : General data to be submitted for bevel and cylindrical gears

<table>
<tr><td colspan="3">Condition of use</td><td colspan="2">Tick the box</td></tr>
<tr><td rowspan="5">Main gears (propulsion)</td><td rowspan="3">Diesel engine</td><td>with hydraulic coupling</td><td colspan="2"></td></tr>
<tr><td>with elastic coupling</td><td colspan="2"></td></tr>
<tr><td>with other type of coupling</td><td colspan="2"></td></tr>
<tr><td colspan="2">Turbine</td><td colspan="2"></td></tr>
<tr><td colspan="2">Electric motor</td><td colspan="2"></td></tr>
<tr><td colspan="3">Gears intended for ahead running</td><td colspan="2"></td></tr>
<tr><td colspan="3">Gears intended for astern running only</td><td colspan="2"></td></tr>
<tr><td colspan="3">Other intermittent running</td><td colspan="2"></td></tr>
<tr><td colspan="3">Gears with occasional part load in reverse direction (main wheel in reverse gearbox)</td><td colspan="2"></td></tr>
<tr><td colspan="3">Idler gears</td><td colspan="2"></td></tr>
<tr><td colspan="3">Shrunk on pinions and wheel rims</td><td colspan="2"></td></tr>
<tr><td colspan="3">Otherwise</td><td colspan="2"></td></tr>
<tr><td colspan="5">Arrangement</td></tr>
<tr><td colspan="3">Single gear</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Dual tandem gear</td><td colspan="2">without quill shaft(1)</td><td colspan="2"></td></tr>
<tr><td colspan="2">with quill shaft(1)</td><td colspan="2"></td></tr>
<tr><td rowspan="4">Epicyclic gear</td><td colspan="2">with 3 planetary gears and less</td><td colspan="2"></td></tr>
<tr><td colspan="2">with 4 planetary gears</td><td colspan="2"></td></tr>
<tr><td colspan="2">with 5 planetary gears</td><td colspan="2"></td></tr>
<tr><td colspan="2">with 6 planetary gears and more</td><td colspan="2"></td></tr>
<tr><td colspan="5">Machining</td></tr>
<tr><td colspan="3">No modification</td><td colspan="2"></td></tr>
<tr><td colspan="3">Central crowning fma</td><td colspan="2"></td></tr>
<tr><td colspan="3">Central crowning fma + fsh</td><td colspan="2"></td></tr>
<tr><td colspan="3">Helix correction</td><td colspan="2"></td></tr>
<tr><td colspan="3">Helix correction + crowning</td><td colspan="2"></td></tr>
<tr><td colspan="3">End relief</td><td colspan="2"></td></tr>
<tr><td colspan="3">Maximum base pitch deviation of the wheel</td><td colspan="2"></td></tr>
<tr><td colspan="3">With optimum profile correction</td><td colspan="2"></td></tr>
<tr><td colspan="3">Material</td><td>Pinion</td><td>Wheel</td></tr>
<tr><td>St</td><td rowspan="2">Normalized low carbon steels / cast steels</td><td>Wrought normalized low carbon steels</td><td></td><td></td></tr>
<tr><td>St (Cast)</td><td>Cast steels</td><td></td><td></td></tr>
<tr><td>GTS (Perl.)</td><td rowspan="5">Cast iron materials</td><td>Black malleable cast iron (perlitic structure)</td><td></td><td></td></tr>
<tr><td>GGG (Perl.)</td><td>Nodular cast iron (perlitic structure)</td><td></td><td></td></tr>
<tr><td>GGG (Bai.)</td><td>Nodular cast iron (bainitic structure)</td><td></td><td></td></tr>
<tr><td>GGG (ferr.)</td><td>Nodular cast iron (ferritic structure)</td><td></td><td></td></tr>
<tr><td>GG</td><td>Grey cast iron</td><td></td><td></td></tr>
<tr><td>V</td><td>Through-hardened wrought steels</td><td>Carbon steels, alloy steels</td><td></td><td></td></tr>
<tr><td>V (cast)</td><td>Through-hardened cast steels</td><td>Carbon steels, alloy steels</td><td></td><td></td></tr>
<tr><td>Eh</td><td colspan="2">Case-hardened wrought steels</td><td></td><td></td></tr>
<tr><td>IF</td><td colspan="2">Flame or induction hardened wrought or cast steels</td><td></td><td></td></tr>
<tr><td>NT (nitr.)</td><td rowspan="2">Nitrided wrought steels/nitrided steels / nitrided through-hardening steels</td><td>Nitriding steels</td><td></td><td></td></tr>
<tr><td>NV (nitr.)</td><td>Through-hardening steels</td><td></td><td></td></tr>
<tr><td>NV (nitrocar.)</td><td>Wrought steels, nitrocarburized</td><td>Through-hardening steels</td><td></td><td></td></tr>
<tr><td colspan="5">(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.</td></tr>
</table>

2 Design of gears - Determination of the load capacity of cylindrical gears

2.1 Symbols, units, definitions

2.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013
a : Operating centre distance, in mm
b : Effective face width, in mm (for double helix gear, $b = 2\ b_B$)
b_B : Common face width, in mm (for double helix gear, width of one helix)
b_S : Web thickness, in mm
B : Total face width of double helix gear, including gap, in mm
d : Reference diameter, in mm
d_a : Tip diameter, in mm
d_b : Base diameter, in mm
d_{ext} : External diameter of shaft, in mm
d_{int} : Internal diameter of shaft, in mm
d_f : Root diameter, in mm
d_s : Shrinkage diameter, in mm
d_w : Working pitch diameter, in mm
F_t : Nominal tangential load, in N
F_β : Total helix deviation, in μm
h : Tooth depth, in mm
h_{fp} : Basic rack dedendum, in mm
HB : Brinell hardness, in N/mm^2
HRC : Rockwell hardness
HV : Vickers hardness, in N/mm^2
k : Gear axial position on shaft with respect to the bearings
ℓ : Bearing span, in mm
m_n : Normal module, in mm
n : Rotational speed, in rpm
P : Transmitted power, in kW
pr : Protuberance of the tool, in mm
q : Material allowance for finish machining, in mm
$R_{m,rim}$: Ultimate tensile strength of the rim material, in N/mm^2
$R_{e,s}$: Minimum yield strength of the shaft material, in N/mm^2
R_Z : Mean peak-to-valley roughness of the gear pair, in μm
R_{Zf} : Mean peak-to-valley flank roughness of the gear pair, in μm
s_R : Rim thickness, in mm
T : Transmitted torque, in kN.m
u : Reduction ratio
v : Linear speed at pitch diameter, in m/s
x : Addendum modification coefficient
z : Number of teeth
z_n : Virtual number of teeth
α_a : Transverse profile angle at tooth tip
α_n : Normal pressure angle at reference cylinder
α_t : Transverse pressure angle at reference cylinder
α_{tw} : Transverse pressure angle at working pitch cylinder
β : Helix angle at reference cylinder
β_b : Base helix angle
ε_α : Transverse contact ratio
ε_β : Overlap ratio
ε_γ : Total contact ratio

ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s

ρ_{a0} : Tip radius of the tool, in mm

σ_F : Tooth root bending stress, in N/mm²

σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²

σ_{FP} : Permissible tooth root bending stress, in N/mm²

σ_H : Contact stress, in N/mm²

$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²

σ_{HP} : Permissible contact stress, in N/mm²

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

2.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_n (in case of width of one gear much more important than the other).

For internal gear, z_2, a, d_2, d_{a2}, d_{b2}, x_2 and d_{w2} are to be taken negative.

$$u = \frac{z_2}{z_1}$$

Note 1: u > 0 for external gears, u < 0 for internal gears.

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

$$d_i = \frac{z_i \cdot m_n}{\cos\beta}$$

$$d_{bi} = d_i \cdot \cos\alpha_t$$

$$d_{w1} = \frac{2 \cdot a}{1+u}$$

$$d_{w2} = \frac{2 \cdot a \cdot u}{1+u}$$

$$d_{fi} = d_i + 2 \cdot m_n \cdot x_i - 2 \cdot h_{fPi}$$

$$h_i = 0,5\ (d_{ai} - d_{fi})$$

$$\cos\alpha_{tw} = \frac{d_{b1} + d_{b2}}{2a}$$

$$\sin\beta_b = \sin\beta \cdot \cos\alpha_n$$

$$z_{ni} = \frac{z_i}{\cos\beta \cdot (\cos\beta_b)^2}$$

$$\cos\alpha_{ai} = \frac{d_{bi}}{d_{ai}}$$

$$\varepsilon_\alpha = \frac{z_1}{2\pi}(\tan\alpha_{a1} - \tan\alpha_{wt}) + \frac{z_2}{2\pi}(\tan\alpha_{a2} - \tan\alpha_{wt})$$

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi \cdot m_n}$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$F_{\beta i} = 2^{0,5 \cdot (Q_i - 5)} \cdot (0,1 \cdot |d_i|^{0,5} + 0,63 \cdot b_B{}^{0,5} + 4,2)$$

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_t = \frac{P}{n_1} \cdot \frac{60}{\pi \cdot d_1} \cdot 10^6$$

$$v_i = \frac{\pi \cdot n_i}{60} \cdot \frac{d_{wi}}{10^3}$$

2.2 Principle

2.2.1

a) The following requirements apply to cylindrical involute spur or helical gears with external or internal teeth, and provide a method for the calculation of the load capacity with regard to:

- the surface durability (contact stress)
- the tooth root bending stress.

The cylindrical gears for marine application are to comply with the following restrictions:

- $1,2 < \varepsilon_\alpha < 2,5$
- $\beta < 30°$
- $s_R > 3,5\ m_n$

The relevant formulae are provided in [2.4] and [2.5].

The influence factors common to the formulae are given in [2.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with the ISO 6336 series standards.

2.3 General influence factors

2.3.1 General

General influence factors are defined in [2.3.2], [2.3.3], [2.3.4], [2.3.5] and [2.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

2.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A are given in Tab 5.

2.3.3 Load sharing factor K_γ

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ are given in Tab 6.

Table 5 : Application factor K_A

Type of installation			K_A
Main gears (propulsion)	Diesel engine	with hydraulic coupling	1,05
		with elastic coupling	1,30
		with other type of coupling	1,50
	Turbine		1,05
	Electric motor		1,05
Auxiliary gears	Diesel engine	with hydraulic coupling	1,00
		with elastic coupling	1,20
		with other type of coupling	1,40
	Electric motor		1,00

Table 6 : Load sharing factor K_γ

Type of gear		K_γ
Dual tandem gear	without quill shaft **(1)**	1,15
	with quill shaft **(1)**	1,10
Epicyclic gear	with 3 planetary gears and less	1,00
	with 4 planetary gears	1,20
	with 5 planetary gears	1,30
	with 6 planetary gears and more	1,40
(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.		

2.3.4 Dynamic factor K_V (method B)

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and the wheel.

The calculation of the dynamic factor K_V is defined in Tab 7, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi z_1} \cdot \sqrt{\frac{c_{\gamma\alpha}}{m_{red}}}$$

with:

m_{red} : Reduced mass of gear pair, in kg/mm

In case of external gears, estimated calculation of m_{red} is given in Tab 8

$c_{\gamma\alpha}$: Mesh stiffness, in N/(mm·µm).

For gears with $\beta \leq 30°$, the calculation of $c_{\gamma\alpha}$ is detailed in Tab 9.

The value of N determines the range of vibrations:

- subcritical range, when $N \leq N_S$
- main resonance range, when $N_S < N < 1,15$

  This field is not permitted
- intermediate range, when $1,15 \leq N \leq 1,50$

  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

The lower limit of resonance N_S is defined as follows:

- if $F_t K_A / b \geq 100$ N/mm:

  $N_s = 0,85$
- if $F_t K_A / b < 100$ N/mm:

$$N_s = 0{,}5 + 0{,}35 \sqrt{\frac{F_t K_A}{100b}}$$

2.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$ (method C)

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

a) The values of $K_{H\beta}$ are given in Tab 10. They apply only to gears with:
   - wheel, case, wheel shaft and bearings of stiff construction
   - pinion on a solid or hollow shaft with an inner diameter ratio not exceeding 0,5 and located symmetrically between the bearings
   - no effect of clearances
   - no external loads acting on the pinion shaft.

Note 1: Gears for which the above conditions are not satisfied will be given special consideration by the Society.

The calculation of the initial equivalent misalignment $F_{\beta x}$ is defined in Tab 11.

The calculations of the running-in allowance $y\beta$ and the running-in factor χ_β are defined in Tab 12.

The calculation of the mesh misalignment due to deformations of shafts depends on the constant of the pinion K' and the distance s of the pinion. They are defined in Tab 13.

b) $K_{F\beta}$ is to be determined using the following formula:

$$K_{F\beta} = K_{H\beta}^{\frac{1}{1 + h/b_B + (h/b_B)^2}}$$

where b/h is the smaller of b_{B1}/h_1 and b_{B2}/h_2 but is not to be taken lower than 3.

2.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ (method B)

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 14.

Table 7 : Dynamic factor K_V

Resonance domain	Factor K_V
$N \le N_S$	$K_V = N\,(C_{v1}\,B_P + C_{v2}\,B_F + C_{v3}\,B_K) + 1$
$N > 1{,}50$	$K_V = C_{v5}\,B_P + C_{v6}\,B_F + C_{v7}$

Note 1:

B_P : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_P = \frac{c' \cdot f_{pb,\,eff}}{K_A \cdot (F_t / b)}$$

with:

- c' : Single stiffness defined in Tab 9
- $f_{pb,eff}$: Effective base pitch deviation, in µm, equal to: $f_{pb,eff} = f_{pb} - y_\alpha$ with f_{pb} defined in Tab 14 and y_α defined in Tab 15

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications: $B_f = B_P$

B_k : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_k = \left| 1 - \frac{c' \cdot C_a}{K_A \cdot F_t / b} \right|$$

with:

$$C_a = \frac{1}{18} \cdot \left(\frac{\sigma_{Hlim}}{97} - (18{,}45\,) \right)^2 + 1{,}5$$

When material of the pinion is different from that of the wheel: $C_a = 0{,}5\,(C_{a1} + C_{a2})$

C_{v1} : Factor for pitch deviation effects: $C_{v1} = 0{,}32$

C_{v2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v2} = 0{,}34$
- if $2 < \varepsilon_\gamma$: $C_{v2} = 0{,}57 / (\varepsilon_\gamma - 0{,}3)$

C_{v3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v3} = 0{,}23$
- if $2 < \varepsilon_\gamma$: $C_{v3} = 0{,}096 / (\varepsilon_\gamma - 1{,}56)$

C_{v5} : Factor: $C_{v5} = 0{,}47$

C_{v6} : Factor:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v6} = 0{,}47$
- if $2 < \varepsilon_\gamma$: $C_{v6} = 0{,}12 / (\varepsilon_\gamma - 1{,}74)$

C_{v7} : Factor:

- if $1 < \varepsilon_\gamma \le 1{,}5$: $C_{v7} = 0{,}75$
- if $1{,}5 < \varepsilon_\gamma \le 2{,}5$: $C_{v7} = 0{,}125\,\sin[\pi\,(\varepsilon_\gamma - 2)] + 0{,}875$
- if $2{,}5 < \varepsilon_\gamma$: $C_{v7} = 1$

Table 8 : Estimated calculation of reduced mass m_{red}

Gear rim	Rim ratio	m_{red}, in kg/mm
$s_{Ri} = 0$	$1 - q_i^4 = 1$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left(\frac{1}{\rho_1} + \frac{1}{\rho_2 \cdot u^2}\right)}$
$s_{Ri} \ne 0$	$q_i = \frac{2 \cdot (d_{fi} - 2 \cdot s_{Ri})}{d_{fi} + d_{ai}}$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left[\frac{1}{(1 - q_1^4) \cdot \rho_1} + \frac{1}{(1 - q_2^4) \cdot \rho_2 \cdot u^2}\right]}$

Note 1:
ρ_i is the density of gearing material ($\rho = 7{,}83 \cdot 10^{-6}$ for steel)

Table 9 : Mesh stiffness $c_{\gamma\alpha}$ (method B)

Specific load	$c_{\gamma\alpha}$, in N/(mm.µm)**(1)**
$F_t K_A / b \geq 100$ N/mm	$c_{\gamma\alpha} = c' (0{,}75\ \varepsilon_\alpha + 0{,}25) = c'_{th} C_M C_R C_B \cos\beta (0{,}75\ \varepsilon_\alpha + 0{,}25)$
$F_t K_A / b < 100$ N/mm	$c_{\gamma\alpha} = c'(0{,}75\ \varepsilon_\alpha + 0{,}25) = c'_{th} C_M C_R C_B \cos\beta \left(\frac{F_t K_A / b}{100}\right)(0{,}75\ \varepsilon_\alpha + 0{,}25)$

(1) When $\varepsilon_\alpha < 1{,}2$: $c_{\gamma\alpha}$ may be reduced up to 10% in case of spur gears.

Note 1:

c' : Single stiffness, in N/(mm.µm)

c'_{th} : Theoretical mesh stiffness, in N/(mm.µm), equal to:

$$c'_{th} = \frac{1}{0{,}04723 + \frac{0{,}15551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635\ x_1 - 0{,}00193\ x_2 - \frac{0{,}11654\ x_1}{z_{n1}} - \frac{0{,}24188\ x_2}{z_{n2}} + 0{,}00529\ x_1^2 + 0{,}00182\ x_2^2}$$

where the following limitations are to be verified:

- $x_1 \geq x_2$, and
- $-0{,}5 \leq x_1 + x_2 \leq 2{,}0$

For internal gears, z_{n2} should be replaced by infinity

C_M : Measurements correction factor, equal to:

$C_M = 0{,}8$

C_R : Gear blank factor:

- for solid disc gears ($s_R = 0$):

  $C_R = 1{,}0$
- otherwise:

  $$C_R = 1 + \frac{\ln(b_s / b)}{5 \cdot e^{s_R / 5 m_n}}$$

  with the following limitations:

  $0{,}2 \leq b_s / b \leq 1{,}2$ and $s_R / m_n \geq 1$

C_B : Basic rack factor, equal to:

$$C_B = 1 + 0{,}5 \cdot \left(1{,}2 - \frac{h_{fP}}{m_n}\right) \cdot [1{,}0 - 0{,}02 \cdot (20 - \alpha_n)]$$

When pinion basic rack dedendum is different from that of the wheel, $C_B = 0{,}5\ (C_{B1} + C_{B2})$.

Table 10 : Face load factor for contact stress $K_{H\beta}$

	Calculated face width	Factor $K_{H\beta}$
$\frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} \geq 1$	$\frac{b_{cal}}{b} = \sqrt{\frac{2 F_m / b}{F_{\beta y} c_{\gamma\beta}}} \leq 1$	$K_{H\beta} = \sqrt{\frac{2 F_{\beta y} c_{\gamma\beta}}{F_m / b}} \geq 2$
$\frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} < 1$	$\frac{b_{cal}}{b} = 0{,}5 + \frac{F_m / b}{F_{\beta y} c_{\gamma\beta}} > 1$	$K_{H\beta} = 1 + \frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} < 2$

Note 1:

b_{cal} : Calculated face width, in mm

F_m : Mean transverse tangential load, in N:

$F_m = F_t K_A K_V$

$F_{\beta y}$: Effective misalignment after running-in, in µm:

$F_{\beta y} = F_{\beta x} - y_\beta = F_{\beta x}\ \chi_\beta$

where:

$F_{\beta x}$: Initial equivalent misalignment. Estimated values are given in Tab 11

y_β, χ_β : Running-in allowance, in µm, and running-in factor, respectively, defined in Tab 12

$c_{\gamma\beta}$: Mesh stiffness, in N/(mm·µm):

$c_{\gamma\beta} = 0{,}85\ c_{\gamma\alpha}$

$c_{\gamma\alpha}$ being the mesh stiffness defined in Tab 9.

Table 11 : Initial equivalent misalignment $F_{\beta x}$

Helix modification	$F_{\beta x}$, in µm**(1)**	Default estimated values of f_{ma}
None	$F_{\beta x} = 1,33\ f_{sh} + f_{ma}$	$f_{ma} = F_\beta$
Central crowning with $C_\beta = 0,5\ f_{ma}$	$F_{\beta x} = 1,33\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Central crowning with $C_\beta = 0,5\ (f_{ma} + f_{sh})$	$F_{\beta x} = 0,665\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Helix correction	$F_{\beta x} = 0,133\ f_{sh} + f_{ma}$	$f_{ma} = 0,5\ F_\beta$
Helix correction plus central crowning	$F_{\beta x} = 0,133\ f_{sh} + 0,5\ f_{ma}$	$f_{ma} = 0,5\ F_\beta$
End relief	$F_{\beta x} = 0,931\ f_{sh} + 0,7\ f_{ma}$	$f_{ma} = 0,7\ F_\beta$

(1) The misalignment $F_{\beta x}$ is to be taken greater than $F_{\beta x,min} = 0,005\ F_m / b$

Note 1:

f_{sh} : Mesh misalignment due to deformations of shafts, in µm:

$$f_{sh} = \frac{F_m}{b} \cdot 0,023 \left(\left| B^* + K' \frac{\ell \cdot s \cdot d_1^{\ 2}}{d_{ext}^{\ 4}} - 0,3 \right| + 0,3 \right) \cdot \left(\frac{d_B}{d_1} \right)^2$$

where:

B^* : Transmitted torque factor depending on k, percentage of input torque transmitted in one gear mesh:
- for spur and single helical gears: $B^* = 1 + 2\ (100 - k) / k$
- for double helical gears: $B^* = 0,5 + (200 - k) / k$

K' : Constant of the pinion defined in Tab 13

s : Distance of the pinion, in mm, as shown in Tab 13

f_{ma} : Mesh misalignment due to manufacturing deviations, in µm.

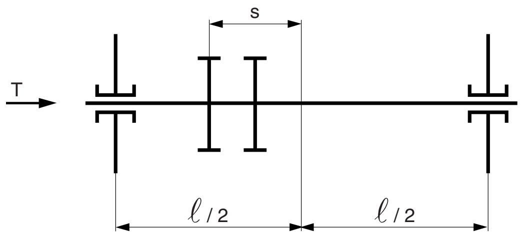
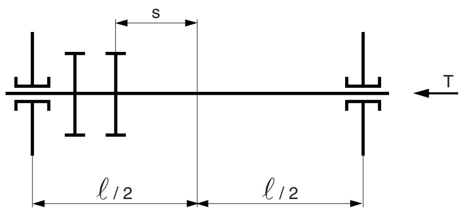
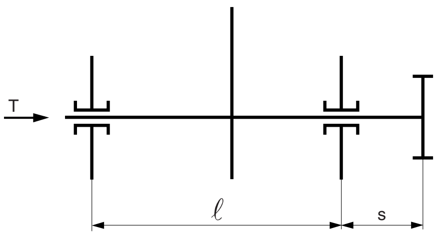
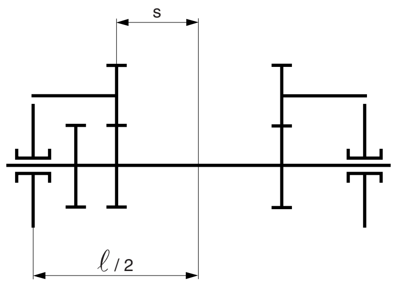
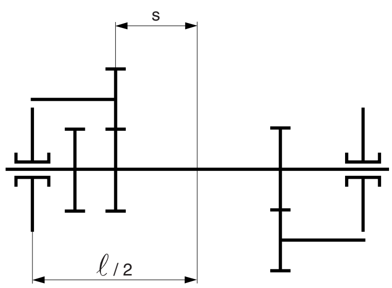
Table 12 : Running-in allowance y_β and running-in factor $\chi\beta$

Material	y_β , in µm	χ_β	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_\beta = \dfrac{320}{\sigma_{H,\,lim}} F_{\beta x}$	$\chi_\beta = 1 - \dfrac{320}{\sigma_{H,\,lim}}$	$y_\beta \le F_{\beta x}$ and $\chi_\beta \ge 0$ • if 5 m/s < v ≤ 10 m/s: $y_\beta \le 25600 / \sigma_{H,\,lim}$ • if 10 m/s < v: $y_\beta \le 12800 / \sigma_{H,\,lim}$
GGG (ferr.), GG	$y_\beta = 0,55\ F_{\beta x}$	$\chi_\beta = 0,45$	• if 5 m/s < v ≤ 10 m/s: $y_\beta \le 45$ • if 10 m/s < v: $y_\beta \le 22$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_\beta = 0,15\ F_{\beta x}$	$\chi_\beta = 0,85$	$y_\beta \le 6$

Note 1: $\sigma_{H,\,lim}$ is defined in [2.4.9].

Note 2: When material of the pinion differs from that of the wheel: $y_\beta = 0,5\ (y_{\beta 1} + y_{\beta 2})$ and $\chi_\beta = 0,5\ (\chi_{\beta 1} + \chi_{\beta 2})$

Table 13 : Constant of the pinion K' and distance of the pinion s

Arrangement **(1)**	Constant K' with stiffening	Constant K' without stiffening **(2)**
	0,48	0,8
	– 0,48	– 0,8
	1,33	1,33
	– 0,36	– 0,6
	– 0,6	– 1,0

(1) The following limitation is to be verified except when helix correction is applied:
$s / \ell < 0,3$

(2) No stiffening is assumed when $d_1 / d_{sh} < 1,15$ or when the pinion is keyed or shrinked to the shaft.

Table 14 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_\gamma \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_\gamma}{2}\left[0{,}9 + 0{,}4\,\frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}\right]$	$\frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^{2}} \ge K_{H\alpha} \ge 1$
$\varepsilon_\gamma > 2$	$K_{H\alpha} = K_{F\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}\,\frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}}$	$\frac{\varepsilon_\gamma}{0{,}25\ \varepsilon_\alpha + 0{,}75} \ge K_{F\alpha} \ge 1$

Note 1:

$c_{\gamma\alpha}$: Mesh stiffness, in N/mm.µm, defined in Tab 9

f_{pb} : Larger value of the base pitch deviation of pinion or wheel, in µm.

Default value: $f_{pb} = 0{,}3\ (m_n + 0{,}4\ |d_{bi}|^{0{,}5} + 4) \cdot 2^{0{,}5\ (Q_i - 5)}$

In case of optimum profile correction, f_{pb} is to be replaced by f_{pb} / 2

y_α : Running-in allowance, in µm, defined in Tab 15

F_{tH} : Determinant tangential load in transverse plane, in N:

$F_{tH} = F_t \cdot K_A \cdot K_V \cdot K_{H\beta}$

Table 15 : Running-in allowance y_α

Material	y_α, in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_\alpha = \frac{160}{\sigma_{H,\,lim}} f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 12800 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\alpha \le 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	$y_\alpha = 0{,}275\ f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 22$ • if 10 m/s < v: $y_\alpha \le 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_\alpha = 0{,}075\ f_{pb}$	$y_\alpha \le 3$

Note 1: f_{pb} is defined in Tab 14 and $\sigma_{H,lim}$ is defined in [2.4.9].
Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0{,}5\ (y_{\alpha 1} + y_{\alpha 2})$.

2.4 Calculation of surface durability

2.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H, defined in [2.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [2.4.8].

2.4.2 Contact stress σ_H

The contact stress σ_H, in N/mm², is to be determined as follows.

- for the pinion:

$$\sigma_H = Z_B \cdot \sigma_{H0}\sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

- for the wheel:

$$\sigma_H = Z_D \cdot \sigma_{H0}\sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

Z_B, Z_D : Single pair mesh factors, respectively for pinion and for wheel, defined in [2.4.3]

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{H\beta}$: Face load distribution factor (see [2.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

$$\sigma_{H0} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{|u| + 1}{|u|}}$$

with:

Z_H : Zone factor, defined in [2.4.4]

Z_E : Elasticity factor, defined in [2.4.5]

Z_ε : Contact ratio factor, defined in [2.4.6]

Z_β : Helix angle factor, defined in [2.4.7].

2.4.3 Single pair mesh factors Z_B and Z_D

The single pair mesh factors Z_B for pinion and Z_D for wheel account for the influence on contact stresses of the tooth flank curvature at the inner point of single pair contact in relation to Z_H. These factors transform the contact stress determined at the pitch point to contact stresses, considering the flank curvature at the inner point of single pair contact.

Z_B and Z_D are to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

- $Z_B = M_1$ or 1, whichever is the greater, with:

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{z_1}\right] \cdot \left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_2}\right]}}$$

- $Z_D = M_2$ or 1, whichever is the greater, with:

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \frac{2\pi}{z_2}\right] \cdot \left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_1}\right]}}$$

b) for helical gears:

- if $\varepsilon_\beta \geq 1$: $Z_B = Z_D = 1$
- if $\varepsilon_\beta < 1$:

  $Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$ or 1, whichever is the greater

  $Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$ or 1, whichever is the greater.

Note 1: For gears with $\varepsilon_\alpha \leq 1$, a specific analysis of the decisive contact stress along the path of contact is necessary.

Note 2: For internal gears, $Z_D = 1$.

2.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point and transforms the tangential force at the reference cylinder to normal force at the pitch cylinder.

Z_H is to be determined as follows:

$$Z_H = \sqrt{\frac{2 \cdot \cos\beta_b \cdot \cos\alpha_{tw}}{(\cos\alpha_t)^2 \cdot \sin\alpha_{tw}}}$$

2.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

For steel gears: $Z_E = 189{,}8\ N^{1/2}/mm$.

Note 1: Refer to ISO 6336-2 for other materials.

2.4.6 Contact ratio factor Z_ε

The contact ratio factor Z_ε accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

Z_ε is to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

b) for helical gears:

- for $\varepsilon_\beta \geq 1$:

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

- for $\varepsilon_\beta < 1$:

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3} \cdot (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

2.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact. Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos\beta(2,\ )}}$$

Table 16 : Constants A and B and limitations on surface hardness HB or HV

	Quality **(1)**	A	B (N/mm^2)	Hardness	x_{min} (N/mm^2)	x_{max} (N/mm^2)
St	ML	1,000	190	HB	110	210
	MQ	1,000	190	HB	110	210
	ME	1,520	250	HB	110	210
St (cast)	ML	0,986	131	HB	140	210
	MQ	0,986	131	HB	140	210
	ME	1,143	237	HB	140	210
GTS (perl.)	ML	1,371	143	HB	135	250
	MQ	1,371	143	HB	135	250
	ME	1,333	267	HB	175	250
GGG	ML	1,434	211	HB	175	300
	MQ	1,434	211	HB	175	300
	ME	1,500	250	HB	200	300
GG	ML	1,033	132	HB	150	240
	MQ	1,033	132	HB	150	240
	ME	1,465	122	HB	175	275
V (carbon steels)	ML	0,963	283	HV	135	210
	MQ	0,925	360	HV	135	210
	ME	0,838	432	HV	135	210
V (alloy steels)	ML	1,313	188	HV	200	360
	MQ	1,313	373	HV	200	360
	ME	2,213	260	HV	200	390
V (cast, carbon steels)	ML	0,831	300	HV	130	215
	MQ	0,831	300	HV	130	215
	ME	0,951	345	HV	130	215
V (cast, alloy steels)	ML	1,276	298	HV	200	360
	MQ	1,276	298	HV	200	360
	ME	1,350	356	HV	200	360
Eh	ML	0,000	1300	HV	600	800
	MQ	0,000	1500	HV	660	800
	ME	0,000	1650	HV	660	800
IF	ML	0,740	602	HV	485	615
	MQ	0,541	882	HV	500	615
	ME	0,505	1013	HV	500	615
NT (nitr.)	ML	0,000	1125	HV	650	900
	MQ	0,000	1250	HV	650	900
	ME	0,000	1450	HV	650	900
NV (nitr.)	ML	0,000	788	HV	450	650
	MQ	0,000	998	HV	450	650
	ME	0,000	1217	HV	450	650
NV (nitrocar.)	ML	0,000	650	HV	300	650
	MQ	1,167	425	HV	300	450
	ME	1,167	425	HV	300	450

(1) The requirements for each material quality are defined in ISO 6336-5.

2.4.8 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP} , in N/mm², is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [2.4.9]

Z_{NT} : Life factor for contact stress, defined in [2.4.10]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [2.4.11]

Z_W : Hardness ratio factor, defined in [2.4.12]

Z_X : Size factor for contact stress, defined in [2.4.13]

S_H : Safety factor for contact stress, defined in [2.4.14].

2.4.9 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$, in N/mm², is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given, in N/mm², with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{H,lim} = A\,x + B$

where:

A, B : Constants determined in Tab 16

x : Surface hardness HB or HV, in N/mm². The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 16.

Special consideration will be given to other values of $\sigma_{H,lim}$, depending on the material category and specification of the steel employed.

2.4.10 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given for information in Tab 17.

The value of Z_{NT} to be used will be given special consideration by the Society, depending on the equipment's arrangement and use.

Table 17 : Life factor Z_{NT}

Material	Number of load cycles N_L	Z_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.),V, V (cast), Eh, IF	$N_L \leq 10^5$ or static	1,6
	$N_L = 5 \cdot 10^7$	1,0
	$N_L = 10^9$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \leq 10^5$ or static	1,3
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \leq 10^5$ or static	1,1
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.4.11 Lubricant factor Z_L , speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined as follows:

a) Lubricant factor Z_L

$$Z_L = C_{ZL} + \frac{4 \cdot (1{,}0 - C_{ZL})}{\left(1{,}2 + \frac{134}{\nu_{40}}\right)^2}$$

where:

C_{ZL} : Constant for lubricant factor, equal to:

- for $\sigma_{H,lim} < 850$ N/mm²:

  $C_{ZL} = 0{,}83$

- if 850 N/mm² $\leq \sigma_{H,lim} \leq$ 1200 N/mm²:

  $$C_{ZL} = \frac{\sigma_{H,lim}}{4375} + 0{,}6357$$

- if $\sigma_{H,lim} > 1200$ N/mm²:

  $C_{ZL} = 0{,}91$

b) Speed factor Z_V

$$Z_V = C_{ZV} + \frac{2 \cdot (1{,}0 - C_{ZV})}{\sqrt{0{,}8 + \frac{32}{v}}}$$

where:

C_{ZV} : Constant for speed factor, equal to:

$C_{ZV} = C_{ZL} + 0{,}02$

c) Roughness factor Z_R

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where:

R_{Z10} : Mean relative peak-to-valley roughness for the gear pair, in µm, equal to:

$$R_{Z10} = R_{Zf}\left(\frac{10}{\rho_{red}}\right)^{1/3}$$

ρ_{red} : Relative radius of curvature, in mm, equal to:

$$\rho_{red} = \frac{0{,}5 \cdot d_{b1} \cdot d_{b2} \cdot \tan\alpha_{wt}}{d_{b1} + d_{b2}}$$

d_b being taken negative for internal gears

R_{Zf} : Mean peak-to-valley flank roughness for the gear pair, in µm, equal to:

$$R_{Zf} = \frac{R_{Zf1} + R_{Zf2}}{2}$$

C_{ZR} : Constant for roughness factor, equal to:

- if $\sigma_{H,lim} < 850$ N/mm²:

  $C_{ZR} = 0{,}15$

- if 850 N/mm² $\leq \sigma_{H,lim} \leq$ 1200 N/mm²:

  $$C_{ZR} = 0{,}32 - \frac{\sigma_{H,lim}}{5000}$$

- if $\sigma_{H,lim} > 1200$ N/mm²:

  $C_{ZR} = 0{,}08$

2.4.12 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability in the following cases:

a) Surface-hardened with through-hardened wheel

- if HB < 130:

  $$Z_W = 1{,}2 \cdot \left(\frac{3}{R_{ZH}}\right)^{0{,}15}$$

- if 130 ≤ HB ≤ 470:

  $$Z_W = \left(1{,}2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{ZH}}\right)^{0{,}15}$$

- if HB > 470:

  $$Z_W = \left(\frac{3}{R_{ZH}}\right)^{0{,}15}$$

where:

R_{ZH} : Equivalent roughness, in µm, equal to:

$$R_{ZH} = \frac{R_{Zf1}(10/\rho_{red})^{0,33} \cdot (R_{Zf1}/R_{Zf2})^{0,66}}{(\nu_{40} \cdot v/1500)^{0,33}}$$

ρ_{red} being the relative radius of curvature defined in [2.4.11].

b) Through-hardened pinion and wheel with pinion substantially harder than the wheel (in that case, the hardness factor is to be applied only to the wheel)

- if HB_1 / HB_2 < 1,2:

  Z_W = 1,0
- if 1,2 ≤ HB_1 / HB_2 ≤ 1,7:

  $$Z_W = 1 + \left(0{,}00898\frac{HB_1}{HB_2} - 0{,}00829\right) \cdot (u - 1{,}0)$$
- if HB_1 / HB_2 > 1,7:

  Z_W = 1,0 + 0,00698 (u − 1,0)

Note 1: In any cases, $Z_W \geq 1$

Note 2: If u > 20, u = 20 is to be taken.

2.4.13 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value of Z_X to be used will be given special consideration by the Society depending on the material.

2.4.14 Safety factor for contact stress S_H

The values to be adopted for safety factor for contact stress S_H are given in Tab 18.

Table 18 : Safety factor for contact stress S_H

Type of installation		S_H
Main gears (propulsion)	single machinery	1,25
	duplicate machinery	1,25
Auxiliary gears		1,20

2.5 Calculation of tooth bending strength

2.5.1 General

The criterion for the tooth root bending strength is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F , defined in [2.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [2.5.8].

2.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_t}{b \cdot m_n} Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT} \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_F : Tooth form factor, defined in [2.5.3]

Y_S : Stress correction factor, defined in [2.5.4]

Y_β : Helix angle factor, defined in [2.5.5]

Y_B : Rim thickness factor, defined in [2.5.6]

Y_{DT} : Deep tooth factor, defined in [2.5.7]

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{F\beta}$: Face load distribution factor (see [2.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [2.3.6]).

When a shot peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

2.5.3 Tooth form factor Y_F (method B)

The tooth form factor Y_F takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact.

In the case of helical gears, the form factors are to be determined in the normal section, i.e. for the virtual spur gear with the virtual number of teeth z_n.

Y_F is to be determined separately for the pinion and the wheel, using the following formula:

$$Y_F = \frac{6\dfrac{h_{Fe}}{m_n}\cos\alpha_{Fen}}{\left(\dfrac{s_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where:

h_{Fe} : Bending moment arm, in mm:

- for external gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{3}-\theta\right) - \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

- for internal gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{6}-\theta\right) - \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

- for external gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3}-\theta\right) + \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

- for internal gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{6}-\theta\right) + \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

ρ_{fPv} : Fillet radius at the basic rack, in mm:

- for external gears:

$\rho_{fPv} = \rho_{a0}$

- for internal gears:

$$\rho_{fPv} = \rho_{a0} + m_n \cdot \frac{(x_2 + h_{fP}/m_n - \rho_{a0}/m_n)^{1,95}}{3,156 \cdot 1,036^{z_2}}$$

G : Parameter defined by the following formula:

$$G = \frac{\rho_{fPv}}{m_n} - \frac{h_{fP}}{m_n} + x$$

θ : Parameter defined by the following formula:

$$\theta = \frac{2G}{z_n}\tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by the following formulae:

- for external gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

- for internal gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{6}$$

E : Parameter defined by the following formula:

$$E = \frac{\pi}{4}m_n - h_{fP}\tan\alpha_n + \frac{s_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fen} : Load direction angle:

$\alpha_{Fen} = \alpha_{en} - \gamma_e$

γ_e : Parameter defined by the following formula:

$$\gamma_e = \frac{0,5\ \pi + 2 \cdot \tan\alpha_n \cdot x}{z_n} + \mathrm{inv}\alpha_n - \mathrm{inv}\alpha_{en}$$

with inv, involute function, equal to:

inv $\alpha = \tau\alpha\nu\ \alpha - \alpha$

α_{en} : Form factor pressure angle:

$$\cos\alpha_{en} = \frac{d_{bn}}{d_{en}}$$

d_{bn} : Virtual base diameter, in mm:

$d_{bn} = d_n \cos \alpha_n$

with:

d_n : Virtual reference diameter, in mm:

$$d_n = \frac{d}{(\cos\beta_b)^2} = m_n z_n$$

d_{en} : Parameter defined by the following formula:

$$d_{en} = \frac{2z}{|z|}\sqrt{\left[\frac{\sqrt{d_{an}^2 - d_{bn}^2}}{2} - \frac{\pi d \cos\beta \cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \frac{d_{bn}^2}{4}}$$

with:

d_{an} : Virtual tip diameter, in mm:

$d_{an} = d_n + d_a - d$

$\varepsilon_{\alpha n}$: Virtual transverse contact ratio:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{(\cos\beta_b)^2}$$

2.5.4 Stress correction factor Y_S (method B)

The stress correction factor Y_S is used to convert the nominal bending stress to local tooth root stress, assuming the load is applied at the outer point of a single pair tooth contact. It takes into account the influence of:

- the bending moment
- the proximity of the load application to the critical section.

Y_S is to be determined as follows:

$$Y_S = (1,2 + 0,13L)q_s^{\left(\frac{1}{1,21 + (2,3/L)}\right)}$$

where:

$$L = \frac{s_{Fn}}{h_{Fe}}$$

with s_{Fn} and h_{Fe} defined in [2.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [2.5.3]

Note 1: The notch parameter should be within the range:
$1 \le q_s < 8$

ρ_F : Radius of root fillet, in mm:

$$\frac{\rho_F}{m_n} = \frac{\rho_{fPv}}{m_n} + \frac{2G^2}{\cos\theta \cdot (|z_n| \cdot \cos^2\theta - 2G)}$$

2.5.5 Helix angle factor Y_β

The helix angle factor Y_β converts the tooth root stress of a virtual spur gear to that of the corresponding helical gear, taking into account the oblique orientation of the lines of mesh contact.

Y_β is to be determined as follows:

if $\varepsilon_\beta \le 1$ and $\beta \le 30°$: $Y_\beta = 1 - \varepsilon_\beta \beta / 120$

if $\varepsilon_\beta \le 1$ and $\beta > 30°$: $Y_\beta = 1 - 0{,}25\ \varepsilon_\beta$

if $\varepsilon_\beta > 1$ and $\beta \le 30°$: $Y_\beta = 1 - \beta / 120$

if $\varepsilon_\beta > 1$ and $\beta > 30°$: $Y_\beta = 0{,}75$

2.5.6 Rim thickness factor Y_B

The rim thickness factor Y_B is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis.

Y_B is to be determined as follows:

- for external gears:
  - when $s_R / h \ge 1{,}2$:

    $Y_B = 1{,}0$
  - when $1{,}2 > s_R / h > 0{,}5$:

    $$Y_B = 1{,}6\ \ln\left(2{,}242\ \frac{h}{s_R}\right)$$

Note 1: $s_R / h \le 0{,}5$ is to be avoided.

- for internal gears:
  - when $s_R / m_n \ge 3$:

    $Y_B = 1{,}0$
  - when $3 > s_R / m_n > 1{,}75$:

    $$Y_B = 1{,}15\ \ln\left(8{,}324\ \frac{m_n}{s_R}\right)$$

Note 2: $s_R / h \le 1{,}75$ is to be avoided.

2.5.7 Deep tooth factor Y_{DT}

The deep tooth factor Y_{DT} adjusts the tooth root stress to take into account high precision gears and contact ratios within the range $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$ (where $\varepsilon_{\alpha n}$ is defined in [2.5.3]).

Y_{DT} is to be determined as follows:

- if $\varepsilon_{\alpha n} > 2{,}5$ and $A \le 4$: $Y_{DT} = 0{,}7$
- if $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$ and $A \le 4$: $Y_{DT} = -0{,}666\ \varepsilon_{\alpha n} + 2{,}366$
- otherwise: $Y_{DT} = 1{,}0$

2.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE}	:	Endurance limit for tooth root bending stress, defined in [2.5.9]
Y_d	:	Design factor, defined in [2.5.10]
Y_{NT}	:	Life factor for tooth root bending stress, defined in [2.5.11]
$Y_{\delta relT}$	:	Relative notch sensitive factor, defined in [2.5.12]
Y_{RrelT}	:	Relative surface factor, defined in [2.5.13]
Y_X	:	Size factor for tooth root bending stress, defined in [2.5.14]
S_F	:	Safety factor for tooth root bending stress, defined in [2.5.15].

Table 19 : Constants A and B and limitations on surface hardness HB or HV

Material	Quality **(1)**	A	B (N/mm²)	Hardness	x_{min} (N/mm²)	x_{max} (N/mm²)
St	ML	0,910	138	HB	110	210
	MQ	0,910	138	HB	110	210
	ME	0,772	294	HB	110	210
St (cast)	ML	0,626	124	HB	140	210
	MQ	0,626	124	HB	140	210
	ME	0,508	274	HB	140	210
GTS (perl.)	ML	0,700	154	HB	135	250
	MQ	0,700	154	HB	135	250
	ME	0,806	256	HB	175	250
GGG	ML	0,700	238	HB	175	300
	MQ	0,700	238	HB	175	300
	ME	0,760	268	HB	200	300
GG	ML	0,512	16	HB	150	240
	MQ	0,512	16	HB	150	240
	ME	0,400	106	HB	175	275
V (carbon steels)	ML	0,500	216	HV	115	215
	MQ	0,480	326	HV	115	215
	ME	0,566	404	HV	115	215
V (alloy steels)	ML	0,846	208	HV	200	360
	MQ	0,850	374	HV	200	360
	ME	0,716	462	HV	200	390
V (cast, carbon steels)	ML	0,448	234	HV	130	215
	MQ	0,448	234	HV	130	215
	ME	0,572	334	HV	130	215
V (cast, alloy steels)	ML	0,728	322	HV	200	360
	MQ	0,728	322	HV	200	360
	ME	0,712	372	HV	200	360
Eh	ML	0,000	624	HV	600	800
	MQ, > 25HRC lower	0,000	850	HV	660	800
	MQ, > 25HRC upper	0,000	922	HV	660	800
	MQ, > 35 HRC	0,000	1000	HV	660	800
	ME	0,000	1050	HV	660	800
IF	ML	0,610	152	HV	485	615
	MQ	0,276	580	HV	500	570
	ME	0,542	474	HV	500	615
NT (nitr.)	ML	0,000	540	HV	650	900
	MQ	0,000	840	HV	650	900
	ME	0,000	936	HV	650	900
NV (nitr.)	ML	0,000	516	HV	450	650
	MQ	0,000	726	HV	450	650
	ME	0,000	864	HV	450	650
NV (nitrocar.)	ML	0,000	448	HV	300	650
	MQ	1,306	188	HV	300	450
	ME	1,306	188	HV	300	450

(1) The requirements for each material quality are defined in ISO 6336-5.

2.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given, in N/mm², with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{FE} = A\,x + B$

where:

A, B : Constants determined in Tab 19

x : Surface hardness HB or HV, in N/mm². The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 19.

Special consideration will be given to other values of σ_{FE}, depending on the material category and specification of the steel employed.

2.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength.

Y_d is to be determined as follows:

- for gears with occasional part load in reverse direction, such as main wheel in reverse gearboxes:
  $Y_d = 0,9$
- for idler gears (driven and driving tooth for each cycle i.e. alternating load):
  $Y_d = 0,7$
- for shrunk on pinions and wheel rims:
  $Y_d = 1 - \sigma_T / \sigma_{FE}$
  with:
  σ_{FE} : Endurance limit for tooth root bending stress (see [2.5.9])
  σ_T : Tangential stress induced by the shrinkage at the tooth root diameter.
  The maximum equivalent stress induced by the shrinkage in the inner diameter of the rim is not to exceed 80% of the yield strength of the rim material.
- otherwise: $Y_d = 1,0$

2.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

Table 20 : Life factor Y_{NT}

Material	Number of load cycles N_L	Y_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast), Eh, IF	$N_L \le 10^3$ or static	2,5
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \le 10^3$ or static	1,6
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \le 10^3$ or static	1,1
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.5.12 Relative notch sensitivity factor $Y_{\delta rel\,T}$

The relative notch sensitivity factor $Y_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + \sqrt{\rho' \cdot 0,2 \cdot (1 + 2 q_s)}}{1 + \sqrt{\rho' \cdot 1,2}}$$

where:

q_s : Notch parameter, as defined in [2.5.4]

ρ' : Slip-layer thickness, in mm, defined in Tab 21.

Table 21 : Slip-layer thickness ρ'

Material	ρ' (mm)
GG, R_m = 150 N/mm²	0,3124
GG, GGG (ferr.) R_m = 300 N/mm²	0,3095
NT, NV	0,1005
St, R_e = 300 N/mm²	0,0833
St, R_e = 400 N/mm²	0,0445
V, GTS, GGG (perl. bai.), R_e = 500 N/mm²	0,0281
V, GTS, GGG (perl. bai.), R_e = 600 N/mm²	0,0194
V, GTS, GGG (perl. bai.), R_e = 800 N/mm²	0,0064
V, GTS, GGG (perl. bai.), R_e = 1000 N/mm²	0,0014
Eh, IF	0,0030

2.5.13 Relative surface factor $Y_{Rrel\ T}$

The relative surface factor $Y_{Rrel\ T}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $Y_{Rrel\ T}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

Table 22 : Relative surface factor $Y_{Rrel\ T}$

Material	Y_{RrelT}	
	$R_z < 0,1$	$0,1 \leq R_z \leq 40$
V, V (cast), GGG (perl.), GGG (bai.), Eh, IF	1,120	$1,674 - 0,529\ (R_z + 1)^{0,1}$
St	1,070	$5,306 - 4,203\ (R_z + 1)^{0,01}$
GG, GGG (ferr.), NT, NV	1,025	$4,299 - 3,259\ (R_z + 1)^{0,0058}$
Note 1: R_z : Mean peak-to-valley roughness, in µm: $R_z = 6\ R_a$ with R_a : Arithmetic mean roughness.		

2.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of the normal module m_n.

Table 23 : Size factor Y_X

Material	Normal module	Y_X
St, V, V (cast), GGG (perl.), GGG (bai.), GTS (perl.)	$m_n \leq 5$	1,00
	$5 < m_n < 30$	$1,03 - 0,006\ m_n$
	$m_n \geq 30$	0,85
Eh, IF, NT, NV	$m_n \leq 5$	1,00
	$5 < m_n < 25$	$1,05 - 0,01\ m_n$
	$m_n \geq 25$	0,80
GG, GGG (ferr.)	$m_n \leq 5$	1,00
	$5 < m_n < 25$	$1,075 - 0,015\ m_n$
	$m_n \geq 25$	0,70

2.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

Table 24 : Safety factor for tooth root bending stress S_F

Type of installation		S_F
Main gears (propulsion)	single machinery	1,80
	duplicate machinery	1,60
Auxiliary gears		1,40

2.6 Calculation of scuffing resistance

2.6.1 General

The following calculations are requested for equipment running in supercritical domain, i.e. when N > 1,5 (see [2.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$(\Theta_{B,Max} - \Theta_{oil}) \leq 0,8\ (\Theta_S - \Theta_{oil})$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [2.6.2]

Θ_{oil} : Oil temperature, in °C

Θ_S : Scuffing temperature, in °C, defined in [2.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$(\Theta_S - \Theta_{B,Max}) \geq 30°C$

Other methods of determination of the scuffing resistance could be accepted by the Society.

2.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$\Theta_{B,Max} = \Theta_{Mi} - \Theta_{fl,Max}$

where:

Θ_{Mi} : Interfacial bulk temperature, in °C, defined in [2.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [2.6.3].

The flash temperature should be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

2.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G \cdot (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v^{0,5}}{a^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [2.6.4]

X_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [2.6.5]

X_J : Approach factor, defined in [2.6.6]

X_G : Geometry factor, defined in [2.6.7]

X_Γ : Load sharing factor, defined in [2.6.8]

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9].

2.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0,6 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}}\right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9]

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\ v \sin \alpha_{wt}$

with v not taken greater than 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u}{(1+u)^2} \cdot a \cdot \sin\alpha_{wt}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor, equal to:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2}\right)^{0,25}$$

Table 25 : Lubricant factor X_L

Type of lubricant	X_L **(1)**
Mineral oils	$X_L = 1,0\ \eta_{oil}{}^{-0,05}$
Water soluble polyglycols	$X_L = 0,6\ \eta_{oil}{}^{-0,05}$
Non water soluble polyglycols	$X_L = 0,7\ \eta_{oil}{}^{-0,05}$
Polyalfaolefins	$X_L = 0,8\ \eta_{oil}{}^{-0,05}$
Phosphate esters	$X_L = 1,3\ \eta_{oil}{}^{-0,05}$
Traction fluids	$X_L = 1,5\ \eta_{oil}{}^{-0,05}$
(1) η_{oil} is the dynamic viscosity at oil temperature Θ_{oil}.	

2.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel:

$$X_M = 1000\frac{E_r^{0,25}}{B_M}$$

where:

E_r : Reduced modulus of elasticity, in N/mm²:

$$E_r = \frac{2}{(1-\nu_1)/E_1 + (1-\nu_2)/E_2}$$

E_1, E_2 : Moduli of elasticity of pinion and wheel material, in N/mm²

ν_1, ν_2 : Poisson's ratios of pinion and wheel material

B_M : Mean thermal contact coefficient, in $N\cdot mm^{-1/2}\cdot m^{-1/2}\cdot s^{-1/2}\cdot K^{-1}$, equal to:

$B_M = (B_{M1} + B_{M2}) / 2$

B_{Mi} : Thermal contact coefficient of pinion material (i = 1) and wheel material (i = 2), given in $N\cdot mm^{-1/2}\cdot m^{-1/2}\cdot s^{-1/2}\cdot K^{-1}$ and equal to:

$B_{Mi} = (0,001\ \lambda_{Mi}\ \rho_{Mi}\ c_{Mi})^{0,5}$

An average value of 435 $N\cdot mm^{-1/2}\cdot m^{-1/2}\cdot s^{-1/2}\cdot K^{-1}$ for martensitic steels could be used when thermo-elastic coefficient is not known

λ_{Mi} : Heat conductivity of pinion material (i = 1) and wheel material (i = 2), in $N\cdot s^{-1}\cdot K^{-1}$

ρ_{Mi} : Density of pinion material (i = 1) and wheel material (i = 2), in $kg\cdot m^{-3}$

c_{Mi} : Specific heat per unit mass of pinion material (i = 1) and wheel material (i = 2), in $J\cdot kg^{-1}\cdot K^{-1}$.

2.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film. The approach factor at any point should be calculated according to the following formula:

- when pinion drives the wheel:
  - for $\Gamma \geq 0$:

    $X_J = 1$
  - for $\Gamma < 0$, provided that $X_J \geq 1$:

$$X_J = 1 + \frac{C_{eff} - C_{a2}}{50}\left(\frac{-\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$

- when wheel drives the pinion:
  - for $\Gamma \le 0$:

    $X_J = 1$
  - for $\Gamma > 0$, provided that $X_J \ge 1$:

$$X_J = 1 + \frac{C_{eff} - C_{a1}}{50}\left(\frac{\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$

where:

C_{eff} : Optimal tip relief, in µm:

$$C_{eff} = \frac{K_A K_\gamma F_t}{b \cdot \cos\alpha_t \cdot c_\gamma}$$

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

$c_{\alpha\gamma}$: Mesh stiffness, in N/(mm.µm) (see Tab 9)

C_{ai} : Tip relief of pinion or wheel, in µm

Γ : Parameter of the point on the line of action, defined in Tab 26

Γ_A : Parameter of the lower end point of the path of contact, defined in Tab 26

Γ_E : Parameter of the upper end point of the path of contact, defined in Tab 26.

2.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following conditions:

- for external gear pair:

$$X_G = 0{,}51\ X_{\alpha\beta}(u+1)^{0,5}\frac{\left|(1+\Gamma)^{0,5} - (1-\Gamma/u)^{0,5}\right|}{(1+\Gamma)^{0,25}(u-\Gamma)^{0,25}}$$

- for internal gear pair:

$$X_G = 0{,}51\ X_{\alpha\beta}(u-1)^{0,5}\frac{\left|(1+\Gamma)^{0,5} - (1+\Gamma/u)^{0,5}\right|}{(1+\Gamma)^{0,25}(u+\Gamma)^{0,25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1{,}22\ (\sin\alpha_{wt})^{0,25}\ (\cos\alpha_{wt})^{-0,5}\ (\cos\beta_b)^{0,25}$

Γ : Parameter of the point on the line of action, defined in Tab 26.

Table 26 : Parameter Γ on the line of action

Point	Γ
A : Lower end point of the path of contact	$\Gamma_A = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right)$
AU: Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0{,}2\sin\beta_b$
AB : Intermediate point between A and B	$\Gamma_{AB} = 0{,}5\ (\Gamma_A + \Gamma_B)$
B : Lower point of single pair tooth contact	$\Gamma_B = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1 - \frac{2\pi}{z_1\tan\alpha_{wt}}$
C : Point with parameter equal to 0	$\Gamma_C = 0$
M : Intermediate point between A and E	$\Gamma_M = 0{,}5\ (\Gamma_A + \Gamma_E)$
D : Upper point of single pair tooth contact	$\Gamma_D = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right) + \frac{2\pi}{z_1\tan\alpha_{wt}}$
DE : Intermediate point between D and E	$\Gamma_{DE} = 0{,}5\ (\Gamma_D + \Gamma_E)$
EU : Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0{,}2\sin\beta_b$
E : Upper end point of the path of contact	$\Gamma_E = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1$

2.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

- for narrow helical gears ($\varepsilon_\gamma < 2$) with unmodified profiles:

  $X_\Gamma = X_{\Gamma,u}\, X_{but}$
- for narrow helical gears ($\varepsilon_\gamma < 2$) with profile modification:

  $X_\Gamma = X_{\Gamma,m}\, X_{but}$
- for wide helical gears ($\varepsilon_\gamma \geq 2$) with unmodified profiles:

  $$X_\Gamma = \frac{1}{\varepsilon_\alpha} X_{but}$$
- for wide helical gears ($\varepsilon_\gamma \geq 2$) with profile modification:

  $X_\Gamma = X_{\Gamma,wm}\, X_{but}$

where:

X_{but} : Buttressing factor:

- for $\Gamma < \Gamma_{AU}$:

  $$X_{but} = X_{butA} - \frac{\Gamma - \Gamma_A}{\Gamma_{AU} - \Gamma_A}(X_{butA} - 1)$$
- for $\Gamma_{AU} \leq \Gamma \leq \Gamma_{EU}$:

  $X_{but} = 1$
- for $\Gamma_{EU} < \Gamma$:

  $$X_{but} = X_{butE} - \frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{EU}}(X_{butE} - 1)$$

Note 1: X_{but} is to be taken equal to 1 if $C_{ai} \geq C_{eff}$

X_{butA} , X_{butE} : Buttressing factors at, respectively, lower and upper end points of the path of contact:

$X_{butA} = X_{butE} = 1 + 0{,}3\ \varepsilon_\beta$, provided that

$X_{butA} = X_{butE} < 1{,}3$

$X_{\Gamma,u}$: Load sharing factor for unmodified profiles:

- for $\Gamma < \Gamma_B$:

  $$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_B \leq \Gamma \leq \Gamma_D$:

  $X_{\Gamma,u} = 1$
- for $\Gamma_D < \Gamma$:

  $$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

Note 2: A is to be taken at least equal to 7.

$X_{\Gamma,m}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,m} \geq 0$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_{AB} \leq \Gamma < \Gamma_B$, provided that $X_{\Gamma,m} \leq 1$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_B \leq \Gamma \leq \Gamma_D$:

  $X_{\Gamma,m} = 1$
- for $\Gamma_D < \Gamma \leq \Gamma_{DE}$, provided that $X_{\Gamma,m} \leq 1$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$
- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,m} \geq 0$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

$X_{\Gamma,wm}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,wm} \geq 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a1} + (3\varepsilon_\alpha + 1)C_{a2}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}} \cdot \frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_{AB} \leq \Gamma \leq \Gamma_{DE}$, provided that $X_{\Gamma,wm} \leq 1$:

$$X_{\Gamma,wm} = \frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)(C_{a1} + C_{a2})}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}}$$

- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,wm} \geq 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a2} + (3\varepsilon_\alpha + 1)C_{a1}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}} \cdot \frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{DE}}$$

C_{eff} : Optimal tip relief, in µm (see [2.6.6])

C_{ai} : Tip relief of pinion or wheel, in µm

Γ_i : Parameter of any point on the line of action, given in Tab 26.

2.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha} \cdot K_\gamma \cdot \frac{F_t}{b}$$

where:

K_A : Application factor (see [2.3.2])

K_V : Dynamic factor (see [2.3.4])

$K_{H\beta}$: Face load distribution factor (see [2.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

K_γ : Load sharing factor (see [2.3.3]).

2.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. The following estimation could be used in general configurations:

$\Theta_{Mi} = \Theta_{oil} + 0,47\ X_S\ X_{mp}\ \Theta_{fl,m}$

where:

Θ_{oil} : Oil temperature, in °C

X_S : Lubrication system factor:

- for spray lubrication: $X_S = 1,2$
- for dip lubrication: $X_S = 1,0$
- for meshes with additional spray for cooling purpose: $X_S = 1,0$
- for gears submerged in oil, provided sufficient cooling: $X_S = 0,2$

X_{mp} : Multiple mating pinion factor:

$$X_{mp} = \frac{3 + n_p}{4}$$

n_p : Number of mesh in contact

$\Theta_{fl,m}$: Average flash temperature on the path of contact, in °C.
The average temperature should be calculated on at least ten equidistant points on the path line of contact between Γ_A and Γ_E.

2.6.11 Scuffing temperature Θ_S

The scuffing temperature Θ_S may be determined according to the following formula:

$\Theta_S = 80 + (0,85 + 1,4\ X_W)\ X_L\ (S_{FZG} - 1)^2$

where:

X_W : Structural factor given in Tab 27

X_L : Lubricant factor given in Tab 25

S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

Table 27 : Structural factor X_W

Material	X_W
Through-hardened steel	1,00
Phosphated steel	1,25
Copper-plated steel	1,50
Bath or gas nitrided steel	1,50
Hardened carburized steel, with austenite content less than 10%	1,15
Hardened carburized steel, with austenite content between 10% and 20%	1,00
Hardened carburized steel, with austenite content above 20%	0,85
Austenite steel (stainless steel)	0,45

3 Design of gears - Determination of the load capacity of bevel gears

3.1 Symbols, units, definitions

3.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013
a_v : Virtual operating centre distance, in mm
a_{vn} : Virtual operating centre distance, in mm
b : Effective face width, in mm
d_e : Outer pitch diameter, in mm
d_{ext} : External diameter of shaft, in mm
d_{int} : Internal diameter of shaft, in mm
d_m : Mean pitch diameter, in mm
d_s : Shrinkage diameter of the wheel, in mm
d_v : Virtual reference diameter, in mm
d_{va} : Virtual tip diameter, in mm
d_{van} : Virtual tip diameter, in mm
d_{vb} : Virtual base diameter, in mm
d_{vbn} : Virtual base diameter, in mm
d_{vf} : Virtual root diameter, in mm
d_{vn} : Virtual reference diameter, in mm
F_{mt} : Nominal tangential load, in N
F_β : Total helix deviation, in μm
$g_{v\alpha}$: Length of path of contact, in mm
$g_{v\alpha n}$: Length of path of contact, in mm
h_{aP} : Basic rack addendum, in mm
h_{fP} : Basic rack dedendum, in mm
h_v : Virtual tooth depth, in mm
HB : Brinell hardness, in N/mm²
HPX : Rockwell hardness
Hς : Vickers hardness, in N/mm²
κ : Gear axial position on shaft with respect to the bearings
ℓ : Bearing span, in mm
ℓ_{bm} : Length of the line of contact, in mm
ℓ'_{bm} : Length of the line of contact, in mm
m_{et} : Outer transverse module, in mm
m_{mn} : Mean normal module, in mm
m_{mt} : Mean transverse module, in mm
n : Rotational speed, in rpm
Π : Transmitted power, in kW

p_{et} : Transverse base pitch, in mm
pr : Protuberance of the tool, in mm
q : Material allowance for finish machining, in mm
r_{c0} : Cutter radius, in mm
ρ_e : Outer cone distance, in mm
$P_{\varepsilon,\sigma}$: Minimum yield strength of the shaft material, in N/mm²
ρ_m : Mean cone distance, in mm
$P_{m,rim}$: Ultimate tensile strength of the rim material, in N/mm²
P_Z : Mean peak-to-valley roughness, in µm
P_{Zf} : Mean peak-to-valley flank roughness, in µm
s_R : Rim thickness, in mm
T : Transmitted torque, in kN·m
u : Reduction ratio
u_v : Virtual reduction ratio
v_{mt} : Linear speed at mean pitch diameter, in m/s
x_h : Addendum modification coefficient
x_S : Thickness modification coefficient
z : Number of teeth
z_v : Virtual number of teeth
z_{vn} : Virtual number of teeth
α_n : Normal pressure angle
α_{vt} : Virtual transverse pressure angle
β_m : Mean helix angle
β_{vb} : Virtual base helix angle
δ : Pitch angle
$\varepsilon_{v\alpha}$: Virtual transverse contact ratio
$\varepsilon_{v\alpha n}$: Virtual transverse contact ratio
$\varepsilon_{v\beta}$: Virtual overlap ratio
$\varepsilon_{v\gamma}$: Virtual total contact ratio
ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s
ρ_{a0} : Tip radius of the tool, in mm
σ_F : Tooth root bending stress, in N/mm²
σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²
σ_{FP} : Permissible tooth root bending stress, in N/mm²
σ_H : Contact stress, in N/mm²
$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²
σ_{HP} : Permissible contact stress, in N/mm².

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

3.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_{mn} (in case of width of one gear much more important than the other).

a) General geometrical definitions

$$u = \frac{z_2}{z_1}$$

$$d_{ei} = \frac{z_i m_{mn}}{\cos\beta_m} + b_i \sin\delta_i$$

$$r_e = \frac{d_{e1}}{2\sin\delta_1} = \frac{d_{e2}}{2\sin\delta_2}$$

$$r_m = r_e - 0{,}5\ b$$

$$m_{et} = \frac{d_{e1}}{z_1} = \frac{d_{e2}}{z_2}$$

$$m_{mt} = \frac{r_m m_{et}}{r_e}$$

$$d_{mi} = \frac{z_i m_{mn}}{\cos \beta_m}$$

b) Geometrical definitions of virtual cylindrical gears in transverse section (suffix v)

$$z_{vi} = \frac{z_i}{\cos \delta_i}$$

$$u_v = \frac{z_{v2}}{z_{v1}}$$

$$\tan \alpha_{vt} = \frac{\tan \alpha_n}{\cos \beta_m}$$

$\sin \beta_{vb} = \sin \beta_m \cdot \cos \alpha_n$

$$d_{vi} = \frac{d_{mi}}{\cos \delta_i}$$

$a_v = 0{,}5\ (d_{v1} + d_{v2})$

$d_{v\alpha\iota} = d_{vi} + 2\ h_{aPi}$

$d_{v\beta\iota} = d_{vi} \cos \alpha_{vt}$

$d_{v\phi\iota} = d_{vi} + 2\ m_{mn}\ x_{hi} - 2\ h_{fPi}$

$h_{v\iota} = 0{,}5\ (d_{vai} - d_{vfi})$

$p_{\varepsilon\tau} = m_{mt}\ \pi \cos \alpha_{vt}$

$$g_{v\alpha} = 0{,}5\ \left(\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}\right) - a_v \sin \alpha_{vt}$$

$$\varepsilon_{v\alpha} = \frac{g_{v\alpha}}{p_{et}}$$

$$\varepsilon_{v\beta} = \frac{b \sin \beta_m}{\pi m_{mn}}$$

$$\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2}$$

- if $\varepsilon_{v\beta} < 1$:

$$\ell_{bm} = \frac{b \varepsilon_{v\alpha}}{\cos \beta_{vb} \cdot \varepsilon_{v\gamma}^2} \cdot \sqrt{\varepsilon_{v\gamma}^2 - (2 - \varepsilon_{v\alpha})^2 \cdot (1 - \varepsilon_{v\beta})^2}$$

- if $\varepsilon_{v\beta} \geq 1$:

$$\ell_{bm} = \frac{b \varepsilon_{v\alpha}}{\cos \beta_{vb} \cdot \varepsilon_{v\gamma}}$$

$\ell'_{bm} = \ell_{\beta\mu} \cos \beta_{vb}$

c) Geometrical definitions of virtual cylindrical gears in normal section (suffix vn)

$$z_{vni} = \frac{z_{vi}}{\cos \beta_m \cdot (\cos \beta_{vb})^2}$$

$d_{v\nu\iota} = m_{mn}\ \zeta_{v\nu\iota}$

$a_{vn} = 0{,}5\ (d_{vn1} + d_{vn2})$

$d_{v\alpha\nu\iota} = d_{vni} + 2\ h_{aPi}$

$d_{v\beta\nu\iota} = d_{vni} \cos \alpha_v$

$$g_{v\alpha n} = 0{,}5\ \left(\sqrt{d_{van1}^2 - d_{vbn1}^2} + \sqrt{d_{van2}^2 - d_{vbn2}^2}\right) - a_{vn} \sin \alpha_n$$

$$\varepsilon_{v\alpha n} = \frac{\varepsilon_{v\alpha}}{(\cos \beta_{vb})^2}$$

d) Definitions of transmissions characteristics

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_{mt} = \frac{P}{n_1} \cdot \frac{60}{\pi d_{m1}} \cdot 10^6$$

$$v_{mt} = \frac{\pi n_1}{60} \cdot \frac{d_{m1}}{10^3} = \frac{\pi n_2}{60} \cdot \frac{d_{m2}}{10^3}$$

$$F_{\beta i} = 2^{0,5 \cdot (Q_i - 5)} \cdot (0{,}1\ \cdot d_{vi}^{0,5} + 0{,}63\ \sqrt{b} + 4{,}2)$$

3.2 Principle

3.2.1

a) The following requirements apply to bevel spur or helical gears with external teeth, and provide a method for the calculation of the load capacity with regard to:

- the surface durability (contact stress)
- the tooth root bending stress.

The bevel gears for marine application are to comply with the following restrictions:

- $1,2 < \varepsilon_{v\alpha} < 2,5$
- $\beta_m < 30°$
- $s_R > 3,5\ m_{mn}$

The relevant formulae are provided in [3.4] and [3.5].

The influence factors common to the formulae are given in [3.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with the ISO 6336 series standards.

3.3 General influence factors

3.3.1 General

General influence factors are defined in [3.3.2], [3.3.3], [3.3.4], [3.3.5] and [3.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

3.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A to be used are given in Tab 5.

3.3.3 Load sharing factor K_γ

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ to be used are given in Tab 6.

3.3.4 Dynamic factor K_V

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and wheel.

The calculation of the dynamic factor K_V is defined in Tab 31, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi \cdot z_1} \cdot \sqrt{\frac{c_\gamma}{m_{red}}}$$

where:

m_{red} : Reduced mass of gear pair, in kg/mm. Estimated calculation of m_{red} is given by the following formula:

$$m_{red} = \frac{\rho \cdot \pi}{8} \cdot \frac{d_{m1}^2}{(\cos\alpha_n)^2} \cdot \frac{u^2}{1+u^2}$$

ρ : Density of gearing material, equal to:

$\rho = 7,83 \cdot 10^6$ for steel

c_γ : Mesh stiffness, in N/(mm.µm):

$c_\gamma = 20\ C_F\ C_b$

C_F and C_b being the correction factors for non average conditions defined in Tab 28.

The value of N determines the range of vibrations:

- subcritical range, when $N \leq 0,75$
- main resonance range, when $0,75 < N < 1,25$

  This field is not permitted

- intermediate range, when $1,25 \le N \le 1,50$

  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

3.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root ending stress, account for the effects of non-uniform distribution of load across the face width.

a) The calculation of $K_{H\beta}$ is to be defined according to the mounting conditions of pinion and wheel:

- neither member cantilever mounted:

  $K_{H\beta} = 1,575 / C_b$
- one member cantilever mounted:

  $K_{H\beta} = 1,650 / C_b$
- both members cantilever mounted:

  $K_{H\beta} = 1,875 / C_b$

where C_b is the correction factor defined in Tab 28

b) $K_{F\beta}$ is to be determined using the following formula:

$K_{F\beta} = K_{H\beta} / K_{F0}$, with:

K_{F0} : Lengthwise curvature factor. It is to be taken above 1,0 and below 1,15 considering the following formula:

$$K_{F0} = 0,211 \cdot \left(\frac{r_{c0}}{r_m}\right)^{\frac{0,279}{\log(\sin\beta_m)}} + 0,789$$

3.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 29.

Table 28 : Correction factors C_F and C_b

Conditions	Factors C_F and C_b
if $F_{mt}\, K_A / b_e \ge 100$ N/mm	$C_F = 1$
if $F_{mt}\, K_A / b_e < 100$ N/mm	$C_F = (F_{mt}\, K_A / b_e) / 100$
if $b_e / b \ge 0,85$	$C_b = 1$
if $b_e / b < 0,85$	$C_b = (b_e / b) / 0,85$
b_e : Effective face width, the real length of contact pattern. When b_e is not supplied, $b_e = 0,85\, b$ could be used.	

Table 29 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_{v\gamma} \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_{v\gamma}}{2} \cdot \left(0,9 + 0,4 \cdot \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}\right)$	$\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Z_{LS}^2} \ge K_{H\alpha} \ge 1$
$\varepsilon_{v\gamma} > 2$	$K_{H\alpha} = K_{F\alpha} = 0,9 + 0,4 \cdot \sqrt{\frac{2 \cdot (\varepsilon_{v\gamma} - 1)}{\varepsilon_{v\gamma}}} \cdot \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}$	$\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Y_\varepsilon} \ge K_{F\alpha} \ge 1$
Note 1: c_γ : Mesh stiffness, in N/mm.µm, defined in [3.3.4] $f_{\pi\tau}$: Larger value of the single pitch deviation of pinion or wheel, in µm. Default value: $f_{pt} = 0,3\,(m_{mn} + 0,4\,\lvert d_{bi}\rvert^{0,5} + 4) \cdot 2^{0,5\,(Q_i - 5)}$ In case of optimum profile correction, f_{pt} is to be replaced by $f_{pt} / 2$ y_α : Running-in allowance, in µm, defined in Tab 30 $f_{\mu\tau H}$: Determinant tangential load at mid-face width on the reference cone, in N: $F_{\mu\tau H} = F_{\mu\tau} \cdot K_A \cdot K_V \cdot K_{H\beta}$		

Table 30 : Running-in allowance y_α

Material	y_α , in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$\dfrac{160}{\sigma_{H,\,lim}} f_{pt}$	• if 5 m/s < v ≤ 10 mm/s: $y_\alpha \leq 12800 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\alpha \leq 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	0,275 f_{pt}	• if 5 m/s < v ≤ 10 mm/s: $y_\alpha \leq 22$ • if 10 m/s < v: $y_\alpha \leq 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	0,075 f_{pt}	$y_\alpha \leq 3$

Note 1: f_{pt} ισ δεφινεδ ιν Tab 29 ανδ $\sigma_{H,lim}$ is defined in [3.4.10].
Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0,5\ (y_{\alpha 1} + y_{\alpha 2})$

Table 31 : Dynamic factor K_V

Resonance domain	Factor K_V
N ≤ 0,75	$K_V = N\ (C_{V1}\ B_p + C_{V2}\ B_f + C_{V3}) + 1$
N > 1,50	$K_V = C_{V5}\ B_p + C_{V6}\ B_f + C_{V7}$

Note 1:

B_p : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_p = \frac{c' f_{p,\,eff}}{K_A (F_{mt}/b)}$$

with:

c' : Single stiffness, in N/(mm·µm):
$c' = 14\ C_F\ C_b$, with C_F and C_b defined in Tab 28

$f_{\pi,\varepsilon\phi\phi}$: Effective base pitch deviation, in µm:
$f_{\pi,\varepsilon\phi\phi} = f_{\pi\tau} - y_\alpha$
with f_{pt} defined in Tab 29 and y_α defined in Tab 30

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:
$B_f = B_p$

C_{V1} : Factor for pitch deviation effects:
$C_{v1} = 0,32$

C_{V2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V2} = 0,34$
- if $2 < \varepsilon_\gamma$:

$$C_{V2} = \frac{0,57}{\varepsilon_\gamma - 0,3}$$

C_{V3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V3} = 0,23$
- if $2 < \varepsilon_\gamma$:

$$C_{V3} = \frac{0,096}{\varepsilon_\gamma - 1,56}$$

C_{V5} : Factor equal to: $C_{V5} = 0,47$

C_{V6} : Factor:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V6} = 0,47$
- if $2 < \varepsilon_\gamma$:

$$C_{V6} = \frac{0,12}{\varepsilon_\gamma - 1,74}$$

C_{V7} : Factor:

- if $1 < \varepsilon_\gamma \leq 1,5$:
  $C_{V7} = 0,75$
- if $1,5 < \varepsilon_\gamma \leq 2,5$:
  $C_{V7} = 0,125 \sin[\pi\ (\varepsilon_\gamma - 2)] + 0,875$
- if $2,5 < \varepsilon_\gamma$:
  $C_{V7} = 1$

3.4 Calculation of surface durability

3.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H , defined in [3.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [3.4.9].

3.4.2 Contact stress σ_H

The contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{H0} \cdot \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

K_A : Application factor (see [3.3.2])

K_γ : Load sharing factor (see [3.3.3])

K_ς : Dynamic factor (see [3.3.4])

$K_{H\beta}$: Face load distribution factor (see [3.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])

$$\sigma_{H0} = Z_{M-B} \cdot Z_H \cdot Z_E \cdot Z_{LS} \cdot Z_\beta \cdot Z_K \cdot \sqrt{\frac{F_{mt}}{d_{v1} \cdot \ell_{bm}} \cdot \frac{u_v + 1}{u_v}}$$

with:

Z_{M-B} : Mid-zone factor, defined in [3.4.3]

Z_H : Zone factor, defined in [3.4.4]

Z_E : Elasticity factor, defined in [3.4.5]

$Z_{\Lambda\Sigma}$: Load-sharing factor, defined in [3.4.6]

Z_β : Helix angle factor, defined in [3.4.7]

Z_K : Bevel gear ratio factor, defined in [3.4.8].

3.4.3 Mid-zone factor Z_{M-B}

The mid-zone factor Z_{M-B} accounts for the difference of contact pressure between the pitch point and the determinant point of load application.

Z_{M-B} is to be determined as follows:

$$Z_{M-B} = \frac{\tan\alpha_{vt}}{\sqrt{\left[\sqrt{\frac{d_{va1}^2}{d_{vb1}^2}} - 1 - \left(F_1 \cdot \frac{\pi}{Z_{v1}}\right)\right] \cdot \left[\sqrt{\frac{d_{va2}^2}{d_{vb2}^2}} - 1 - \left(F_2 \cdot \frac{\pi}{z_{v2}}\right)\right]}}$$

where F_1 and F_2 are defined according to the following conditions:

- if $0 \le \varepsilon_{v\beta} < 1$:

  $F_1 = 2 + (\varepsilon_{v\alpha} - 2) \cdot \varepsilon_{v\beta}$

  $F_2 = 2\ \varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha}) \cdot \varepsilon_{v\beta}$

- if $\varepsilon_{v\beta} \ge 1$:

  $F_1 = \varepsilon_{v\alpha}$

  $F_2 = \varepsilon_{v\alpha}$

3.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point.

Z_H is to be determined as follows:

$$Z_H = 2 \cdot \sqrt{\frac{\cos\beta_{vb}}{\sin(2 \cdot \alpha_{vt})}}$$

3.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

The values of Z_E to be used are given in [2.4.5].

3.4.6 Load-sharing factor Z_{LS}

The load-sharing factor Z_{LS} accounts for load sharing between two or more pairs of teeth.

Z_{LS} is to be determined as follows:

- if $\varepsilon_{v\gamma} > 2$ and $\varepsilon_{v\beta} > 1$:

$$Z_{LS} = \left\{1 + 2\left[1 - \left(\frac{2}{\varepsilon_{v\gamma}}\right)^{1,5}\right] \cdot \sqrt{1 - \frac{4}{\varepsilon_{v\gamma}^2}}\right\}^{-0,5}$$

- if $\varepsilon_{v\gamma} \leq 2$:

  $Z_{LS} = 1$

- otherwise, an alternative calculation should be supplied and will be given special consideration by the Society.

3.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact.

Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos \beta_m}}$$

3.4.8 Bevel gear factor Z_K

The bevel gear factor Z_K is an empirical factor which accounts for the difference between bevel and cylindrical gears loading.

Z_K is to be determined as follows:

$Z_K = 0,8$

3.4.9 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP} , in N/mm², is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,\lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [3.4.10]

Z_{NT} : Life factor for contact stress, defined in [3.4.11]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [3.4.12]

Z_Ω : Hardness ratio factor, defined in [3.4.13]

Z_Ξ : Size factor for contact stress, defined in [3.4.14]

Σ_H : Safety factor for contact stress, defined in [3.4.15].

3.4.10 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$, in N/mm², is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given in [2.4.9] in relation to the type of steel employed and the heat treatment performed.

3.4.11 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given in Tab 17 for information.

The value of Z_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.4.12 Lubrication factor Z_L , speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined according to the formulae of [2.4.11], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculation of Z_V

ρ_{red} : Relative radius of curvature, in mm:

$$\rho_{red} = \frac{a_v \cdot \sin \alpha_{vt}}{\cos \beta_{vb}} \cdot \frac{u_v}{(1 + u_v)^2}$$

3.4.13 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability. This factor is to be determined according to the formulae of [2.4.12], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculations

ρ_{red} : Relative radius of curvature, in mm, as defined in [3.4.12]

υ_ϖ : Virtual reduction ratio. It is to replace u in the calculations.

3.4.14 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value Z_X to be used will be given special consideration by the Society depending on the material.

3.4.15 Safety factor for contact stress S_H

The values to be adopted for the safety factor for contact stress S_H are given in Tab 18.

3.5 Calculation of tooth bending strength

3.5.1 General

The criterion for tooth root bending stress is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F , defined in [3.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [3.5.8].

3.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_{mt}}{b \cdot m_{mn}} \cdot Y_{Fa} \cdot Y_{Sa} \cdot Y_\varepsilon \cdot Y_{LS} \cdot Y_K \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_{Fa} : Tooth form factor, defined in [3.5.3]

Y_{Sa} : Stress correction factor, defined in [3.5.4]

Y_ε : Contact ratio factor, defined in [3.5.5]

Y_{LS} : Load sharing factor, defined in [3.5.6]

Y_K : Bevel gear factor, defined in [3.5.7]

K_A : Application factor (see [3.3.2])

K_γ : Load sharing factor (see [3.3.3])

K_V : Dynamic factor (see [3.3.4])

$K_{F\beta}$: Face load distribution factor (see [3.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [3.3.6]).

When a shot-peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

3.5.3 Tooth form factor Y_{Fa}

The tooth form factor Y_{Fa} takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact of the virtual cylindrical gears in normal section.

Y_{Fa} is to be determined separately for the pinion and for the wheel, using the following formula:

$$Y_{Fa} = \frac{6 \cdot \frac{h_{Fa}}{m_{mn}} \cdot \cos\alpha_{Fan}}{\left(\frac{S_{Fn}}{m_{mn}}\right)^2 \cdot \cos\alpha_n}$$

where:

h_{Fa} : Bending moment arm, in mm:

$$\frac{h_{Fa}}{m_{mn}} = \frac{1}{2}\left[(\cos\gamma_a - \sin\gamma_a \cdot \tan\alpha_{Fan}) \cdot \frac{d_{van}}{m_{mn}} - z_{vn} \cdot \cos\left(\frac{\pi}{3} - \theta\right) - \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

$$\frac{s_{Fn}}{m_{mn}} = z_{vn} \cdot \sin\left(\frac{\pi}{3} - \theta\right) + \sqrt{3} \cdot \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)$$

G : Parameter defined by:

$$G = \frac{\rho_{a0}}{m_{mn}} - \frac{h_{fP}}{m_{mn}} + x_h$$

θ : Parameter defined by:

$$\theta = \frac{2 \cdot G}{z_{vn}} \cdot \tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by:

$$H = \frac{2}{z_{vn}} \cdot \left(\frac{\pi}{2} - \frac{E}{m_{mn}}\right) - \frac{\pi}{3}$$

E : Parameter defined by:

$$E = \left(\frac{\pi}{4} - x_s\right) \cdot m_{mn} - h_{fP} \cdot \tan\alpha_n$$

$$+ \frac{s_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fan} : Load direction angle:

$\alpha_{Fan} = \alpha_{an} - \gamma_a$

γ_a : Parameter defined by:

$$\gamma_a = \frac{0,5 \cdot \pi + 2(\tan\alpha_n \cdot x_h + x_s)}{z_{vn}} + \mathrm{inv}\alpha_n - \mathrm{inv}\alpha_{an}$$

with inv, involute function, equal to:

$\mathrm{inv}\ \alpha = \tau\alpha\nu\ \alpha - \alpha$

α_{an} : Form factor pressure angle:

$$\cos\alpha_{an} = \frac{d_{vbn}}{d_{van}}$$

3.5.4 Stress correction factor Y_{Sa}

The stress correction factor Y_{Sa} is used to convert the nominal bending stress to local tooth root stress.

Y_{Sa} is to be determined as follows:

$$Y_{Sa} = (1,2 + 0,13 L_a) \cdot q_s^{\frac{1}{1,21 + (2,3)/L_a}}$$

where:

$$L_a = \frac{s_{Fn}}{h_{Fa}}$$

with s_{Fn} and h_{Fa} defined in [3.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [3.5.3]

Note 1: The notch parameter should be within the range:

$1 \le q_s < 8$

ρ_F : Fillet radius at contact point of 30° tangent, in mm:

$$\frac{\rho_F}{m_{mn}} = \frac{\rho_{a0}}{m_{mn}} + \frac{2G^2}{\cos\theta \cdot (z_{vn} \cdot \cos^2\theta - 2G)}$$

3.5.5 Contact ratio factor Y_ε

The contact ratio factor Y_ε converts the load application at the tooth tip to the decisive point of load application.

Y_ε is to be determined as follows:

- if $\varepsilon_{v\beta} \le 1$:

$$Y_\varepsilon = 0,25 + \frac{0,75}{\varepsilon_{v\alpha}} - \varepsilon_{v\beta} \cdot \left(\frac{0,75}{\varepsilon_{v\alpha}} - 0,375\right)$$

- if $\varepsilon_{v\beta} > 1$:

  $Y_\varepsilon = 0{,}625$

Note 1: A minimum of 0,625 should always be taken for Y_ε.

3.5.6 Load sharing factor Y_{LS}

The load sharing factor Y_{LS} accounts for load sharing between two or more pairs of teeth.

Y_{LS} is to be determined as follows:

$$Y_{LS} = Z_{LS}^2$$

3.5.7 Bevel gear factor Y_K

The bevel gear factor Y_K accounts for the difference between bevel and cylindrical gears loading.

Y_K is to be determined as follows:

$$Y_K = \left(\frac{1}{2} + \frac{\ell'_{bm}}{2b}\right)^2 \cdot \frac{b}{\ell'_{bm}}$$

3.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE} : Endurance limit for tooth root bending stress, defined in [3.5.9]

Ψ_{δ} : Design factor, defined in [3.5.10]

Ψ_{NT} : Life factor for tooth root bending stress, defined in [3.5.11]

$\Psi_{\delta relT}$: Relative notch sensitivity factor, defined in [3.5.12]

$\Psi_{P\rho\varepsilon IT}$: Relative surface factor, defined in [3.5.13]

Ψ_{Ξ} : Size factor for tooth root bending stress, defined in [3.5.14]

Σ_{Φ} : Safety factor for tooth root bending stress, defined in [3.5.15].

3.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given in [2.5.9]] in relation to the type of steel employed and the heat treatment performed.

3.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit pre-stressing on the tooth root strength.

Y_d is defined in [2.5.10].

3.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.5.12 Relative notch sensitivity factor $\Psi_{\delta relT}$

The relative notch sensitivity factor $\Psi_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$\Psi_{\delta relT}$ is to be determined according to [2.5.12].

3.5.13 Relative surface factor $\Psi_{P\rho\varepsilon IT}$

The relative surface factor $\Psi_{P\rho\varepsilon IT}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $\Psi_{P\rho\varepsilon IT}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

3.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of normal module m_{mn}.

3.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

3.6 Calculation of scuffing resistance

3.6.1 General

The following calculations are requested for equipment running in supercritical domain i.e. when N > 1,5 (see [3.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$(\Theta_{B,Max} - \Theta_{o\iota\lambda}) \leq 0{,}8\ (\Theta_{\sigma} - \Theta_{o\iota\lambda})$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [3.6.2]

$\Theta_{o\iota\lambda}$: Oil temperature, in °C

Θ_{Σ} : Scuffing temperature, in °C, defined in [3.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$(\Theta_{\sigma} - \Theta_{B,Max}) \geq 30°C$

Other methods of determination of the scuffing resistance could be accepted by the Society.

3.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$\Theta_{B,Max} = \Theta_{Mi} + \Theta_{fl,Max}$

where:

$\Theta_{M\iota}$: Interfacial bulk temperature, in °C, defined in [3.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [3.6.3].

The flash temperature is to be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

3.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v_{mt}^{0,5}}{r_m^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [3.6.4]

Ξ_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [3.6.5]

Ξ_J : Approach factor, defined in [3.6.6]

Ξ_G : Geometry factor, defined in [3.6.7]

Ξ_Γ : Load sharing factor, defined in [3.6.8]]

ω_{Bt} : Transverse unit load, in N/mm, defined in [3.6.9].

3.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0,06 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}}\right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm (see [2.6.9])

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\ v_{mt} \sin \alpha_{vt}$

with the maximum value of v_{mt} equal to 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u \cdot \tan\delta_1 \cdot \tan\delta_2}{\tan\delta_1 + u \cdot \tan\delta_2} \cdot r_m \cdot \sin\alpha_{vt}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2}\right)^{0,25}$$

3.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel.

The values to be adopted for X_M are given in [2.6.5] in relation to the gear material characteristics.

3.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film.

The values to be adopted for X_J are given in [2.6.6] in relation to the gear material characteristics.

3.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following formula:

$$X_G = 0,51 X_{\alpha\beta}\left(\frac{1}{\tan\delta_1} + \frac{1}{\tan\delta_2}\right)^{0,25} \frac{\left|(1+\Gamma)^{0,5} - \left(1+\Gamma\frac{\tan\delta_1}{\tan\delta_2}\right)^{0,5}\right|}{(1+\Gamma)^{0,25}\cdot\left(1-\Gamma\frac{\tan\delta_1}{\tan\delta_2}\right)^{0,25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1,22\,(\sin\alpha_{vt})^{0,25}\cdot(\cos\alpha_{vt})^{-0,5}\cdot(\cos\beta_{vb})^{0,25}$

Γ : Parameter of the point on the line of action, defined in Tab 32.

3.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

The values to be adopted for X_Γ are given in [2.6.8].

The parameter of the line of action Γ to be used is given in Tab 32.

Table 32 : Parameter Γ on the line of action

Point			Γ
A	:	Lower end point of the path of contact	$\Gamma_A = -\frac{\tan\delta_2}{\tan\delta_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right)$
AU	:	Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0,2\sin\beta_{vb}$
AB	:	Intermediate point between A and B	$\Gamma_{AB} = 0,5\,(\Gamma_A + \Gamma_B)$
B	:	Lower point of single pair tooth contact	$\Gamma_B = \frac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1 - \frac{2\pi\cdot\cos\delta_1}{z_1\tan\alpha_{vt}}$
C	:	Point with parameter equal to 0	$\Gamma_C = 0$
M	:	Intermediate point between A and E	$\Gamma_M = 0,5\,(\Gamma_A + \Gamma_E)$
D	:	Upper point of single pair tooth contact	$\Gamma_D = -\frac{\tan\delta_2}{\tan\delta_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right) + \frac{2\pi\cdot\cos\delta_1}{z_1\tan\alpha_{vt}}$
DE	:	Intermediate point between D and E	$\Gamma_{DE} = 0,5\,(\Gamma_D + \Gamma_E)$
EU	:	Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0,2\sin\beta_{vb}$
E	:	Upper end point of the path of contact	$\Gamma_E = \frac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1$

Note 1:

$\alpha_{\alpha i}$: Transverse tip pressure angle of pinion and wheel, in rad:

$$\cos\alpha_{ai} = \frac{\cos\alpha_{vt}}{1 + 2h_{f0i}\cdot(\cos\delta_i)/d_{mi}}$$

3.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A\cdot K_V\cdot K_{H\beta}\cdot K_{H\alpha}\cdot K_\gamma\cdot\frac{F_{mt}}{b}$$

where:

K_A : Application factor (see [3.3.2])

K_V : Dynamic factor (see [3.3.4])
$K_{H\beta}$: Face load distribution factor (see [3.3.5])
$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])
K_γ : Load sharing factor (see [3.3.3]).

3.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. An estimation of Θ_{Mi} , given in [2.6.10], could be used in general configurations.

3.6.11 Scuffing temperature Θ_σ

The scuffing temperature Θ_S may be determined according to the following formula:

$\Theta_S = 80 + (0{,}85 + 1{,}4\ X_W) \cdot X_L \cdot (S_{FZG} - 1)^2$

where:

X_W : Structural factor given in Tab 27
X_L : Lubricant factor given in Tab 25
S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

4 Design and construction - except tooth load capacity

4.1 Materials

4.1.1 General

a) Forged, rolled and cast materials used in the manufacturing of shafts, couplings, pinions and wheels are to comply with the requirements of NR216 Materials and Welding.
b) Materials other than steels will be given special consideration by the Society.

4.1.2 Steels for pinions and wheel rims

a) Steels intended for pinions and wheels are to be selected considering their compatibility in service. In particular, for through-hardened pinion / wheel pairs, the hardness of the pinion teeth is to exceed that of the corresponding wheel. For this purpose, the minimum tensile strength of the pinion material is to exceed that of the wheel by at least 15%.
b) The minimum tensile strength of the core is not to be less than:
   - 750 N/mm^2 for case-hardened teeth
   - 800 N/mm^2 for induction-hardened or nitrided teeth.

4.2 Teeth

4.2.1 Manufacturing accuracy

a) The teeth design flank tolerance class of propulsion machinery gearing, as defined by ISO 1328-1:2013, is not to exceed 4. A lower tolerance class (i.e. ISO 1328-1:2013 class higher than 4) may be accepted for auxiliary machinery gearing and for particular cases of propulsion machinery gearing of auxiliary ships subject to special consideration by the owner.
b) Where the quality class of the gear is indicated by the gear Manufacturer according to another Standard accepted by the Society, the corresponding accuracy of teeth is to be to the satisfaction of the Society.
c) Mean roughness (R_a) of shaved or ground teeth is not to exceed 0,7 µm.
d) Wheels are to be cut by cutters with a method suitable for the expected type and quality. Whenever necessary, the cutting and grinding is to be carried out in a temperature controlled environment.

4.2.2 Tooth root

Teeth are to be well faired and rounded at the root. The fillet radius at the root of the teeth, within a plane normal to the teeth, is to be not less than 0,25 m_n.

Profile-grinding of gear teeth is to be performed in such a way that no notches are left in the fillet.

4.2.3 Tooth tips and ends

a) All sharp edges on the tips and ends of gear teeth are to be removed after cutting and finishing of teeth.
b) Where the ratio b/d exceeds 0,3, the ends of pinion and wheel are to be chamfered to an angle between 45 and 60 degrees. The chamfering depth is to be at least equal to 1,5 m_n.

4.2.4 Surface treatment

a) The hardened layer on surface-hardened gear teeth is to be uniform and extended over the whole tooth flank and fillet.
b) Where the pinions and the toothed portions of the wheels are case-hardened and tempered, the teeth flanks are to be ground while the bottom lands of the teeth remain only case-hardened. The superficial hardness of the case-hardened zone is to be at least equal to 56 C Rockwell units.

c) Where the pinions and the toothed part of the wheel are case hardened, the thickness of the hardened layer after finish grinding is to be at least equal to the following value:

$$T = \sqrt{0,5 \cdot m_n + 1,1} - (0,7)$$

Thickness of the hardened layer for case hardening is the depth, measured normally to the tooth flank surface, where the local hardness falls below the value of 52,5 HRC (550 HV).

d) Where the pinions and the toothed portions of the wheels are nitrided, the hardened layer is to comply with Tab 33.

e) The use of other processes of superficial hardening of the teeth, such as flame hardening, will be given special consideration, in particular as regards the values to be adopted for $\sigma_{H,lim}$ and σ_{FE}.

Table 33 : Characteristics of the hardened layer for nitrided gears

Type of steel	Minimum thickness of hardened layer (mm)**(1)**	Minimum hardness (HV)
Nitriding steel	0,6	500 (at 0,25 mm depth)
Other steels	0,3	450 (surface)
(1) Depth of the hardened layer to core hardness. When the grinding of nitrided teeth is performed, the depth of the hardened layer to be taken into account is the depth after grinding.		

4.3 Wheels and pinions

4.3.1 General

Wheel bodies are to be so designed that radial deflections and distorsions under load are prevented, so as to ensure a satisfactory meshing of teeth.

4.3.2 Welding

a) Where welding is employed for the construction of wheels, the welding procedure is to be submitted to the Society for approval. Welding processes and their qualification are to comply with NR216 Materials and Welding.

b) Stress relieving treatment is to be performed after welding.

c) Examination of the welded joints is to be performed by means of magnetic particle or dye penetrant tests to the satisfaction of the Surveyor. Suitable arrangements are to be made to permit the examination of the internal side of the welded joints.

4.3.3 Shrink-fits

a) The shrink fit assembly of wheel body and shaft is to be designed with a safety factor against slippage of not less than $2,8 \cdot K_a$.

For different type of drives the value to be adopted will be specially considered.

b) The shrink fit assembly of wheel rim and body is to be designed with a safety factor against slippage of not less than 5.

Note 1: The manufacturer is to ensure that the maximum torque transmitted during the clutch engagement does not exceed the nominal torque by more than 20%.

c) The shrink-fit assembly is to take into account the thermal expansion differential between the shrunk-on parts in the service conditions.

4.3.4 Bolting

The bolting assembly of:

- rim and wheel body
- wheel body and shaft,

is to be designed according to Ch 1, Sec 7, [2.5.1].

The nuts are to be suitably locked by means other than welding.

4.4 Shafts and bearings

4.4.1 General

Shafts and their connections, in particular flange couplings and shrink-fits connections, are to comply with the provisions of Ch 1, Sec 7.

4.4.2 Pinion and wheel shafts

The minimum diameter of pinion and gear wheel shafts is not to be less than the value d_S, in mm, given by the following formula:

$$d_S = \left\{\left[\left(10,2 + \frac{28000}{R_{S,min}}\right)T\right]^2 + \left[\frac{170000}{412 + R_{s,min}}M\right]^2\right\}^{\frac{1}{6}} \left(\frac{1}{1 - K_d{}^4}\right)^{\frac{1}{3}}$$

where:

$R_{S,min}$: Minimum yield strength of the shaft material, in N/mm²

T : Nominal torque transmitted by the shaft, in Nm

M : Bending moment on the shaft, in Nm

K_d : Coefficient having the following values:

- for solid shafts: $K_d = 0$
- for hollow shafts, K_d is equal to the ratio of the hole diameter to the outer shaft diameter.

  Where $K_d \le 0{,}3$: $K_d = 0$ may be taken.

Note 1: The values of d_S, T and M refer to the cross-section of the shaft concerned.

Note 2: In correspondence of keyways d_S shall be increased by 10%.

As an alternative to the above given formula, the Society may accept direct strength calculations showing that the equivalent stress represented in a diagram average stress vs. alternate stress falls below the lines defined by the points having coordinates:

$(R_m;0), (0;\sigma_{fa}/1,5)$

and

$(0,8 \cdot R_s;0), (0;0,8 \cdot R_s)$

where σ_{fa} is the pure alternate bending fatigue limit for a survival probability not less than 80%.

4.4.3 Quill shafts

The minimum diameter of quill shafts subject to torque only is not to be less than the value d_{QS}, in mm, given by the following formula:

$$d_{QS} = \left[\left(7{,}65 + \frac{27000}{R_{S,min}}\right) \cdot \frac{T}{1 - K_d^{\,4}}\right]^{\frac{1}{3}}$$

$R_{S,min}$ and K_d being defined in [4.4.2].

4.4.4 Bearings

a) Thrust bearings and their supports are to be so designed as to avoid detrimental deflections under load.

b) Life duration of bearings L_{10h} calculated according to ISO 281-1, is not be less than 40000 hours. Shorter durations may be accepted on the basis of the actual load time distribution, and subject to the agreement of the owner.

4.5 Casings

4.5.1 General

Gear casings are to be of sufficient stiffness such that misalignment, external loads and thermal effects in all service conditions do not adversely affect the overall tooth contact.

4.5.2 Welded casings

a) Carbon content of steels used for the construction of welded casings is to comply with the provisions of NR216 Materials and Welding.

b) The welded joints are to be so arranged that welding and inspection can be performed satisfactorily. They are to be of the full penetration type.

c) Welded casings are to be stress-relieved after welding.

4.5.3 Openings

Access or inspection openings of sufficient size are to be provided to permit the examination of the teeth and the structure of the wheels.

4.6 Lubrication

4.6.1 General

a) Manufacturers are to take care of the following points:
   - reliable lubrication of gear meshes and bearings is ensured:
     - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
     - for all angles stated in Ch 1, Sec 1, [2.4]
   - in multi-propellers plants and a transient black-out, provision is to be made to ensure lubrication of gears likely to be affected by windmilling.

b) Lubrication by means other than oil circulation under pressure will be given special consideration.

4.6.2 Pumps

a) Gears intended for propulsion or other essential services independent gearbox are to be provided with at least 2 lubricating pumps, so arranged as to maintain a sufficient lubrication of the gearbox in the whole speed range in case of failure of one pump. At least one of the pumps is not to be mechanically driven by the gearbox.

One of the two lubricating pumps could be a common one for the two gearboxes if they are located in the same compartment.

b) In the case of gears having a transmitted power not exceeding 375 kW one of the pumps mentioned in a) may be a spare pump ready to be connected to the reduction gear lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

c) Provisions are to be made to maintain a sufficient lubrication of the gearbox in:

- black-out conditions, and
- in any operating conditions mentioned in the ship specification.

4.6.3 Filtration

a) Forced lubrication systems are to be fitted with a device which efficiently filters the oil in the circuit.

b) When fitted to gears intended for propulsion machinery or machinery driving electric propulsion generators, such filters are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

4.7 Control and monitoring

4.7.1 Gears are to be provided with the alarms and safeguards listed in Tab 34.

Table 34 : Reduction gears / reversing gears

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by start	Stop
Lubricating oil temperature		local					
Lubricating oil pressure		local					
	L **(1)**			x			
Oil tank level		local					
(1) May be omitted in case of restricted navigation notation							

5 Installation

5.1 General

5.1.1 Manufacturers and shipyards are to take care directly that stiffness of gear seating and alignment conditions of gears are such as not to adversely affect the overall tooth contact and the bearing loads under all operating conditions of the ship.

5.2 Fitting of gears

5.2.1 Means such as stoppers or fitted bolts are to be arranged in the case of gears subject to propeller thrust. However, where the thrust is transmitted by friction and the relevant safety factor is not less than 2, such means may be omitted.

6 Certification, inspection and testing

6.1 General

6.1.1

a) Inspection and testing of shafts and their connections (flange couplings, hubs, bolts, pins) are to be carried out in accordance with the provisions of Ch 1, Sec 7.

b) For inspection of welded joints of wheels, refer to [4.3.2].

6.2 Workshop inspection and testing

6.2.1 Testing of materials

Chemical composition and mechanical properties are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Chapter 5 for the following items:

- pinions and wheel bodies
- rims
- plates and other elements intended for propulsion gear casings of welded construction.

6.2.2 Testing of pinion and wheel forgings

a) Mechanical tests of pinions and wheels are to be carried out in accordance with:
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.6] for normalised and tempered or quenched and tempered forgings
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.7] for surface-hardened forgings.

b) Non-destructive examination of pinion and wheel forgings is to be performed in accordance with NR216 Materials and Welding, Ch 5, Sec 5, [1.8].

6.2.3 Balancing test

Rotating components, in particular gear wheel and pinion shaft assemblies with the coupling part attached, are to undergo a static balancing test.

Propulsion gear wheels and pinion shaft assemblies having a speed in excess of 150 rpm are also to undergo a dynamic balancing test after finish machining; the residual imbalance shall be as small as possible and anyway, is not exceed the Grade 2,5 according to ISO 1940.

Auxiliary gear wheels and pinion shaft assemblies are also to undergo a dynamic balancing test after finish machining, when

$n^2 \cdot d > 1{,}5 \;.\; 10^9$

the residual imbalance shall not exceed the Grade 2,5 according to ISO 1940.

6.2.4 Verification of cutting accuracy

Examination of the accuracy of tooth cutting is to be performed in the presence of the Surveyor. Records of measurements of errors, tolerances and clearances of teeth are to be submitted at the request of the Surveyor.

6.2.5 Meshing test

a) A tooth meshing test is to be performed in the presence of the Surveyor. This test is to be carried out at a load sufficient to ensure tooth contact, with the journals located in the bearings according to the normal running conditions. Before the test, the tooth surface is to be coated with a thin layer of suitable coloured compound.

b) The results of such test are to demonstrate that the tooth contact is adequately distributed on the length of the teeth. Strong contact marks at the end of the teeth are not acceptable. In case the test is carried out at full load, the contact pattern shall meet with the one requested under Ch 1, Sec 16, Tab 1.

c) In case of helix modification or crowning the tooth meshing test is to be performed before these corrections will be carried out.

d) A permanent record of the tooth contact is to be made for the purpose of subsequent checking of alignment following installation on board.

6.2.6 Hydrostatic tests

a) Hydraulic or pneumatic clutches are to be hydrostatically tested before assembly to 1,5 times the maximum working pressure.

b) Pressure piping, pumps casings, valves and other fittings are to be hydrostatically tested in accordance with the requirements of Ch 1, Sec 10, [19].

Section 7 Main Propulsion Shafting

1 General

1.1 Application

1.1.1 This Section applies to shafts, couplings, clutches and other shafting components transmitting power for main propulsion. In addition, main propulsion machinery components are to comply with the requirements listed in Tab 1.

Table 1 : Rule requirements for main propulsion component

Item		Reference
Power transmission equipment	Diesel engines	Ch 1, Sec 2
	Turbines	Ch 1, Sec 4 Ch 1, Sec 5
	Propellers	Ch 1, Sec 8
	Gear	Ch 1, Sec 6
	Thrusters	Ch 1, Sec 13
Shaft line analysis	Shaft alignment	Ch 1, Sec 7
	Torsional vibration	Ch 1, Sec 9

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 2 for approval.

Plans of power transmitting parts and shaft liners listed in Tab 2 are to include the relevant material specifications.

Table 2 : Documentation to be submitted

No.	Document (drawings, calculations, etc.)
1	Shafting arrangement **(1)**
2	Thrust shaft
3	Intermediate shafts
4	Propeller shaft
5	Shaft liners, relevant manufacture and welding procedures, if any
6	Couplings and coupling bolts
7	Flexible couplings **(2)**
8	Sterntube
9	Details of sterntube glands
10	Oil piping diagram for oil lubricated propeller shaft bearings
11	Shaft alignment calculation, see also [3.3]

(1) This drawing is to show the entire shafting, from the main engine coupling flange to the propeller. The location of the thrust block, and the location and number of shafting bearings (type of material and length) are also to be shown.

(2) The Manufacturer of the elastic coupling is also to submit the following data:
- allowable mean transmitted torque (static) for continuous operation
- maximum allowable shock torque
- maximum allowable speed of rotation
- maximum allowable values for radial, axial and angular misalignment

In addition, when the torsional vibration calculation of main propulsion system is required (see Ch 1, Sec 9), the following data are also to be submitted:
- allowable alternating torque amplitude and power loss for continuous operation, as a function of frequency and/or mean transmitted torque
- static and dynamic stiffness, as a function of frequency and/or mean transmitted torque
- moments of inertia of the primary and secondary halves of the coupling
- damping coefficient or damping capability
- properties of rubber components
- for steel springs of couplings: chemical composition and mechanical properties of steel employed.

2 Design and construction

2.1 Materials

2.1.1 General

The use of other materials or steels having values of tensile strength exceeding the limits given in [2.1.2], [2.1.3] and [2.1.4] will be considered by the Society in each case.

2.1.2 Shaft materials

Where shafts may experience vibratory stresses close permissible stresses for transient operation (see Ch 1, Sec 9), the materials are to have a specified minimum ultimate tensile strength Rm of 500 N/mm^2. Otherwise materials having a specified minimum ultimate tensile strength Rm of 400 N/mm^2 may be used.

For use in the following formulae in this Section, Rm is limited as follows:

- for carbon and carbon manganese steels, Rm is not exceed 760 N/mm^2
- for alloy steels, Rm is not to exceed 800 N/mm^2
- for propeller shafts, Rm is not to exceed 600 N/mm^2 (for carbon, carbon manganese and alloy steels).

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formulae given in this Section unless the Society verifies that the materials exhibit similar fatigue life as conventional steels (see Ch 1, App 4).

2.1.3 Couplings, flexible couplings, hydraulic couplings

Non-solid-forged couplings and stiff parts of elastic couplings subjected to torque are to be of forged or cast steel, or nodular cast iron.

Rotating parts of hydraulic couplings may be of grey cast iron, provided that the peripheral speed does not exceed 40m/s.

2.1.4 Coupling bolts

Coupling bolts are to be of forged, rolled or drawn steel.

In general, the value of the tensile strength of the bolt material R_{mB} is to comply with the following requirements:

- $R_m \leq R_{mB} \leq 1{,}7\ R_m$
- $R_{mB} \leq 1000$ N/mm^2.

2.1.5 Shaft liners

Liners are to be of metallic corrosion resistant material complying with the applicable requirements of NR216 Materials and Welding with the approved specification, if any; in the case of liners fabricated in welded lengths, the material is to be recognised as suitable for welding.

In general, they are to be manufactured from castings.

For small shafts, the use of liners manufactured from pipes instead of castings may be considered.

Where shafts are protected against contact with seawater not by metal liners but by other protective coatings, the coating procedure is to be approved by the Society.

2.1.6 Sterntubes

Sterntubes are to comply with the requirements of Pt B, Ch 8, Sec 2, [6.7].

2.2 Shafts - Scantling

2.2.1 General

The provisions of this sub-article apply to propulsion shafts such as an intermediate and propeller shafts of traditional straight forged design and which are driven by rotating machines such as diesel engines, turbines or electric motors.

For shafts that are integral to equipment, such as for gear boxes, podded drives, electrical motors and/or generators, thrusters, turbines and which in general incorporate particular design features, additional criteria in relation to acceptable dimensions have to be taken into account. For the shafts in such equipment, the provisions of this sub-article apply only to shafts subject mainly to torsion and having traditional design features. Other shafts will be given special consideration by the Society.

2.2.2 Alternative calculation methods

Alternative calculation methods may be considered by the Society. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions.

2.2.3 Shaft diameters

The diameter of intermediate shafts, thrust shafts and propellers shafts is not to be less than that determined from the following formula:

$$d = F \cdot k \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160}\right]^{1/3}$$

where:

d : Minimum required diameter in mm

Q : Factor equal to d_i / d_o , where:

- d_i : Actual diameter of the shaft bore, in mm (to be taken as 0 for solid shafts)
- d_o : Outside diameter of the shaft, in mm.

Note 1: Where $d_i \leq 0,4\ d_o$, Q may be taken as 0.

F : Factor for type of propulsion installation equal to:

- 95 for intermediate and thrusts shafts in turbine installations, diesel installations with hydraulic (slip type) couplings and electric propulsion installations
- 100 for all other diesel installation and all propeller shafts.

k : Factor for the particular shaft design features, see Tab 3

n : Speed of rotation of the shaft, in revolution per minute, corresponding to power P

P : Maximum continuous power of the propulsion machinery for which the classification is requested, in kW

R_m : Specified minimum tensile strength of the shaft material, in N/mm², see [2.1.2].

The diameter of the propeller shaft located forward of the inboard stern tube seal may be gradually reduced to the corresponding diameter required for the intermediate shaft using the minimum specified tensile strength of the propeller shaft in the formula and recognising any limitations given in [2.1.2].

Note 2: Transitions of diameters are to be designed with either a smooth taper or a blending radius equal to the change in diameter.

Table 3 : Values of factor k

For intermediate shafts with						For thrust shafts external to engines		propeller shafts		
straight sections and integral coupling flange **(1)**	shrink fit coupling **(2)**	keyway, tapered connection **(3)(4)**	keyway, cylindrical connection **(3)(4)**	radial hole **(5)**	longitudinal slots **(6)**	on both sides of thrust collar **(1)**	in way of bearing when a roller bearing is used	flange mounted or keyless taper fitted propellers **(7)**	key fitted propellers **(7)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	1,10	1,10	1,10	1,20	1,10	1,10	1,22	1,26	1,15

(1) The fillet radius is to be in accordance with the provisions of [2.5.1].

(2) k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in [2.2.3] Note 2.

(3) At a distance of not less than 0,2 d_o from the end of the keyway the shaft diameter may be reduced to the diameter calculated with k = 1,0.

(4) Keyways are to be in accordance with the provisions of [2.5.5].

(5) Diameter of the radial bore is not to exceed 0,3 d_o.

(6) Subject to limitations as $\ell/d_o < 0,8$ and $d_i/d_o < 0,7$ and $e/d_o > 0,15$, where:

ℓ : slot length in mm

e : slot width in mm

The end rounding of the slot is not to be less than e/2. an edge rounding should preferably be avoided as this increases the stress concentration slightly.

The k value is valid for 1, 2, 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(7) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2,5 times the required diameter.

2.3 Liners

2.3.1 General

Metal liners or other protective coatings approved by the Society are required where propeller shafts are not made of corrosion-resistant material.

Metal liners are generally to be continuous; however, discontinuous liners, i.e. liners consisting of two or more separate lengths, may be accepted by the Society on a case by case basis, provided that:

- they are fitted in way of all supports
- the shaft portion between liners, likely to come into contact with sea water, is protected with a coating of suitable material with characteristics, fitting method and thickness approved by the Society.

2.3.2 Scantling

The thickness of metal liners fitted on propeller shafts or on intermediate shafts inside sterntubes is to be not less than the value t, in mm, given by the following formula:

$$t = \frac{d + 230}{32}$$

where:

d : Actual diameter of the shaft, in mm.

Between the sternbushes, the above thickness t may be reduced by 25%.

The shrinkage induced equivalent stress in the liner is not exceed 70% of liner yield strength; a calculation in this respect is to be submitted.

2.4 Aft bearings

2.4.1 General

The bearings are to be so designed and lubricated as to withstand the continuous operation of the propulsion plant at the minimum rotating speed mentioned in the ship specification.

2.4.2 Oil lubricated aft bearings of antifriction metal

a) The length of the two aft most bearings lined with white metal or other antifriction metal and with oil glands of a type approved by the Society is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above, provided the nominal bearing pressure is not more than 0,8 N/mm², as determined by static bearing reaction calculations taking into account shaft and propeller weight, as exerting solely on the aft bearing, divided by the projected area of the shaft.

   However, the minimum bearing length is to be not less than 1,5 times its actual inner diameter.

2.4.3 Oil lubricated aft bearings of synthetic rubber, reinforced resin or plastic material

a) For bearings of synthetic rubber, reinforced resin or plastic material which are approved by the Society for use as oil lubricated sternbush bearings, the length of the two aft most bearings is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above provided the nominal bearing pressure is not more than 0,6 N/mm², as determined according to [2.4.2], item b).

   However, the minimum length of the bearing is to be not less than 1,5 times its actual inner diameter.

   Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

c) Synthetic materials for application as oil lubricated stern tube bearings are to be of an approved type.

2.4.4 Water lubricated aft bearings

a) The length of the two aft most bearings is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

b) For a bearing of synthetic material, consideration may be given to a bearing length less than 4 times, but in no case less than 2 times, the rule diameter of the shaft in way of the bearing, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

c) Synthetic materials for application as water lubricated stern tube bearings are to be type approved by the Society.

2.4.5 Water circulation system

For water lubricated bearings, means are to be provided to ensure efficient water circulation. In case of open loop systems, the sea water suction is normally to be from a sea chest.

The water grooves on the bearings are to be of ample section such as to ensure efficient water circulation and be scarcely affected by wear-down, particularly for bearings of the plastic type.

The shut-off valve or cock controlling the water supply is to be fitted direct to the stuffing box bulkhead or in way of the water inlet to the sterntube, when this is fitted forward of such bulkhead.

2.5 Couplings

2.5.1 Flange couplings

a) Flange couplings of intermediate and thrust shafts and the flange of the forward coupling of the propeller shaft are to have a thickness not less than 0,2 times the rule diameter of the solid intermediate shaft and not less than the coupling bolt diameter calculated for a tensile strength equal to that of the corresponding shaft.

The fillet radius at the base of solid forged flanges is to be not less than 0,08 times the actual shaft diameter.

The fillet may be formed of multi-radii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0,08 times the actual shaft diameter.

For non-solid forged flange couplings, the above fillet radius is not to cause a stress in the fillet higher than that caused in the solid forged flange as above.

Fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

b) Where the propeller is connected to an integral propeller shaft flange, the thickness of the flange is to be not less than 0,25 times the rule diameter of the aft part of the propeller shaft. The fillet radius at the base of the flange is to be not less than 0,125 times the actual diameter.

The strength of coupling bolts of the propeller boss to the flange is to be equivalent to that of the aft part of the propeller shaft.

c) Non-solid forged flange couplings and associated keys are to be of a strength equivalent to that of the shaft.

They are to be carefully fitted and shrunk on to the shafts, and the connection is to be such as to reliably resist the vibratory torque and astern pull.

d) For couplings of intermediate and thrust shafts and for the forward coupling of the propeller shaft having all fitted coupling bolts, the coupling bolt diameter in way of the joining faces of flanges is not to be less than the value d_B, in mm, given by the following formula:

$$d_B = 0{,}65 \cdot \left[\frac{d^3 \cdot (R_m + 160)}{n_B \cdot D_C \cdot R_{mB}}\right]^{0{,}5}$$

where:

d	:	Rule diameter of solid intermediate shaft, in mm
n_B	:	Number of fitted coupling bolts
D_C	:	Pitch circle diameter of coupling bolts, in mm
R_m	:	Value of the minimum tensile strength of intermediate shaft material taken for calculation of d, in N/mm^2
R_{mB}	:	Value of the minimum tensile strength of coupling bolt material, in N/mm^2. Where, in compliance with [2.1.1], the use of a steel having R_{mB} in excess of the limits specified in [2.1.4] is allowed for coupling bolts, the value of R_{mB} to be introduced in the formula is not exceed the above limits.

e) Flange couplings with non-fitted coupling bolts may be accepted on the basis of the calculation of bolt tightening, bolt stress due to tightening, and assembly instructions.

To this end, the torque based on friction between the mating surfaces of flanges is not to be less than 2,8 times the transmitted torque, assuming a friction coefficient for steel on steel of 0,18. In addition, the bolt stress due to tightening in way of the minimum cross-section is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2 proof stress ($R_{p\,0,2}$), of the bolt material.

Transmitted torque has the following meanings:

- For main propulsion systems powered by diesel engines fitted with slip type or high elasticity couplings, by turbines or by electric motors: the mean transmitted torque corresponding to the maximum continuous power P and the relevant speed of rotation n, as defined under [2.2.3].
- For main propulsion systems powered by diesel engines fitted with couplings other than those mentioned in (a): the mean torque above increased by 20% or by the torque due to torsional vibrations, whichever is the greater.

The value 2,8 above may be reduced to 2,5 in the following cases:

- ships having two or more main propulsion shafts
- when the transmitted torque is obtained, for the whole functioning rotational speed range, as the sum of the nominal torque and the alternate torque due to the torsional vibrations, calculated as required in Ch 1, Sec 9.

2.5.2 Shrunk couplings

Non-integral couplings which are shrunk on the shaft by means of the oil pressure injection method or by other means may be accepted on the basis of the calculation of shrinking and induced stresses, and assembly instructions.

To this end, the force due to friction between the mating surfaces is not to be less than 2,8 times the total force due to the transmitted torque and thrust.

The value of 2,8 above may be reduced to 2,5 in the cases specified under [2.5.1], item e)

The values of 0,14 and 0,18 will be taken for the friction coefficient in the case of shrinking under oil pressure and dry shrink fitting, respectively.

In addition, the equivalent stress due to shrinkage determined by means of the von Mises-Hencky criterion in the points of maximum stress of the coupling is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the material of the part concerned.

The transmitted torque is that defined under item e) of [2.5.1].

For the determination of the thrust, see Ch 1, Sec 8, [3.1.2].

2.5.3 Other couplings

Types of couplings other than those mentioned in [2.5.1] and [2.5.2] above will be specially considered by the Society.

2.5.4 Flexible couplings

a) The scantlings of stiff parts of flexible couplings subjected to torque are to be in compliance with the requirements of Article [2].

b) For flexible components, the limits specified by the Manufacturer relevant to static and dynamic torque, speed of rotation and dissipated power are not to be exceeded.

c) Where all the engine power is transmitted through one flexible component only (ships with one propulsion engine and one shafting only), the flexible coupling is to be fitted with a torsional limit device or other suitable means to lock the coupling should the flexible component break.

   In stiff transmission conditions with the above locking device, a sufficiently wide speed range is to be provided, free from excessive torsional vibrations, such as to enable safe navigation and steering of the ship. As an alternative, a spare flexible element is to be provided on board.

2.5.5 Propeller shaft keys and keyways

a) Keyed connections are in general not to be used in installations with a barred speed range.

b) Keyways

   Keyways on the propeller shaft cone are to comply with the following requirements (see Fig 1).

   Keyways are to have well rounded corners, with the forward end faired and preferably spooned, so as to minimize notch effects and stress concentrations.

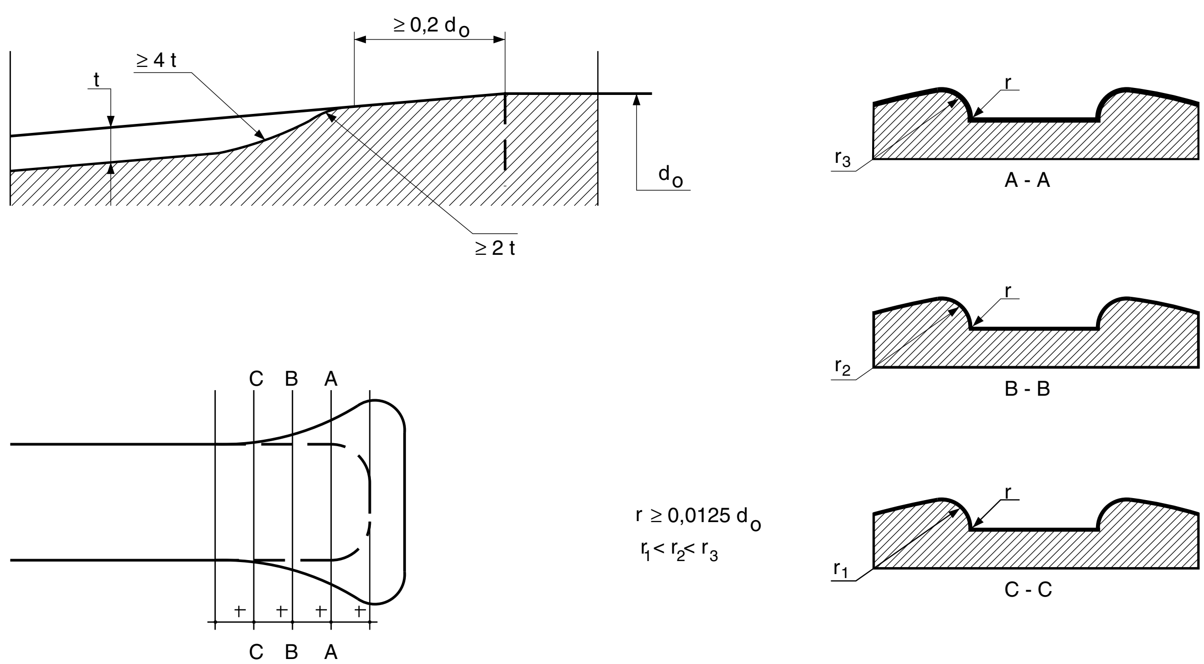
   The fillet radius at the bottom of the keyway is to be not less than 1,25% of the actual propeller shaft diameter at the large end of the cone.

   The distance from the large end of the propeller shaft cone to the forward end of the key is to be not less than 20% of the actual propeller shaft diameter in way of the large end of the cone.

   Key securing screws are not to be located within the first one-third of the cone length from its large end; the edges of the holes are to be carefully faired.

Note 1: Different scantlings may be accepted, provided that at least the same reduction in stress concentration is ensured.

Figure 1 : Details of forward end of propeller shaft keyway



c) Keys

The sectional area of the key subject to shear stress is to be not less than the value A, in mm², given by the following formula:

$$A = 0,4 \cdot \frac{d^3}{d_{PM}}$$

where:

d : Rule diameter, in mm, of the intermediate shaft calculated in compliance with the requirements of [2.2.3], assuming:

R_m = 400 N/mm²

d_{PM} : Actual diameter of propeller shaft at mid-length of the key, in mm.

The edges of the key are to be rounded.

2.6 Design of oil control systems for clutches

2.6.1 Separate oil systems intended for the control of clutches are to include at least two power pumps, of such a capacity as to maintain normal control with any one pump out of action.

2.6.2 In the case of propulsion plants comprising:

- more than one shaft line with the clutches fitted with their own control system, or
- one engine with an output not exceeding 220 kW

one of the pumps mentioned in [2.6.1] may be a spare pump ready to be connected to the oil control system, provided disassembling and reassembling operations can be carried out on board in a short time.

2.6.3 However, when the propulsion plant comprises one or more engines, each with an output not exceeding 220 kW, the standby or spare pump may be omitted for the clutches provided that they are so designed as to be fixed mechanically in the "clutched" position and that the capacity of the starting means ensures the number of starts required in such conditions.

2.7 Monitoring

2.7.1 General

In addition to those given in this item, the requirements of Part C, Chapter 3 apply.

2.7.2 Propeller shaft monitoring

For the assignment of the propeller shaft monitoring system notation, see Pt E, Ch 5, Sec 2.

2.7.3 Indicators

The local indicators for main propulsion shafting to be installed on ships of 500 gross tonnage and upwards without automation notations are given in Tab 4. For monitoring of engines, turbines, gears, controllable pitch propellers and thrusters, see Ch 1, Sec 2, Ch 1, Sec 4, Ch 1, Sec 6, Ch 1, Sec 8 and Ch 1, Sec 13, respectively.

The indicators listed in Tab 4 are to be fitted at a normally attended position.

Table 4 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Temperature of each shaft thrust bearing (non applicable for ball or roller bearings)	H		X				
Stern tube bush oil gravity tank level	L						
Clutches lubricating oil temperature	H		X				
Clutches oil tank level	L						

3 Arrangement and installation

3.1 General

3.1.1 The installation is to be carried out according to the instructions of the component Manufacturer or approved documents, when required.

3.1.2 The installation of sterntubes and/or associated non-shrunk bearings is subject to approval of procedures and materials used.

3.1.3 The joints between liner parts are not to be located in way of supports and sealing glands.

Metal liners are to be shrunk on to the shafts by pre-heating or forced on by hydraulic pressure with adequate interference; dowels, screws or other means of securing the liners to the shafts are not acceptable.

3.1.4 When shaft line is crossing bulkheads, crossing devices are to be fitted enabling to keep characteristics of bulkhead regarding watertightness and fire integrity with a motionless shaft line. Design of these devices is to be submitted to the Society.

Fire integrity of the crossing may be achieved by fitting of local water spraying system on each side of the bulkhead.

Automatised systems are to be provided with additional manual control.

Controls for systems involved in achieving watertightness and fire integrity are to be operable from outside the impacted compartments.

3.2 Protection of propeller shaft against corrosion

3.2.1 The propeller shaft surface between the propeller and the sterntube, and in way of propeller nut, is to be suitably protected in order to prevent any entry of sea water, unless the shaft is made of austenitic stainless steel.

3.3 Shaft alignment

3.3.1 General

Shaft alignment procedures are to be submitted for review in the following cases:

a) Propulsion shafting installations, where the shaft diameter is 350 mm or greater in way of the aftermost stern tube bearing.

b) Propulsion shafting installations, incorporating two or more engines.

c) Propulsion shafting installations, with one or even no shaft line bearing, inboard of the forward stern tube bearing, where the shaft diameter is 200 mm or greater in way of the aftermost stern tube bearing.

d) Propulsion shafting installations, incorporating power take-off or power take-in units.

e) Propulsion shafting installations, where a slope boring should be introduced at the aft stern tube bearing.

f) Propulsion shafting installations, with bearings with offsets from a reference line.

g) Propulsion shafting installations with turbines.

The Society may also require the above calculation in the case of special arrangements.

3.3.2 Shaft alignment calculations

a) Scope of the calculations

   The shaft alignment calculations are to be carried out in the following conditions:

   1) alignment conditions during the shafting installation (ship in dry dock or afloat with propeller partly immersed)

   2) cold, static, afloat conditions

   3) hot, static, afloat conditions

   4) hot, running conditions.

Note 1: Vertical and horizontal calculations are to carried out, as deemed relevant.

b) Information to be submitted

   The shaft alignment calculation report should contain the following information:

   1) Description of the shaftline model:

      - length, diameters and density of material for each shaft
      - definition of the reference line
      - longitudinal, vertical and horizontal position of the bearing with respect to the reference line
      - bearings characteristics: material, length, clearance.

2) Input parameters
   - hydrodynamic propeller loads (horizontal and vertical forces and moments)
   - weight and buoyancy effect of the propeller, depending on the propeller immersion corresponding to the different loading cases of the ship
   - engine power and rotational speed of the propeller (for calculations in running conditions)
   - machining data of aft bush slope boring
   - for slow speed engines, equivalent model of the crankshaft, with indication of the input loads
   - for geared installation, gear tooth forces and moments
   - thermal expansion of the gearbox or of the main engine between cold and hot conditions
   - jack-up location.
3) Limits
   - limits specified by engine or gearbox manufacturer (such as allowable bearing loads, allowable moments and forces at the shaft couplings)
   - allowable loads specified by bearing manufacturer.
4) Results
   - bearings influence coefficients table
   - expected bearing reactions, for the different calculation conditions
   - expected shaft deflections, shear forces and bending moments alongside the shaftline, for the different calculation conditions
   - gap and sag values (depending on the alignment method)
   - jack-up correction factors.

c) Acceptability criteria for the calculations

The results of the shaft alignment calculations are to comply with the following acceptability criteria:
- relative slope between propeller shaft and aftermost boring axis is not to exceed 0,3 mm/m
- all bearings are to remain loaded
- loads on intermediate shaft bearings are not to exceed 80% of the maximum permissible load specified by the manufacturer
- stern tube bearing loads are not to exceed the limits stated in [2.4].

Note 2: Relative slope between propeller shaft and aftermost boring axis exceeding 0,3mm/m may be accepted according to the bearing manufacturer's specification provided it is also demonstrated that a higher slope is not detrimental to the lubrication.

3.3.3 Shaft alignment procedure

The shaft alignment procedure is to be submitted for review and is to be consistent with the shaft alignment calculations.

The shaft alignment procedure should include at least the following:
- Ship conditions in which the alignment is to be carried out (drafts, propeller immersion, engine room temperature)
- Method used for establishing the reference line (using laser or optical instruments or piano wire)
- Description of the different steps of the shafting installation:
  - bearing slope boring
  - setting of the bearing offset and installation of the temporary shaft support (where relevant) in accordance with the results of the shaft alignment calculation
  - flange coupling parameter setting (gap and sag)
  - bearing load test (jack-up test).

3.3.4 Verification of the alignment procedure

The purpose of the verification procedure is to ensure that the alignment measurements comply with the calculated values. The shaft alignment verification procedure is described in Ch 1, Sec 16, [3.7.1].

The shaft alignment verification is to be carried out by the shipyard in presence of the Surveyor and submitted to the Society.

The criteria for acceptability of the alignment conditions include the following:
- the position of the two aftermost bearings should not differ from the specified offsets by more than ± 0,1 mm.
- gap and sag values should not differ from the calculated values by more than ± 0,1 mm.
- bearing loads should not differ from the calculated values by more than ± 20%.

The tolerance values given in the above list are guidance values provided to designers and shipyards.

4 Material tests, workshop inspection and testing, certification

4.1 Material and non-destructive tests, workshop inspections and testing

4.1.1 Material tests

Shafting components are to be tested in accordance with Tab 5 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the Manufacturer and the Surveyor, where experience shows defects are most likely to occur.

Ultrasonic testing requires the Manufacturer’s signed certificate.

4.1.2 Hydrostatic tests

Parts of hydraulic couplings, clutches of hydraulic reverse gears and control units, hubs and hydraulic cylinders of controllable pitch propellers, including piping systems and associated fittings, are to be hydrostatically tested to 1,5 times the maximum working pressure.

Sterntubes, when machine-finished, and propeller shaft liners, when machine-finished on the inside and with an overthickness not exceeding 3 mm on the outside, are to be hydrostatically tested to 0,2 N/mm^2.

4.2 Certification

4.2.1 Testing certification

Society’s certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in items 1 to 5 of Tab 5.

Works’ certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for hydrostatic tests of components indicated in [4.1.2] and for material and non-destructive tests of components in items of Tab 5 other than those for which Society’s certificates (C) are required.

Table 5 : Material and non-destructive tests

Shafting component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Coupling (separate from shafts)	all	all	all
2) Propeller shafts	all	all	all
3) Intermediate shafts	all	all	all
4) Thrust shafts	all	all	all
5) Cardan shafts (flanges, crosses, shafts, yokes)	all	all	all
6) Sterntubes	all	–	–
7) Sterntube bushes and other shaft bearings	all	–	–
8) Shaft liners	all	all	–
9) Coupling bolts or studs	all	if diameter ≥ 40 mm	–
10) Flexible couplings (metallic parts only)	all	–	–
11) Thrust sliding-blocks (frame only)	all	–	–

Section 8 Propellers

1 General

1.1 Application

1.1.1 Propulsion propellers

The requirements of this Section apply to propellers of any size and type intended for propulsion. They include fixed and controllable pitch propellers, including those ducted in fixed nozzles.

1.1.2 Exclusions

The requirements of this Section do not apply to propellers and impellers in rotating or bow and stern thrusters, which are covered in Ch 1, Sec 13.

1.2 Definitions

1.2.1 Solid propeller

A solid propeller is a propeller (including hub and blades) cast in one piece.

1.2.2 Built-up propeller

A built-up propeller is a propeller cast in more than one piece. In general, built up propellers have the blades cast separately and fixed to the hub by a system of bolts and studs.

1.2.3 Controllable pitch propellers

Controllable pitch propellers are built-up propellers which include in the hub a mechanism to rotate the blades in order to have the possibility of controlling the propeller pitch in different service conditions.

1.2.4 Nozzle

A nozzle is a circular structural casing enclosing the propeller.

1.2.5 Ducted propeller

A ducted propeller is a propeller installed in a nozzle.

1.2.6 Geometry of propeller

For all the geometrical definitions of propeller, see Fig 1.

1.2.7 Blade areas and area ratio

- The projected blade area A_P is the projection of the blade area in the direction of the propeller shaft.
- The developed blade area A_D is the area enclosed by the connection line between the end points of the cylindrical profile sections turned in the propeller plane.
- The expanded blade area A_E is the area enclosed by the connection line between the end points of the developed and additionally straightened sections.

A_O : Disc area calculated by means of the propeller diameter

B : Developed area ratio equal to: $B = A_D / A_O$.

1.2.8 Rake and rake angle

- The rake h is the horizontal distance between the line connecting the blade tip to the blade root and the vertical line crossing the propeller axis in the same point where the prolongation of the first line crosses it, taken in correspondence of the blade tip. Aft rakes are considered positive, fore rakes are considered negative.
- The rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles.

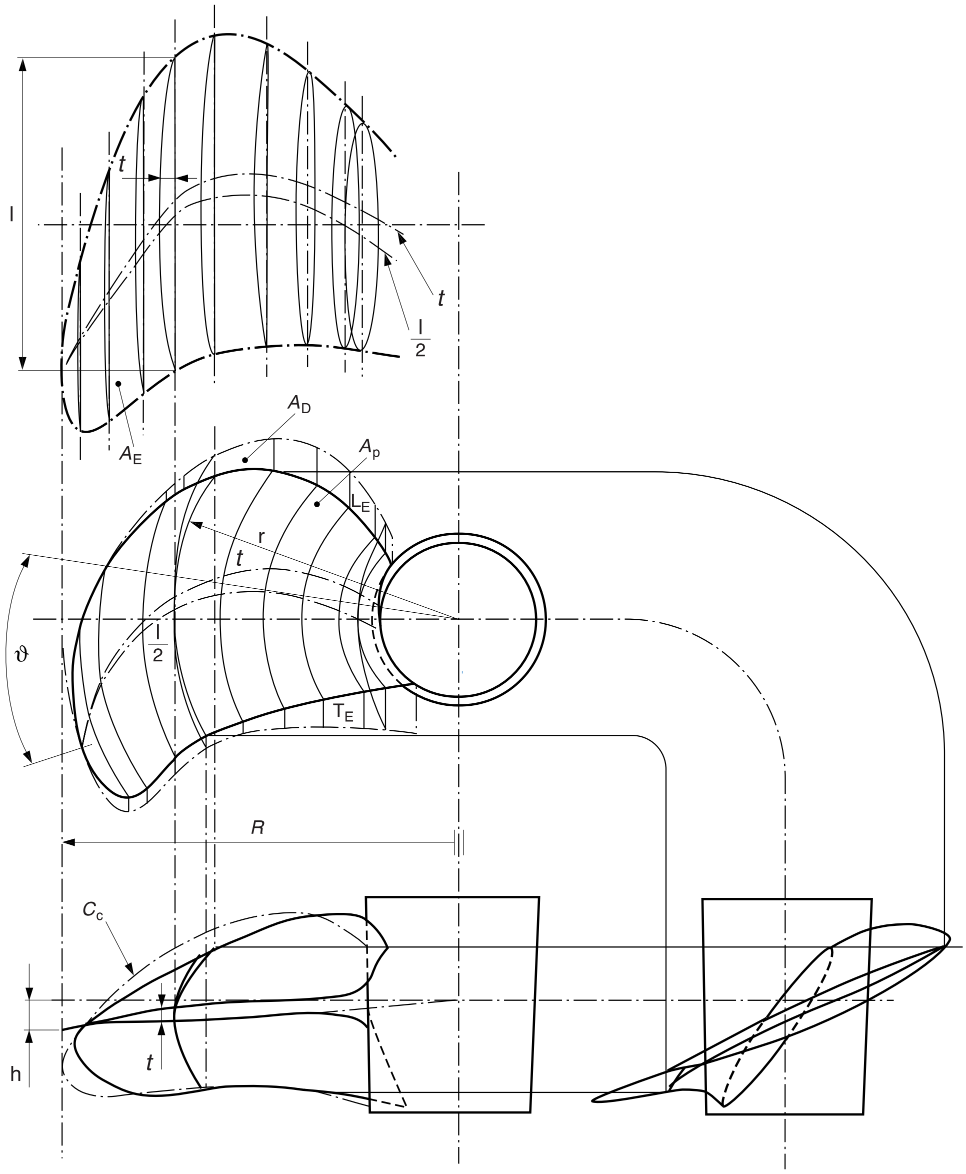
1.2.9 Skew angle at tip of blade

The skew angle ϑ at the tip of blade is the angle on the projected blade plane between a line starting at the centre of the propeller axis and tangent to the blade midchord line and a line also starting at the centre of the propeller axis and passing at the outer end of this midchord line as measured.

1.2.10 Skewed propellers

The skewed propellers are propellers whose blades have a skew angle other than 0.

Figure 1 : Description of propeller



1.2.11 Highly skewed propellers and very highly skewed propellers

The highly skewed propellers are propellers having blades with skew angle between 25° and 50°. The very highly skewed propellers are propellers having blades with skew angle exceeding 50°.

1.2.12 Leading and trailing edges

The leading edge LE of a propeller blade is the edge of the blade at side entering the water while the propeller rotates.

The trailing edge TE of a propeller blade is the edge of the blade opposite the leading edge.

1.3 Documentation to be submitted

1.3.1 Solid propellers

The documents listed in Tab 1 are to be submitted for solid propellers intended for propulsion.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

1.3.2 Built-up and controllable pitch propellers

The documents listed in Tab 2, as applicable, are to be submitted for built-up and controllable pitch propellers intended for propulsion.

1.3.3 Very highly skewed propellers and propellers of unusual design

For very highly skewed propellers and propellers of unusual design, in addition to the documents listed in Tab 1 and Tab 2, as applicable, a detailed hydrodynamic load and stress analysis is to be submitted (see [2.4.2]).

Table 1 : Documents to be submitted for solid propellers

No.	A/I **(1)**	ITEM
1	A	Sectional assembly
2	A	Blade and hub details
3	I	Rating (power, rpm, etc.)
4	A	Data and procedures for fitting propeller to the shaft
(1) A = to be submitted for approval I = to be submitted for information.		

Table 2 : Documents to be submitted for built-up and controllable pitch propellers

No.	A/I **(1)**	ITEM
1	A/I	Same documents as requested for solid propellers
2	A	Blade bolts and pre-tensioning procedures
3	I	Pitch corresponding to maximum propeller thrust and to normal service condition
4	A	Pitch control mechanism
5	A	Pitch control hydraulic system
(1) A = to be submitted for approval I = to be submitted for information.		

2 Design and construction

2.1 Materials

2.1.1 Normally used materials for propeller hubs and blades

a) Tab 3 indicates the minimum tensile strength R_m (in N/mm^2), the density δ (in kg/dm^3) and the material factor f of normally used materials.

b) Common bronze, special types of bronze and cast steel used for the construction of propeller hubs and blades are to have a minimum tensile strength of 400 N/mm^2.

c) Other materials are subject of special consideration by the Society following submission of full material specification.

Table 3 : Normally used materialsfor propeller blades and hub

Material	R_m	δ	f
Common brass	400	8,3	7,6
Manganese brass (Cu1)	440	8,3	7,6
Nickel-manganese brass (Cu2)	440	8,3	7,9
Aluminium bronze (Cu3 and Cu4)	590	7,6	8,3
Steel	440	7,9	9,0

2.1.2 Materials for studs

In general, steel (preferably nickel-steel) is to be used for manufacturing the studs connecting steel blades to the hub of built-up or controllable pitch propellers, and high tensile brass or stainless steel is to be used for studs connecting bronze blades.

2.2 Solid propellers - Blade thickness

2.2.1

a) The maximum thickness $t_{0,25}$, in mm, of the solid propeller blade at the section at 0,25 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,25} = 3,2\left[f\cdot\frac{1,5.10^6.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l\cdot z\cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

$\rho = D / H$

H : Mean pitch of propeller, in m. When H is not known, the pitch $H_{0.7}$ at 0,7 radius from the propeller axis, may be used instead of H.

D : Propeller diameter, in m

M_T : Continuous transmitted torque, in kN.m; where not indicated, the value given by the following formula may be assumed for M_T:

$$M_T = 9{,}55 \cdot \left(\frac{P}{N}\right)$$

P : Maximum continuous power of propulsion machinery, in kW

N : Rotational speed of the propeller, in rev/min

δ : Density of blade material, in kg/dm³, as indicated in Tab 3

B : Expanded area ratio

h : Rake, in mm

l : Developed width of blade section at 0,25 radius from propeller axis, in mm

z : Number of blades

R_m : Minimum tensile strength of blade material, in N/mm²

$R = D / 2$

b) The maximum thickness $t_{0,6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,6} = 1{,}9\left[f\,\frac{1{,}5.10^6.\rho_{0,6}.M_T + 18{,}4.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l_{0,6} \cdot z \cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,6} = D / H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Developed width of blade section at 0,6 radius from propeller axis, in mm.

c) The radius at the blade root is to be at least ¾ of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account. If the propeller hub extends over 0,25 radius, the thickness calculated by the formula in a) is to be compared with the thickness obtained by linear interpolation of the actual blade thickness up to 0,25 radius.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.3 Built-up propellers and controllable pitch propellers

2.3.1 Blade thickness

a) The maximum thickness $t_{0.35}$, in mm, of the blade at the section at 0,35 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,35} = 2{,}7\left[f\,\frac{1{,}5.10^6.\rho_{0,7}.M_T + 41.\delta\left(\frac{D}{100}\right)^3 B.l_{0,35}.N^2 h}{l_{0,35} \cdot z \cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,7}$: $D/H_{0.7}$

$H_{0.7}$: Pitch at 0,7 radius from the propeller axis, in m. The pitch to be used in the formula is the actual pitch of the propeller when the propeller develops the maximum thrust.

$l_{0.35}$: Developed width of blade section at 0,35 radius from propeller axis, in mm.

b) The maximum thickness $t_{0.6}$, in mm, of the propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the formula in [2.2.1], item b), using the value of $l_{0,35}$ in lieu of l.

c) The radius at the blade root is to be at least 3/4 of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:
   - full load end of life displacement
   - sea state
   - hull fouling
   - doubts on ship resistance and global propulsion efficiency.

   A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.3.2 Flanges for connection of blades to hubs

a) The diameter D_F, in mm, of the flange for connection to the propeller hub is not to be less than that obtained from the following formula:

   $D_F = D_C + 1,8\ d_{PR}$

   where:

   D_C : Stud pitch circle diameter, in mm

   d_{PR} : Nominal stud diameter.

b) The thickness of the flange is not to be less than 1/10 of the diameter D_F.

2.3.3 Connecting studs

a) The diameter d_{PR}, in mm, at the bottom of the thread of the studs is not to be less than obtained from the following formula:

$$d_{PR} = \left(\frac{4{,}6 \cdot 10^7 \cdot \rho_{0,7} \cdot M_T + 0{,}88 \cdot \delta \cdot \left(\frac{D}{10}\right)^3 \cdot B \cdot l_{0,35} \cdot N^2 \cdot h_1}{n_{PR} \cdot z \cdot D_C \cdot R_{m,PR}}\right)^{0,5}$$

   where:

   $h_1 = h + 1,125\ D$

   n_{PR} : Total number of studs in each blade

   $R_{m,PR}$: Minimum tensile strength of stud material, in N/mm^2.

b) The studs are to be tightened in a controlled manner such that the tension on the studs is approximately 60-70% of their yield strength.

c) The shank of studs may be designed with a minimum diameter equal to 0,9 times the root diameter of the thread.

d) The studs are to be properly secured against unintentional loosening.

2.4 Skewed propellers

2.4.1 Skewed propellers

The thickness of skewed propeller blades may be obtained by the formulae in [2.2] and [2.3.1], as applicable, provided the skew angle is less than 25°.

2.4.2 Highly skewed propellers

a) For solid and controllable pitch propellers having skew angles between 25° and 50°, the blade thickness, in mm, is not to be less than that obtained from the following formulae:
   1) For solid propellers:

      $t_{S-0,25} = t_{0,25}\ (0,92 + 0,0032\ \vartheta)$

2) For built-up and controllable pitch propellers:

$t_{S-0,35} = t_{0,35}\,(0,90 + 0,0040\ \vartheta)$

3) For all propellers:

$t_{S-0,6} = t_{0,6}\,(0,74 + 0,0129\ \vartheta - 0,0001\ \vartheta^2)$

$t_{S-0,9} = t_{0,6}\,(0,35 + 0,0015\ \vartheta)$

where:

$t_{S-0,25}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,25 radius from the propeller axis

$t_{0,25}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,25 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,35}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,35 radius from the propeller axis

$t_{0,35}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,35 radius from the propeller axis, obtained by the formula in [2.3.1]

$t_{S-0,6}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,6 radius from the propeller axis

$t_{0,6}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,6 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,9}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,9 radius from the propeller axis

ϑ : Skew angle.

b) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). The stress analysis is to be carried out by a FEM method. The safety factor resulting form such calculation is not to be less than 8 with respect to the minimum ultimate tensile strength of the propeller material R_m.

Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.4.3 Very highly skewed propellers

For very highly skewed propellers, the blade thickness is to be obtained by a stress analysis according to a calculation criteria accepted by the Society. The safety factor to be used in this direct analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller blade material, R_m.

2.5 Ducted propellers

2.5.1 The minimum blade thickness of propellers with wide tip blades running in nozzles is not to be less than the values obtained by the applicable formula in [2.2] or [2.3.1], increased by 10%.

2.6 Features

2.6.1 Blades and hubs

a) All parts of propellers are to be free of defects and are to be built and installed with clearances and tolerances in accordance with sound marine practice.

b) Particular care is to be given to the surface of blades to comply with the specified class of ISO 484-1 and 484-2.

c) In case of direct calculation the class to be specified is to take in account the safety factor resulting of the fatigue strength calculation.

d) Where the mean load of the propeller, computed on the basis of the developed blades surface, exceeds 50 kN/m², the hydrodynamic characteristics of the propeller are to be verified with tests of properly scaled model performed in a cavitation tunnel to evaluate the risk of erosive cavitation in the whole operating speed range.

Table 4 : Controllable pitch propeller monitoring

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Oil tank level	L	local					
Pitch position **(1)**	H**(2)(3)**	R					
Control oil pressure	L	local				x	
(1) Local manual control is to be available **(2)** High difference from set point **(3)** For feathering propellers, too high pitch value is also to give an alarm							

2.6.2 Controllable pitch propellers pitch control system

a) Where the pitch control mechanism is operated hydraulically, two independent, power-driven pump sets are to be fitted. Hydraulic actuating system of controllable pitch propellers are also to comply with relevant requirements of Ch 1, Sec 10, [13].

b) Pitch control systems are to be provided with an engine room indicator showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge and in the engine control room, if any.

c) Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

d) Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades

- does not change, or
- assumes a final position slowly enough to allow the emergency control system to be put into operation.

e) Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to operate should the remote control system fail. This requirement may be complied with by means of a device which locks the propeller blades in the "ahead" setting.

f) Tab 4 indicates the monitoring requirements to be displayed at the control console.

3 Arrangement and installation

3.1 Fitting of propeller on the propeller shaft

3.1.1 General

a) Screw propeller hubs are to be properly adjusted and fitted on the propeller shaft cone. The contacts are to be checked to be not less than 70% of the theoretical contact area. Non-contact bands extending circumferentially around the boss (excluding the center shanked part), or over the full length of the boss are not acceptable.

b) The forward end of the hole in the hub is to have the edge rounded to a radius of approximately 6 mm.

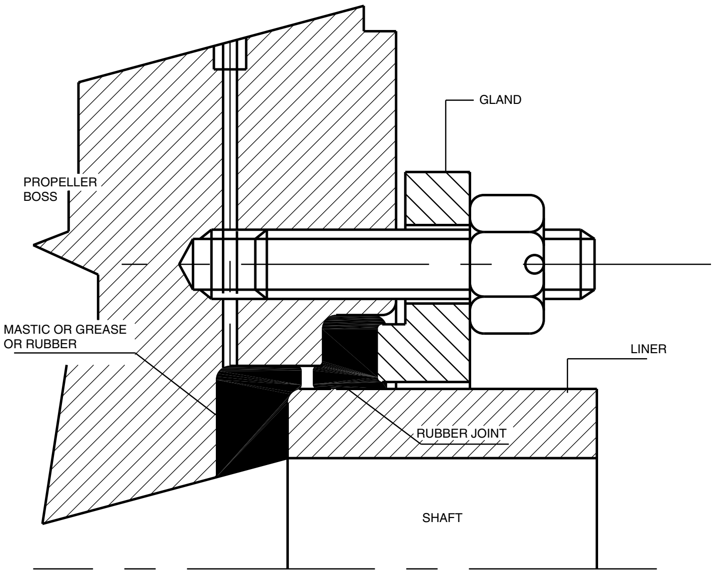
c) In order to prevent any entry of sea water under the liner and onto the end of the propeller shaft, the arrangement of Fig 2 is generally to be adopted for assembling the liner and propeller boss.

d) The external stuffing gland is to be provided with a seawater resistant rubber ring preferably without joints. The clearance between the liner and the internal air space of the boss is to be as small as possible. The internal air space is to be filled with an appropriate protective material which is insoluble in sea water and non-corrodible or fitted with a rubber ring.

e) All free spaces between the propeller shaft cone, propeller boss, nut and propeller cap are to be filled with a material which is insoluble in sea water and non-corrodible. Arrangements are to be made to allow any air present in these spaces to withdraw at the moment of filling. It is recommended that these spaces be tested under a pressure at least equal to that corresponding to the immersion of the propeller in order to check the tightness obtained after filling.

f) For propeller keys and key area, see Ch 1, Sec 7, [2.5.5].

Figure 2 : Example of sealing arrangement



3.1.2 Shrinkage of keyless propellers

In the case of keyless shrinking of propellers, the following requirements apply:

a) The meaning of the symbols used in the subparagraphs below is as follows:

A	:	100% theoretical contact area between propeller boss and shaft, as read from plans and disregarding oil grooves, in mm²
d_{PM}	:	Diameter of propeller shaft at the mid-point of the taper in the axial direction, in mm
d_H	:	Mean outer diameter of propeller hub at the axial position corresponding to d_{PM}, in mm
K	:	$K = d_H / d_{PM}$
F	:	Tangential force at interface, in N
M_T	:	Continuous torque transmitted; in N.m, where not indicated, M_T may be assumed as indicated in [2.2.1]
C	:	• C = 1,0 for turbines, geared diesel engines, electrical drives and direct-drive reciprocating internal combustion engines with a hydraulic, electromagnetic or high elasticity coupling • C = 1,2 for diesel engines having couplings other than those specified above. The Society reserves the right to increase the value of C if the shrinkage needs to absorb an extremely high pulsating torque,
T	:	Temperature of hub and propeller shaft material, in °C, assumed for calculation of pull-up length and push-up load
V	:	Ship speed at P power, in knots
S	:	Continuous thrust developed for free running ship, in N
s_F	:	Safety factor against friction slip at 35°C
θ	:	Half taper of propeller shaft (for instance: taper = 1/15, θ = 1/30)
μ	:	Coefficient of friction between mating surfaces
p_{35}	:	Surface pressure between mating surfaces, in N/mm², at 35°C
p_T	:	Surface pressure, in N/mm², between mating surfaces at temperature T
p_0	:	Surface pressure between mating surfaces, in N/mm², at 0°C
p_{MAX}	:	Maximum permissible surface pressure, in N/mm², at 0°C
d_{35}	:	Push-up length, in mm, at 35°C
d_T	:	Push-up length, in mm, at temperature T
d_{MAX}	:	Maximum permissible pull-up length, in mm, at 0°C
W_T	:	Push-up load, in N, at temperature T
σ_{ID}	:	Equivalent uni-axial stress in the boss according to the von Mises-Hencky criterion, in N/mm²
α_P	:	Coefficient of linear expansion of shaft material, in mm/(mm°C)
α_M	:	Coefficient of linear expansion of boss material, in mm/(mm°C)
E_P	:	Value of the modulus of elasticity of shaft material, in N/ mm²
E_M	:	Value of the modulus of elasticity of boss material, in N/ mm²
ν_P	:	Poisson's ratio for shaft material
ν_M	:	Poisson's ratio for boss material

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of propeller boss material, in N/mm².

For other symbols not defined above, see [2.2].

b) The manufacturer is to submit together with the required constructional plans specifications containing all elements necessary for verifying the shrinkage. Tests and checks deemed necessary for verifying the characteristics and integrity of the propeller material are also to be specified.

c) Moreover, the manufacturer is to submit an instruction handbook, in which all operations and any precautions necessary for assembling and disassembling the propeller, as well as the values of all relevant parameters, are to be specified. A copy, endorsed by the Society, is to be kept on board each ship where the propeller is installed.

d) The formulae and other provisions below do not apply to propellers where a sleeve is introduced between shaft and boss or in the case of hollow propeller shafts. In such cases, a direct shrinkage calculation is to be submitted to the Society.

e) The taper of the propeller shaft cone is not to exceed 1/15.

f) Prior to final pull-up, the contact area between the mating surfaces is to be checked according to general requirements of [3.1.1] item a).

g) After final push-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

h) The safety factor s_F against friction slip at 35°C is not to be less than 2,5, under the combined action of torque and propeller thrust, based on the maximum continuous power P for which classification is requested at the corresponding speed of rotation N of the propeller, plus pulsating torque due to torsionals.

i) For the oil injection method, the coefficient of friction μ is to be 0,13 in the case of bosses made of copper-based alloy and steel. For other methods, the coefficient of friction will be considered in each case by the Society.

j) The maximum equivalent uni-axial stress in the boss at 0°C, based on the von Mises-Hencky criterion, is not to exceed 70% of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the propeller material, based on the test piece value. For cast iron, the value of the above stress is not to exceed 30% of the nominal tensile strength.

k) For the formulae given below, the material properties indicated in the following items are to be assumed:

- Modulus of elasticity, in N/mm²:

  Cast and forged steel: E = 206000

  Cast iron: E = 98000

  Type Cu1 and Cu2 brass: E = 108000

  Type Cu3 and Cu4 brass: E = 118000

- Poisson's ratio:

  Cast and forged steel: ν = 0,29

  Cast iron: ν = 0,26

  All copper based alloys: ν = 0,33

- Coefficient of linear expansion in mm/(mm°C):

  Cast and forged steel and cast iron: $\alpha = 12{,}0\ 10^{-6}$

  All copper based alloys: $\alpha = 17{,}5\ 10^{-6}$

l) For shrinkage calculation the formulae in the following items, which are valid for the ahead condition, are to be applied. They will also provide a sufficient margin of safety in the astern condition.

- Minimum required surface pressure at 35°C:

$$p_{35} = \frac{s_F S}{AB} \cdot \left[-s_F\theta + \left(\mu^2 + B \cdot \frac{F^2}{S^2}\right)^{0,5}\right]$$

  where:

  $B = \mu^2 - s_F^2\,\theta^2$

- Corresponding minimum pull-up length at 35°C:

$$d_{35} = \frac{p_{35} d_{PM}}{2\theta} \cdot \left[\frac{1}{E_M} \cdot \left(\frac{K^2+1}{K^2-1} + \nu_M\right) + \frac{1-\nu_P}{E_P}\right]$$

- Minimum pull-up length at temperature T (T<35°C):

$$d_T = d_{35} + \frac{d_{PM}}{2\theta} \cdot (\alpha_M - \alpha_P) \cdot (35 - T)$$

- Corresponding minimum surface pressure at temperature T:

$$p_T = p_{35} \cdot \frac{d_T}{d_{35}}$$

- Minimum push-up load temperature T:

$$W_T = A p_T \cdot (\mu + \theta)$$

- Maximum permissible surface pressure at 0°C:

$$p_{MAX} = \frac{0{,}7 R_{S,MIN} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

- Corresponding maximum permissible pull-up length at 0°C:

$$d_{MAX} = d_{35} \cdot \frac{p_{MAX}}{p_{35}}$$

- Tangential force at interface:

$$F = \frac{2000 C M_T}{d_{PM}}$$

- Continuous thrust developed for free running ship; if the actual value is not given, the value, in N, calculated by one of the following formulae may be considered:

$$S = 1760 \cdot \frac{P}{V}$$

$$S = 57{,}3 \cdot 10^3 \cdot \frac{P}{H \cdot N}$$

3.1.3 Circulating currents

Means are to be provided to prevent circulating electric currents from developing between the propeller and the hull. A description of the type of protection provided and its maintenance is to be kept on board.

4 Testing and certification

4.1 Material tests

4.1.1 Solid propellers

Material used for the construction of solid propellers is to be tested in accordance with the requirements of NR216 Materials and Welding in the presence of the Surveyor.

4.1.2 Built-up propellers and controllable pitch propellers

In addition to the requirement in [4.1.1], materials for studs and for all other parts of the mechanism transmitting torque are to be tested in the presence of the Surveyor.

4.2 Testing and inspection

4.2.1 Inspection of finished propeller

Finished propellers are to be inspected at the manufacturer’s plant by the Surveyor. At least the following checks are to be carried out:

- visual examination of the entire surface of the propeller blades
- conformity to approved plans of blade profile
- liquid penetrant examination of suspected and critical parts of the propeller blade, to the satisfaction of the Surveyor.

Repair of defective casting is not allowed without the previous agreement of the Owner; where agreed, it is to be carried out according to the requirements of NR216 Materials and Welding, Ch 6, Sec 8 [1.12] or NR216 Materials and Welding, Ch 8, Sec 3 [1.12], as applicable.

4.2.2 Controllable pitch propellers

The complete hydraulic system for the control of the controllable pitch propeller mechanism is to be hydrotested at a pressure equal to 1,5 times the design pressure. The proper operation of the safety valve is to be tested in the presence of the Surveyor.

4.2.3 Balancing

Finished propellers are to be statically balanced as required by the relevant class according to ISO 484. For built-up and controllable pitch propellers, the required static balancing of the complete propeller may be replaced by an individual check of blade weight and gravity centre position. Refer also to:

- NR216 Materials and Welding, Ch 6, Sec 8 [1.9.3] for stainless steel propeller blades and
- NR216 Materials and Welding, Ch 8, Sec 3, [1.9.4] for copper alloy propeller blades.

4.3 Certification

4.3.1 Certification of propellers

Propellers in general are to be individually tested and certified by the Society.

4.3.2 Mass produced propellers

Mass produced propellers may be accepted within the framework of the type approval program of the Society.

Section 9 Shaft Vibrations

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the shafting of the following installations:

- propulsion systems with prime movers developing 220 kW or more
- other systems with internal combustion engines developing 110 kW or more and driving auxiliary machinery intended for essential services.

1.1.2 Exemptions

The requirements of this Section may be waived in cases where satisfactory service operation of similar installations is demonstrated.

2 Design of systems in respect of vibrations

2.1 Principle

2.1.1 General

a) Special consideration shall be given by Manufacturers to the design, construction and installation of propulsion machinery systems so that any mode of their vibrations shall not cause undue stresses in these systems in the normal operating ranges.

b) Calculations are to be carried out for the configurations of the system likely to have influence on the torsional vibrations.

c) Where torsional and axial vibrations may be coupled (e.g. due to helical gears), the effect of such vibrations is to be investigated.

2.1.2 Vibration levels

Systems are to have torsional, bending and axial vibrations both in continuous and in transient running acceptable to the Manufacturers, and in accordance with the requirements of this section.

Where vibrations are found to exceed the limits stated in this Section, the builder of the plant is to propose corrective actions, such as:

- operating restrictions, provided that the owner is informed, or
- modification of the plant.

2.1.3 Condition of components

Systems are to be designed considering the following conditions, as deemed necessary by the Manufacturer:

- engine: cylinder malfunction
- flexible coupling: possible variation of the stiffness or damping characteristics due to heating or ageing
- vibration damper: possible variation of the damping coefficient.

2.2 Modifications of existing plants

2.2.1 Where substantial modifications of existing plants, such as:

- change of the running speed or power of the engine
- replacement of an important component of the system (propeller, flexible coupling, damper) by one of different characteristics, or
- connection of a new component

are carried out, new vibration analysis is to be submitted for approval.

3 Torsional vibrations

3.1 Documentation to be submitted

3.1.1 Calculations

Torsional vibration calculations are to be submitted for the various configurations of the plants, showing:

- the equivalent dynamic system used for the modelling of the plant, with indication of:
  - inertia and stiffness values for all the components of the system
  - outer and inner diameters and material properties of the shafts
- the natural frequencies
- the values of the vibratory torques or stresses in the components of the system for the most significant critical speeds and their analysis in respect of the Rules and other acceptance criteria
- the possible restrictions of operation of the plant.

3.1.2 Particulars to be submitted

The following particulars are to be submitted with the torsional vibration calculations:

a) for turbines, multi-engine installations or installations with power take-off systems:
   - description of the operating configurations
   - load sharing law between the various components for each configuration

b) for installations with controllable pitch propellers, the power/rotational speed values resulting from the combinator operation

c) for prime movers, the service speed range and the minimum speed at no load

d) for internal combustion engines:
   - manufacturer and type
   - nominal output and rotational speed
   - mean indicated pressure
   - number of cylinders
   - "V" angle
   - firing angles
   - bore and stroke
   - excitation data, such as the polynomial law of harmonic components of excitations
   - nominal alternating torsional stress considered for crankpin and journal

Note 1: The nominal alternating torsional stress is part of the basic data to be considered for the assessment of the crankshaft. It is defined in Ch 1, App 1.

e) for turbines:
   - nominal output and rotational speed
   - power/speed curve and range of operation
   - number of stages, and load sharing between the stages
   - main excitation orders for each rotating disc
   - structural damping of shafts
   - external damping on discs (due to the fluid)

f) for reduction or step-up gears, the speed ratio for each step

g) for flexible couplings:
   - the maximum torque
   - the nominal torque
   - the permissible vibratory torque
   - the permissible heat dissipation
   - the relative damping
   - the torsional dynamic stiffness / transmitted torque relation where relevant

h) for torsional vibration dampers:
   - the manufacturer and type
   - the permissible heat dissipation
   - the damping coefficient
   - the inertial and stiffness properties, as applicable

i) for propellers:
   - the type of propeller: ducted or not ducted
   - the number of propellers of the ship
   - the number of blades
   - the excitation and damping data, if available

j) for electric motors, generators and pumps, the drawing of the rotating parts, with their mass moment of inertia and main dimensions.

3.2 Definitions, symbols and units

3.2.1 Definitions

a) Torsional vibration stresses referred to in this Article are the stresses resulting from the alternating torque corresponding to the synthesis of the harmonic orders concerned.

b) The misfiring condition of an engine is the malfunction of one cylinder due to the absence of fuel injection (which results in a pure compression or expansion in the cylinder).

3.2.2 Symbols, units

The main symbols used in this Article are defined as follows:

τ : Torsional vibration stress, as defined in [3.2.1], in N/mm^2

τ_1 : Permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_2 : Permissible stress due to torsional vibrations for transient running, in N/mm^2

R_m : Tensile strength of the shaft material, as defined in Ch 1, Sec 7, [2.1.2], in N/mm^2.

C_R : Material factor, equal to:

$$\frac{R_m + 160}{18}$$

d : Minimum diameter of the shaft, in mm

C_D : Size factor of the shaft, equal to:

$0,35 + 0,93\ d^{-0,2}$

N : Speed of the shaft for which the check is carried out, in rev/min

N_n : Nominal speed of the shaft, in rev/min

N_c : Critical speed, in rev/min

λ : Speed ratio, equal to N/N_n

C_λ : Speed ratio factor, equal to:

- $3 - 2\lambda^2$ for $\lambda < 0,9$
- 1,38 for $0,9 \le \lambda < 1,05$

C_k : Factor depending on the stress concentration factor of the shaft design features given in Tab 1.

Table 1 : Values of C_k factors

Intermediate shafts with							Thrust shafts external to engines		Propeller shafts		
straight sections and integral coupling flanges	shrink-fit couplings **(1)**	keyways, tapered connection **(2)**	keyways, cylindrical connection **(2)**	radial hole	longitudinal slot **(3)**	splined shafts	on both sides of thrust collar	in way of axial bearing where a roller bearing is used as a thrust bearing	flange mounted or keyless fitted propellers **(4)**	key fitted propellers **(4)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	0,60	0.45	0.50	0.30	0,80	0,85	0,85	0,55	0,55	0.80

(1) C_k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in Ch 1, Sec 7, [2.5.1]

(2) Keyways are to be in accordance with the provisions of Ch 1, Sec 7, [2.5.5].

(3) Subject to limitations as $\ell/d_o < 0,8$ and $d_i/d_o < 0,7$ and $e/d_o > 0,15$, where:

ℓ : Slot length in mm

e : Slot width in mm

d_i, d_o : As per Sec 7, [2.2.3]

The C_k value is valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(4) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2.5 times the required diameter.

Note 1: Higher values of C_k factors based on direct calculations may also be considered.

Note 2: The determination of C_k factors for shafts other than those given in this table will be given special consideration by the Society.

3.3 Calculation principles

3.3.1 Method

a) Torsional vibration calculations are to be carried out using a recognised method.

b) Where the calculation method does not include harmonic synthesis, attention is to be paid to the possible superimposition of two or more harmonic orders of different vibration modes which may be present in some restricted ranges.

3.3.2 Scope of the calculations

a) Torsional vibration calculations are to be carried out considering:
- normal firing of all cylinders, and
- misfiring of one cylinder.

b) Where the torsional dynamic stiffness of the coupling depends on the transmitted torque, two calculations are to be carried out:
- one at full load
- one at the minimum load expected in service.

c) For installations with controllable pitch propellers, two calculations are to be carried out:
- one for full pitch condition
- one for zero pitch condition.

d) The calculations are to take into account other possible sources of excitation, as deemed necessary by the Manufacturer. Electrical sources of excitations, such as static frequency converters, are to be detailed. The same applies to transient conditions such as engine start up, reversing, clutching in, as necessary.

e) The natural frequencies are to be considered up to a value corresponding to 15 times the maximum service speed. Therefore, the excitations are to include harmonic orders up to the fifteenth.

3.3.3 Criteria for acceptance of the torsional vibration loads under normal firing conditions

a) Torsional vibration stresses in the various shafts are not to exceed the limits defined in [3.4]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society.

   Auxiliary machinery is to be capable of running continuously without restrictions at least within the range between 0,95 N_n and 1,1 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0{,}95$.

b) Torsional vibration levels in other components are to comply with the provisions of [3.5].

c) The generating set is to show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

d) Propulsion systems are to be capable of running continuously without restrictions, and therefore are to respect the limits given in a) and b) in the whole operating speed range.

3.3.4 Criteria for acceptance of torsional vibration loads under misfiring conditions

The provisions of [3.3.3] related to normal firing conditions also apply to misfiring conditions.

3.4 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting

3.4.1 General

a) The limits provided below apply to steel shafts. For shafts made of other material, the permissible limits for torsional vibration stresses will be determined by the Society after examination of the results of fatigue tests carried out on the material concerned.

b) These limits apply to the torsional vibration stresses as defined in [3.2.1]. They relate to the shaft minimum section, without taking account of the possible stress concentrations.

3.4.2 Crankshaft

a) Where the crankshaft has been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
- $\tau_1 = \tau_N$ for continuous running
- $\tau_2 = 1{,}7\ \tau_N$ for transient running,

   where τ_N is the nominal alternating torsional stress on which the crankshaft scantling is based (see Note 1 in [3.1.2]).

b) Where the crankshaft has not been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
- $\tau_1 = 0{,}55 \cdot C_R \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 2{,}3\ \tau_1$ for transient running.

3.4.3 Intermediate shafts, thrust shafts and propeller shafts

The torsional vibration stresses in any intermediate, thrust and propeller shafts are not to exceed the following limits:

- $\tau_1 = C_R . C_k . C_D . C_\lambda$ for continuous running
- $\tau_2 = 1{,}7\ \tau_1 . C_k^{-0{,}5}$ for transient running.

3.4.4 Transmission shafting for generating sets and other auxiliary machinery

The torsional vibration stresses in the transmission shafting for generating sets and other auxiliary machinery, such as pumps or compressors, are not to exceed the following limits:

- $\tau_1 = 0{,}90 . C_R . C_D$ for continuous running
- $\tau_2 = 5{,}4\ \tau_1$ for transient running.

3.4.5 Restricted speed ranges

Restricted speed ranges in normal firing condition are acceptable only for auxiliary machinery:

a) Where the torsional vibration stresses exceed the limit τ_1 for continuous running, restricted speed ranges are to be imposed which are to be passed through rapidly.

b) The limits of the restricted speed range related to a critical speed N_c are to be calculated in accordance with the following formula:

$$\frac{16 \cdot N_c}{18-\lambda} \le N \le \frac{(18-\lambda) \cdot N_c}{16}$$

c) Where the resonance curve of a critical speed is obtained from torsional vibration measurements, the restricted speed range may be established considering the speeds for which the stress limit for continuous running τ_1 is exceeded.

d) Where restricted speed ranges are imposed, they are to be crossed out on the tachometers and an instruction plate is to be fitted at the control stations indicating that:
   - the continuous operation of the engine within the considered speed range is not permitted
   - this speed range is to be passed through rapidly.

e) When restricted speed ranges are imposed, the accuracy of the tachometers is to be checked in such ranges as well as in their vicinity.

3.5 Permissible vibration levels in components other than shafts

3.5.1 Gears

a) The torsional vibration torque in any gear step is not to exceed 30% of the torque corresponding to the approved rating throughout the service speed range.

   Where the torque transmitted at nominal speed is less than that corresponding to the approved rating, higher torsional vibration torques may be accepted, subject to special consideration by the Society.

b) Gear hammering induced by torsional vibration torque reversal is not permitted throughout the service speed range.

3.5.2 Generators

a) In the case of alternating current generators, the torsional vibration amplitude at the rotor is not to exceed ± 2,5 electrical degrees at service rotational speed under full load working conditions.

b) Vibratory inertia torques due to torsional vibrations and imposed on the rotating parts of the generator are not to exceed the values M_A, in N.m, calculated by the following formulae, as appropriate:
   - for $0{,}95 \le \lambda \le 1{,}1$: $M_A = \pm 2{,}5\ M_T$
   - for $\lambda \le 0{,}95$: $M_A = \pm 6\ M_T$

   where:

   M_T : Mean torque transmitted by the engine under full load running conditions, in N.m

   Note 1: In the case of two or more generators driven by the same engine, the portion of M_T transmitted to each generator is to be considered.

   λ : Speed ratio defined in [3.2.2].

3.5.3 Flexible couplings

a) Flexible couplings are to be capable of withstanding the mean transmitted torque and the torsional vibration torque throughout the service speed range, without exceeding the limits for continuous operation imposed by the manufacturer (permissible vibratory torque and power loss).

   Where such limits are exceeded under misfiring conditions of auxiliary machines, appropriate restrictions of power or speed are to be established.

b) The coupling selection for the generating set is to take into account the stresses and torques imposed on it by the torsional vibration of the system.

c) Flexible couplings fitted in generating sets are also to be capable of withstanding the torques and twist angles arising from transient criticals and short-circuit currents. Start up conditions are also to be checked.

3.5.4 Dampers

a) Torsional vibration dampers are to be such that the permissible power loss recommended by the manufacturer is not exceeded throughout the service speed range.

b) Dampers for which a failure may lead to a significant vibration overload of the installation will be the subject of special consideration.

3.6 Torsional vibration measurements

3.6.1 General

a) The Society may require torsional vibration measurements to be carried out under its attendance in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
   - where doubts arise as to the actual stress amplitudes or critical speed location, or
   - where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

3.6.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

4 Bending vibrations

4.1 General

4.1.1 The provisions of this Article apply to the bending vibrations of propulsion systems having a transmitted power in excess of 1000 KW:

- having a l/D ratio exceeding the following value:

$$10\left(\ln\frac{2}{D}\right) + D^2$$

  where:

  l : Span between the aft bearings of the propeller shaft, in m

  D : Diameter of the propeller shaft, in m

  or

- fitted with bearings located outboard the hull (brackets), or
- fitted with cardan shafts.

4.2 Documentation to be submitted

4.2.1 Calculations

Bending vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the mass of the shafts, propeller and other rotating components, and the lateral stiffness of the bearings, including that of the oil film and that of the seating
- the natural bending frequencies
- the values of the vibratory amplitudes and bending moments in the shafting for the most significant critical speeds
- the possible restrictions of operation of the plant.

4.2.2 Particulars to be submitted

The following particulars are to be submitted with the bending vibration calculations:

a) shafting arrangement with indication of:
   - the diameter and length of the shafts
   - the position of the bearings
   - the mounting characteristics of the cardan shafts

b) detailed drawings of the bearings and their seating

c) details of the bearing lubrication, including the oil viscosity

d) for the propeller:
   - the diametral and polar moments of inertia of the propeller in air and water
   - excitations (bending moments and bending forces).

4.3 Calculation principles

4.3.1 Scope of the calculations

a) Bending vibration calculations are to take into account:
   - the stiffness of the bearings and their seatings and, where applicable, that of the lubricating oil film
   - the excitations due to the propeller and cardan shafts.

b) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy, parametric studies are to be carried out.

4.3.2 Criteria for acceptance of the bending vibration levels

The first shafting vibration mode is not to be excited by the first propeller blade excitation order, in the speed range between 80% and 110% of nominal speed.

Furthermore vibration induced stresses should not exceed 1,5 times the one indicated in [3.4.3] in the whole speed range.

In case the shafting is checked by means of direct calculation the allowable stresses will be established on a case by case.

4.4 Bending vibration measurements

4.4.1 General

a) The Society may require bending vibration measurements in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in or near the operating speed range
   - where the accuracy of some data is not deemed sufficient
   - where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

4.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

5 Axial vibrations

5.1 General

5.1.1 The provisions of this Article apply to the axial vibrations of propulsion systems fitted with:

- an internal combustion engine having a power exceeding 2000 kW and a running speed of less than 200 RPM, or
- a shaft line where the power transmitted exceeds 375 kW and the L/D ratio exceeds 50,

  where:

  L : Total length of the shaft line between the propeller and the thrust bearing

  D : Minimum diameter of the shaft line.

5.2 Documentation to be submitted

5.2.1 Calculations

Axial vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the masses and axial stiffnesses for all the components of the system
- the natural frequencies
- the axial vibration amplitude in way of the sterntube sealing gland for the most significant critical speeds
- for engines directly connected to the shaftline, the axial vibration amplitude at the free end of the crankshaft for the most significant critical speeds
- the possible restrictions of operation of the plant.

5.2.2 Particulars to be submitted

The following particulars are to be submitted with the axial vibration calculations:

a) detailed drawing of the thrust bearing and its supporting structure with indication of their flexibility

b) for the propeller:
   - the thrust
   - the excitations (axial forces)
   - the damping characteristics

c) for the engine:
   - the axial excitations
   - the permissible axial amplitude at the free end of the crankshaft

d) the characteristics of the axial vibration damper or detuner.

5.3 Calculation principles

5.3.1 Scope of the calculations

a) Axial vibration calculations are to take into account:
   - the flexibility of the thrust bearing and its supporting structure
   - the excitations due to the engine and to the propeller.

b) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy (e.g. the flexibility of the thrust bearing and its supporting structure), parametric studies are to be carried out.

c) Where the plant includes an axial vibration damper or detuner, a calculation is to be carried out assuming a malfunction of the damper or detuner.

5.3.2 Criteria for acceptance of the axial vibration levels

a) The axial vibration force acting on the thrust bearing is not to exceed 30% of the nominal thrust.

b) The axial vibration amplitude is not to exceed:
   - at the free end of the crankshaft, the limit recommended by the engine manufacturer
   - in way of the sterntube sealing gland, the limit recommended by the sealing gland manufacturer, if any.

c) Where the calculations show that in the continuous operation speed range the above limits may be exceeded in the event of malfunction of the axial vibration damper or detuner, a suitable device is to be fitted to indicate the occurrence of such conditions.

Note 1: When detuners or dampers of satisfactorily proven design are used, this requirement may be waived.

5.4 Axial vibration measurements

5.4.1 General

a) The Society may require axial vibration measurements in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
   - where the accuracy of some data is not deemed sufficient, or
   - where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

5.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

Section 10 Piping Systems

1 General

1.1 Application

1.1.1

a) General requirements applying to all piping systems are contained in:
- Article [2] for their design and construction
- Article [3] for the welding of steel pipes
- Article [4] for the bending of pipes
- Article [5] for their arrangement and installation
- Article [19] for their certification, inspection and testing.

b) Specific requirements for ship piping systems and machinery piping systems are given in Articles [6] to [18].

1.2 Documentation to be submitted

1.2.1 Documents

The documents listed in Tab 1 are to be submitted.

1.2.2 Additional information

The information listed in Tab 2 is also to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Drawing showing the arrangement of the sea chests and ship side valves
2	A	Diagram of the bilge and ballast systems (in and outside machinery spaces)
3	A	Specification of the central priming system intended for bilge pumps, when provided
4	A	Diagram of the scuppers and sanitary discharge systems
5	A	Diagram of the air, sounding and overflow systems
6	A	Diagram of cooling systems (sea water and fresh water)
7	A	Diagram of fuel oil system and of JP5-NATO (F44) system
8	A	Drawings of the fuel oil and of JP5-NATO (F44) tanks not forming part of the ship's structure
9	A	Diagram of the lubricating oil system
10	A	Diagram of the thermal oil system
11	A	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
12	A	Diagram of steam system, including safety valve exhaust and drain pipes
13		For high temperature steam pipes:
	A	• stress calculation note
	I	• drawing showing the actual arrangement of the piping in three dimensions
14	A	Diagram of the boiler feed water and condensate system
15	A	Diagram of the compressed air system
16	A	Diagram of the hydraulic and pneumatic remote control systems
17	A	Diagram of the remote level gauging system
18	I	Diagram of the exhaust gas system
19	A	Diagram of drip trays and gutterway draining system
20	I	Arrangement of the ventilation system
21	A	Diagram of the oxyacetylene welding system
22	A	Drawings and specification of valves and accessories, where required in [2.7]

(1) A = to be submitted for approval ; I = to be submitted for information.
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Table 2 : Information to be submitted

No.	I/A **(1)**	Document
1	I	Nature, service temperature and pressure of the fluids
2	A	Material, external diameter and wall thickness of the pipes
3	A	Type of connections between pipe lengths, including details of the weldings, where provided
4	A	Material, type and size of the accessories
5	A	Capacity, prime mover and, when requested, location of the pumps
6	A	For plastic pipes: • the chemical composition • the physical and mechanical characteristics in function of temperature • the characteristics of inflammability and fire resistance • the resistance to the products intended to be conveyed.
(1) A = to be submitted for approval ; I = to be submitted for information.		

1.3 Definitions

1.3.1 Piping and piping systems

a) Piping includes pipes and their connections, flexible hoses and expansion joints, valves and their actuating systems, other accessories (filters, level gauges, etc.) and pump casings.

b) Piping systems include piping and all the interfacing equipment such as tanks, pressure vessels, heat exchangers, pumps and centrifugal purifiers, but do not include boilers, turbines, internal combustion engines and reduction gears.

Note 1: The equipment other than piping is to be designed in accordance with the relevant Sections of Part C, Chapter 1.

1.3.2 Design pressure

a) The design pressure of a piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device, whichever is the greater.

b) The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

c) The design pressure of steam piping located upstream of pressure reducing valves (high pressure side) is not to be less than the setting pressure of the boiler or superheater safety valves.

d) The design pressure of a piping system located on the low pressure side of a pressure reducing valve where no safety valve is provided is not to be less than the maximum pressure on the high pressure side of the pressure reducing valve.

e) The design pressure of a piping system located on the delivery side of a pump or a compressor is not to be less than the setting pressure of the safety valve for displacement pumps or the maximum pressure resulting from the operating (head-capacity) curve for centrifugal pumps, whichever is the greater.

1.3.3 Design temperature

The design temperature of a piping system is the maximum temperature of the medium inside the system.

1.3.4 Flammable oils

Flammable oils include fuel oils, lubricating oils, thermal oils, hydraulic oils and JP5-NATO (F44).

1.4 Symbols and units

1.4.1 The following symbols and related units are commonly used in this Section. Additional symbols, related to some formulae indicated in this Section, are listed wherever it is necessary.

p : Design pressure, in MPa

T : Design temperature, in °C

t : Rule required minimum thickness, in mm

D : Pipe external diameter, in mm.

1.5 Class of piping systems

1.5.1 Purpose of the classes of piping systems

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and certification of fittings.

1.5.2 Definitions of the classes of piping systems

a) Classes I, II and III are defined in Tab 3.

b) Fluids for refrigerating plants are not covered by Tab 3 (see Ch 1, Sec 14).

Table 3 : Class of piping systems

Media conveyed by the piping system	CLASS I	CLASS II	CLASS III
Fuel oil and JP5-NATO (F44)**(1)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Thermal oil	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 150
Flammable Hydraulic oil **(5)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Lubricating oil	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Other flammable media: • heated above flashpoint, or • having flashpoint <60°C and liquefied gas	without special safeguards**(3)**	with special safeguards**(3)**	
Oxygen and acetylene • upstream the pressure reduction valve • downstream the pressure reduction valve	irrespective of p		
Toxic media	irrespective of p, T		
Corrosive media	without special safeguards**(3)**	with special safeguards**(3)**	
Steam	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 170
Air, gases, water, non-flammable hydraulic oil**(4)**	p > 4 or T > 300	other **(2)**	p ≤ 1,6 and T ≤ 200
Open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes)			irrespective of T

(1) Valves under static pressure on fuel oil and on JP5-NATO (F44) tanks belong to class II.
(2) Pressure and temperature conditions other than those required for class I and class III.
(3) Safeguards for reducing the possibility of leakage and limiting its consequences, to the Society's satisfaction.
(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II.
(5) Steering gear piping belongs to class I irrespective of p and T
Note 1: p : Design pressure, as defined in [1.3.2], in MPa.
Note 2: T : Design temperature, as defined in [1.3.3], in °C.

2 General requirements for design and construction

2.1 Materials

2.1.1 General

Materials to be used in piping systems are to be suitable for the medium and the service for which the piping is intended.

2.1.2 Use of metallic materials

a) Metallic materials are to be used in accordance with Tab 4.

b) Materials for class I and class II piping systems are to be manufactured and tested in accordance with the appropriate requirements of NR216 Materials and Welding.

c) Materials for class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national or international standards or specifications.

d) Mechanical characteristics required for metallic materials are specified in NR216 Materials and Welding.

2.1.3 Use of plastics

a) Plastics, FRP and GRP may be used for piping systems belonging to class III in accordance with Ch 1, App 2. The use of plastics for other systems or in other conditions will be given special consideration.

b) Plastics intended for piping systems dealt with in this Section are to be of a type approved by the Society.

c) Installation of plastic pipes shall be avoided if not agreed by the Society and the Naval Authority.

Table 4 : Conditions of use of metallic materials in piping systems

Material	Allowable classes	Maximum design temperature, in °C**(1)**	Particular conditions of use
Carbon and carbon-manganese steels	III, II, I	400 **(2)**	Class I and II pipes are to be seamless drawn pipes **(3)**
Copper and aluminium brass	III, II, I	200	• Not to be used in fuel oil and JP5-NATO(F44) systems, except for class III pipes of a diameter not exceeding 25 mm not passing through fuel oil or JP5-NATO(F44) tanks • Not to be used for boiler blow-down valves and pieces for connection to the shell plating **(4)**
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	
Stainless steel	III, II, I	300	Except for system fittings, an austenitic stainless steel is not to be used for sea water systems
Spheroidal graphite cast iron	III, II	350	• Spheroidal cast iron of the ferritic type according to the material rules of the Society may be accepted for bilge and ballast piping within double bottom tanks, or other locations to the Society's satisfaction • The use of this material for pipes, valves and fittings for other services, in principle Classes II and III, will be subject to special consideration • Spheroidal cast iron pipes and valves fitted on ship's side should have specified properties to the Society's satisfaction • Minimum elongation is not to be less than 12% on a gauge length of $5{,}65 \cdot S^{0,5}$, where S is the actual cross-sectional area of the test piece • Not to be used for boiler blow-down valves and pieces for connection to the shell plating
Grey cast iron	III, II **(5)**	220	Grey cast iron is not to be used for the following systems: • boiler blow-down systems and other piping systems subject to shocks, high stresses and vibrations • bilge lines in tanks • parts of scuppers and sanitary discharge systems located next to the hull below the maximum ship draft • ship side valves and fittings • valves fitted on the collision bulkhead • valves fitted to fuel oil and lubricating oil tanks under static pressure head • class II fuel oil and JP5-NATO(F44) systems
Aluminium and aluminium alloys	III, II **(6)**	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems • sounding and air pipes of fuel oil tanks and of JP5-NATO(F44) tanks • fire-extinguishing systems • bilge system in boiler or machinery spaces or in spaces containing fuel oil tanks, JP5-NATO(F44) tanks or pumping units • scuppers and overboard discharges except for pipes led to the bottoms or to the shell above the watertight deck or fitted at their upper end with closing means operated from a position above the watertight deck • boiler blow-down valves and pieces for connection to the shell plating

(1) Maximum design temperature is not to exceed that assigned to the class of piping.
(2) Higher temperatures may be accepted if metallurgical behaviour and time dependent strength (ultimate tensile strength after 100 000 hours) are in accordance with national or international standards or specifications and if such values are guaranteed by the steel manufacturer.
(3) Pipes fabricated by a welding procedure approved by the Society may also be used.
(4) Pipes made of copper and copper alloys are to be seamless.
(5) Use of grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.
(6) Accessories of aluminium or aluminium alloys intended for flammable oil systems may be accepted subject to the satisfactory result of an endurance flame test to be carried out according to the "Rules for the type approval of flexible hoses and expansion joints" issued by the Society.

2.2 Thickness of pressure piping

2.2.1 Calculation of the thickness of pressure pipes

a) The thickness t, in mm, of pressure pipes is to be determined by the following formula but, in any case, is not to be less than the minimum thickness given in Tab 5 to Tab 8.

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}}$$

where:

t_0 : Coefficient, in mm, equal to

$$t_0 = \frac{p \cdot D}{2Ke + p}$$

with:

p and D : As defined in [1.4.1]

K : Permissible stress defined in [2.2.2]

e : Weld efficiency factor to be:

- equal to 1 for seamless pipes and pipes fabricated according to a welding procedure approved by the Society
- specially considered by the Society for other welded pipes, depending on the service and the manufacture procedure

b : Thickness reduction due to bending defined in [2.2.3], in mm

c : Corrosion allowance defined in [2.2.4], in mm

a : Negative manufacturing tolerance percentage equal to:

- 7,0 for copper and copper alloy pipes
- 10,0 for cold drawn seamless steel pipes fabricated according to a welding procedure approved by the Society
- 12,5 for hot laminated seamless steel pipes.

b) The thickness thus determined does not take into account the particular loads to which pipes may be subjected. Attention is to be drawn in particular to the case of high temperature and low temperature pipes.

Table 5 : Minimum wall thickness for steel pipes

External diameter, in mm	Minimum nominal wall thickness, in mm			Minimum reinforced wall thickness, in mm **(2)**	Minimum extra reinforced wall thickness, in mm **(3) (4)**
	Sea water pipes, bilge and ballast systems **(1)**		Other piping systems **(1) (4)**		
	normally full **(4)**	normally empty			
10,2 - 12,0	–	–	1,6	–	–
13,5 - 19,3	–	–	1,8	–	–
20,0	–	–	2,0	–	–
21,3 - 25,0	3,2	2,4	2,0	–	–
26,7 - 33,7	3,2	2,4	2,0	–	–
38,0 - 44,5	3,6	2,6	2,0	4,8	7,1
48,3	3,6	2,6	2,3	5,0	7,1
51,0 - 63,5	4,0	2,9	2,3	5,0	7,6
70,0	4,0	2,9	2,6	5,0	7,6
76,1 - 82,5	4,5	2,9	2,6	5,0	7,6
88,9 - 108,0	4,5	3,2	2,9	5,4	7,8
114,3 - 127,0	4,5	3,6	3,2	6,0	8,8
133,0 - 139,7	4,5	4,0	3,6	6,3	9,5
152,4 - 168,3	4,5		4,0	7,1	11,0
177,8	5,0		4,0	8,1	12,7
193,7	5,4		4,0	8,1	12,7
219,1	5,9		4,0	8,1	12,7
244,5 - 273,0	6,3		4,0	8,8	12,7
298,5 - 368,0	6,3		4,5	8,8	12,7
406,4 - 457,2	6,3		5,6	8,8	12,7

External diameter, in mm	Minimum nominal wall thickness, in mm			Minimum reinforced wall thickness, in mm **(2)**	Minimum extra reinforced wall thickness, in mm **(3)** **(4)**
	Sea water pipes, bilge and ballast systems **(1)**		Other piping systems **(1)** **(4)**		
	normally full **(4)**	normally empty			

(1) Attention is drawn to the special requirements regarding:
- bilge and ballast systems
- scupper and discharge pipes
- sounding, air and overflow pipes
- ventilation systems
- oxyacetylene welding systems
- CO_2 fire-extinguishing systems (see Ch 4, Sec 13)

(2) Reinforced wall thickness applies to pipes passing through tanks containing a fluid distinct from that conveyed by the pipe, however the pipe thickness may not be greater than the tank plating.
(3) Extra-reinforced wall thickness applies to pipes connected to the shell, however the pipe thickness may not be greater than what required by these Rules for shell.
(4) For pipes efficiently protected against corrosion, the thickness may be reduced by an amount up to than 1 mm.
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.
Note 2: The thickness of threaded pipes is to be measured at the bottom of the thread.
Note 3: The minimum thickness listed in this table is the nominal wall thickness and no allowance is required for negative tolerance or reduction in thickness due to bending.
Note 4: For larger diameters, the minimum wall thickness will be specially considered by the Society.

Table 6 : Minimum wall thickness for copper and copper alloy pipes

External diameter, in mm	Minimum wall thickness, in mm	
	Copper	Copper alloy
8 - 10	1,0	0,8
12 - 20	1,2	1,0
25 - 44,5	1,5	1,2
50 - 76,1	2,0	1,5
88,9 - 108	2,5	2,0
133 - 159	3,0	2,5
193,7 - 267	3,5	3,0
273 - 457,2	4,0	3,5
470	4,0	3,5
508	4,5	4,0

Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.

Table 7 : Minimum wall thickness for stainless steel pipes

External diameter, in mm	Minimum wall thickness,in mm
up to 17,2	1,0
up to 48,3	1,6
up to 88,9	2,0
up to 168,3	2,3
up to 219,1	2,6
up to 273,0	2,9
up to 406,4	3,6
over 406,4	4

Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.

Table 8 : Minimum wall thickness for aluminium and aluminium alloy pipes

External diameter, in mm	Minimum wall thickness,in mm
0 - 10	1,5
12 - 38	2,0
43 - 57	2,5
76 - 89	3,0
108 - 133	4,0
159 - 194	4,5
219 - 273	5,0
above 273	5,5
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards. **Note 2:** For sea water pipes, the minimum thickness is not to be less than 5 mm.	

2.2.2 Permissible stress

a) For carbon steel and alloy steel pipes with a design temperature equal to or less than 300 °C, the value of the permissible stress K is to be taken equal to the lowest of the following values:

- $R_{m,20}$ / 2,4 or R_e / 1,5 when the materials tests are carried out under the supervision of the Society
- $R_{m,20}$ / 2,7 or R_e / 1,8 when the materials tests are not carried out under the supervision of the Society

where:

$R_{m,20}$: Minimum tensile strength of the material at ambient temperature (20°C), in N/mm²

R_e : Minimum yield strength or 0,2% proof stress at the design temperature, in N/mm²

b) For carbon steel and alloy steel pipes with a design temperature above 300 °C and for copper and copper alloy pipes, the permissible stress K is given in:

- Tab 9 for carbon and carbon-manganese steel pipes
- Tab 10 for alloy steel pipes, and
- Tab 11 for copper and copper alloy pipes,

as a function of the temperature. Intermediate values may be obtained by interpolation.

c) The permissible stress values adopted for materials other than carbon steel, alloy steel, copper and copper alloy will be specially considered by the Society.

2.2.3 Thickness reduction due to bending

a) Unless otherwise justified, the thickness reduction b due to bending is to be determined by the following formula:

$$b = \frac{Dt_0}{2{,}5\rho}$$

where:

ρ : Bending radius measured on the centre line of the pipe, in mm

D : As defined in [1.4.1]

t_0 : As defined in [2.2.1].

b) When the bending radius is not given, the thickness reduction is to be taken equal to:

t_0 / 10

c) For straight pipes, the thickness reduction is to be taken equal to 0.

Table 9 : Permissible stresses for carbon and carbon-manganese steel pipes

Specified minimum tensile strength, in N/mm²	Design temperature, in °C							
	300	350	400	410	420	430	440	450
320	62	57	55	55	54	54	54	49
360	76	69	68	68	68	64	56	49
410	93	86	84	79	71	64	56	49
460	111	101	99	98	85	73	62	53
490	121	111	109	98	85	73	62	53

Table 10 : Permissible stresses for alloy steel pipes

Type of steel	Specified minimum tensile strength, in N/mm²	Design temperature, in °C						
		300	350	400	440	450	460	470
1Cr1/2Mo	440	114	106	102	101	101	100	99
2 1/4Cr1Mo annealed	410	50	47	45	44	43	43	42
2 1/4Cr1Mo normalized and tempered below 750°C	490	144	140	136	130	128	127	116
2 1/4Cr1Mo normalized and tempered above 750°C	490	144	140	136	130	122	114	105
1/2Cr 1/2Mo 1/4V	460	120	115	111	106	105	103	102

Type of steel	Specified minimum tensile strength, in N/mm²	Design temperature, in °C									
		480	490	500	510	520	530	540	550	560	570
1Cr1/2Mo	440	98	97	91	76	62	51	42	34	27	22
2 1/4Cr1Mo annealed	410	42	42	41	41	41	40	40	40	37	32
2 1/4Cr1Mo normalized and tempered below 750°C	490	106	96	86	79	67	58	49	43	37	32
2 1/4Cr1Mo normalized and tempered above 750°C	490	96	88	79	72	64	56	49	43	37	32
1/2Cr 1/2Mo 1/4V	460	101	99	97	94	82	72	62	53	45	37

Table 11 : Permissible stresses for copper and copper alloy pipes

Material (annealed)	Specified minimum tensile strength, in N/mm²	Design temperature, in °C										
		≤ 50	75	100	125	150	175	200	225	250	275	300
Copper	215	41	41	40	40	34	27,5	18,5				
Aluminium brass	325	78	78	78	78	78	51	24,5				
Copper-nickel 95/5 and 90/10	275	68	68	67	65,5	64	62	59	56	52	48	44
Copper-nickel 70/30	365	81	79	77	75	73	71	69	67	65,5	64	62

2.2.4 Corrosion allowance

The values of corrosion allowance c are given for steel pipes in Tab 12 and for non-ferrous metallic pipes in Tab 13.

2.2.5 Tees

As well as complying with the provisions of [2.2.1] to [2.2.4], the thickness t_T of pipes on which a branch is welded to form a Tee is not to be less than that given by the following formula:

$$t_T = \left(1 + \frac{D_1}{D}\right) \cdot t_0$$

where:

D_1 : External diameter of the branch pipe

D : As defined in [1.4.1]

t_0 : As defined in [2.2.1].

Note 1: This requirement may be dispensed with for Tees provided with a reinforcement or extruded.

Table 12 : Corrosion allowance for steel pipes

Piping system		Corrosion allowance, in mm
Superheated steam		0,3
Saturated steam		0,8
Steam coils in liquid fuel tanks		2,0
Feed water for boilers in open circuit systems		1,5
Feed water for boilers in closed circuit systems		0,5
Blow-down systems for boilers		1,5
Compressed air		1,0
Hydraulic oil		0,3
Lubricating oil		0,3
Fuel oil and JP5-NATO(F44)		1,0
Thermal oil		1,0
Fresh water		0,8
Sea water	normally full normally empty **(1)**	3,0 2,0
Refrigerants referred to in Section 13		0,3

(1) Assuming that arrangements are made to allow complete drainage of the pipe.
Note 1: For pipes passing through tanks, an additional corrosion allowance is to be considered in order to account for the external corrosion.
Note 2: The corrosion allowance of pipes efficiently protected against corrosion may be reduced by no more than 50%.
Note 3: When the corrosion resistance of alloy steels is adequately demonstrated, the corrosion allowance may be disregarded.

Table 13 : Corrosion allowance for non-ferrous metal pipes

Piping material **(1)**	Corrosion allowance, in mm**(2)**
Copper	0,8
Brass	0,8
Copper-tin alloys	0,8
Copper-nickel alloys with less than 10% of Ni	0,8
Copper-nickel alloys with at least 10% of Ni	0,5
Aluminium and aluminium alloys	0,5

(1) The corrosion allowance for other materials will be specially considered by the Society. Where their resistance to corrosion is adequately demonstrated, the corrosion allowance may be disregarded.
(2) In cases of media with high corrosive action, a higher corrosion allowance may be required by the Society.

2.3 Calculation of high temperature pipes

2.3.1 General

For main steam piping having a design temperature exceeding 400°C, calculations are to be submitted to the Society concerning the stresses due to internal pressure, piping weight and any other external load, and to thermal expansion, for all cases of actual operation and for all lengths of piping.

The calculations are to include, in particular:

- the components, along the three principal axes, of the forces and moments acting on each branch of piping
- the components of the displacements and rotations causing the above forces and moments
- all parameters necessary for the computation of forces, moments and stresses.

In way of bends, the calculations are to be carried out taking into account, where necessary, the pipe ovalisation and its effects on flexibility and stress increase.

A certain amount of cold springing, calculated on the basis of expected thermal expansion, is to be applied to the piping during installation. Such springing is to be neglected in stress calculations; it may, however, be taken into account in terms of its effect on thrusts on turbines and other parts.

2.3.2 Thermal stress

The combined stress σ_{ID}, in N/mm², due to thermal expansion, calculated by the following formula:

$$\sigma_{ID} = (\sigma^2 + 4\tau^2)^{0,5}$$

is to be such as to satisfy the following equation:

$$\sigma_{ID} \le 0,75K_{20} + 0,25K_T$$

where:

σ : Value of the longitudinal stress due to bending moments caused by thermal expansion, increased, if necessary, by adequate factors for bends, in N/mm²; in general it is not necessary to take account of the effect of axial force

τ : Value of the tangential stress due to torque caused by thermal expansion, in N/mm²; in general it is not necessary to take account of the effect of shear force

K_{20} : Value of the permissible stress for the material employed, calculated according to [2.2.2], for a temperature of 20°C, in N/mm²

K_T : Value of the permissible stress for the material employed, calculated according to [2.2.2], for the design temperature T, in N/mm².

2.3.3 Longitudinal stresses

The sum of longitudinal stresses σ_L, in N/mm², due to pressure, piping weight and any other external loads is to be such as to satisfy the following equation:

$$\sigma_L \le K_T$$

where K_T is defined in [2.3.2].

2.3.4 Alternative limits for permissible stresses

Alternative limits for permissible stresses may be considered by the Society in special cases or when calculations have been carried out following a procedure based on hypotheses other than those considered above.

2.4 Junction of pipes

2.4.1 General

a) The junctions between metallic pipe lengths or between metallic pipe lengths and fittings are to be made by:
   - direct welding (butt-weld, socket-weld)
   - bolted flanges (welded-on or screwed-on)
   - threaded sleeve joints, or
   - mechanical joints (see [2.4.5]).

   The joints are to comply with a recognized standard or to be of a design proven to be suitable for the intended purpose and acceptable to the Society. See also [2.1.2].

   The expression “mechanical joints” means devices intended for direct connection of pipe lengths other than by welding, flanges or threaded joints described in [2.4.2], [2.4.3] and [2.4.4].

b) The number of joints in flammable oil piping systems is to be kept to the minimum necessary for mounting and dismantling purposes.

c) The gaskets and packings used for the joints are to suit the design pressure, the design temperature and the nature of the fluids conveyed.

d) The junction between plastic pipes is to comply with Ch 1, App 2.

2.4.2 Welded metallic joints

a) Welded joints are to be used in accordance with Tab 14. Welding and non destructive testing of welds are to be carried out in accordance with Article [3].

b) Butt-welded joints are to be of full penetration type, with or without special provision for a high quality of root side.

   The expression "special provision for a high quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by the Society.

c) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions in compliance with a standard recognised by the Society.

2.4.3 Metallic flange connections

a) Flanges are to comply with a standard recognized by the Society. This standard is to cover the design pressure and design temperature of the piping system.

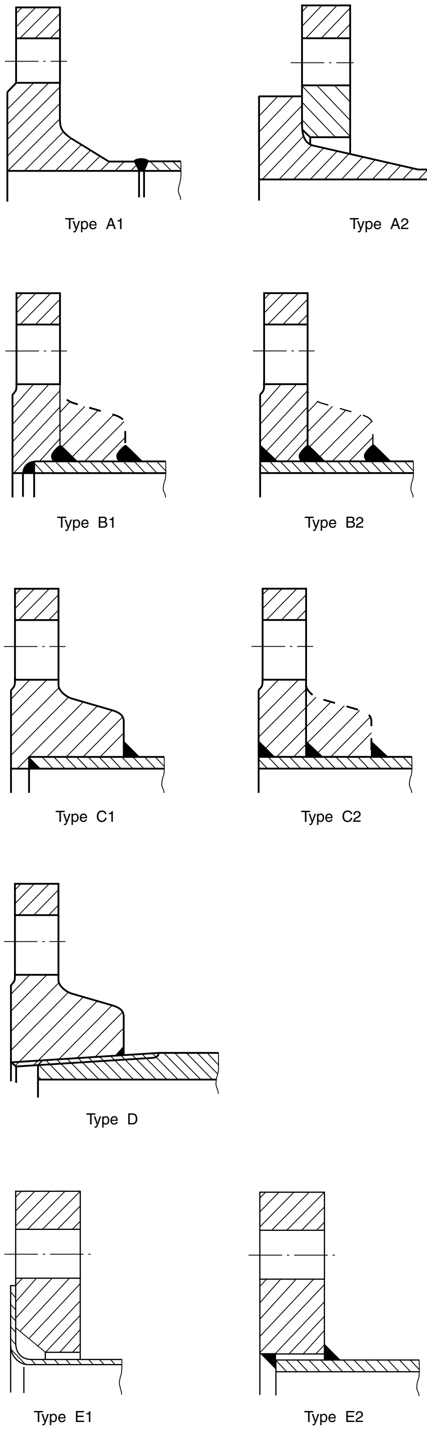
b) Flange material is to be suitable for the nature and temperature of the fluid, as well as for the material of the pipe on which the flange is to be attached.

c) Flanges are to be attached to the pipes by welding or screwing in accordance with one of the designs shown in Fig 1.

Permitted applications are indicated in Tab 15.

Alternative methods of attachment will be specially considered by the Society.

Figure 1 : Types of metallic flange connections



Note 1: For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.

Note 2: The leg length of the fillet weld, as well as the dimension of the groove penetration in the flange, is to be in general equal to 1,5 times the pipe thickness but not less than 5 mm.

2.4.4 Slip-on threaded joints

a) Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads are to comply with requirements of a recognized national or international standard and are to be acceptable to the Society.

b) Slip-on threaded joints may be used for piping systems in accordance with Tab 14.

c) Threaded joints may be accepted also in CO_2 piping systems, provided that they are used only inside protected spaces and in CO_2 cylinder rooms.

Table 14 : Use of welded and threaded metallic joints in piping systems

Joints	Permitted classes of piping	Restrictions of use
Butt-welded, with special provision for a high quality of root side **(1)**	III, II, I	No restrictions
Butt-welded, without special provision for a high quality of root side **(1)**	III, II	No restrictions
Slip-on sleeve and socket welded **(2)**	III	no restrictions
Threaded sleeve joints with tapered thread **(3)**	I	Not allowed for: • pipes with outside diameter of more than 33,7 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
	III, II	Not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
Threaded sleeve joints with parallel thread **(3)**	III	Not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

(1) For expression “special provision for a high quality of root side” see [2.4.2] item b).
(2) Particular cases may be allowed by the Society for piping systems of Class I and II having outside diameter ≤ 88,9 mm except for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
(3) In particular cases, sizes in excess of those mentioned above may be accepted by the Society if found in compliance with a recognised national and/or international standard.
Note 1: Other applications will be specially considered by the Society.

Table 15 : Use of metallic flange connections in piping systems (types as shown in Fig 1)

Type of media conveyed	Class of piping (see Tab 3)		
	I	II	III
Toxic or corrosive media Flammable liquids (where heated above flashpoint or having flashpoint < 60°C) Liquefied gases	A1, A2, B1, B2, B3 **(1) (2) (4)**	A1, A2, B1, B2, B3, C1, C2, C3 **(1) (4)**	not applicable
Fuel oil Lubricating oil	A1, A2, B1, B2, B3	A1, A2, B1, B2, B3, C1, C2, C3	A1, A2, B1, B2, B3, C1, C2, C3, E2
Steam Thermal oil	A1, A2, B1, B2, B3 **(2) (3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2
Other media as water, air, gases (refrigerants), non-flammable hydraulic oil, etc.	A1, A2, B1, B2, B3 **(3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E1, E2 **(5) (6) (7)**

(1) When design pressure p (see [1.3.2]) exceeds 1 MPa, types A1 and A2 only.
(2) For nominal diameter ND ≥ 150 mm, types A1 and A2 only.
(3) When design temperature T (see [1.3.3] exceeds 400°C, types A1 and A2 only.
(4) For cargo piping carrying chemical products covered by the IBC Code, IBC Code Ch. 5, 5.3 is to be applied. For cargo piping carrying gas products covered by the IGC Code, IGC Code Ch. 5, 5.4 is to be applied.
(5) Type E2 only, for design pressure p ≤ 1,6 Mpa and design temperature T ≤ 150°C.
(6) Types D and E1 only, for design temperature T ≤ 250°C.
(7) Type E1 only, for water pipelines and for open ended lines (e.g. drain, overflow, air vent piping, etc.).

2.4.5 Mechanical joints

Due to the great variations in design and configuration of mechanical joints, specific recommendation regarding calculation method for theoretical strength calculations is not specified. The Type Approval is to be based on the results of testing of the actual joints.

Below specified requirements are applicable to pipe unions, compression couplings, slip-on joints as shown in Fig 2. Similar joints complying with these requirements may be acceptable.

a) Mechanical joints including pipe unions, compression couplings, slip-on joints and similar joints are to be of approved type for the service conditions and the intended application.

b) Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

c) Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

d) Material of mechanical joints is to be compatible with the piping material and internal and external media.

e) As far as applicable, the mechanical joints are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure is to be specially considered by the Society.

f) In general, mechanical joints are to be of fire resistant type as required by Tab 16.

g) Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the shell openings or tanks containing flammable fluids.

h) The mechanical joints are to be designed to withstand internal and external pressure as applicable and, where used in suction lines, are to be capable of operating under vacuum.

i) The number of mechanical joints in flammable liquid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

j) Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

k) Slip-on joints are not to be used in pipelines in tanks and other spaces which are not easily accessible (refer to IMO Circular MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media as the pipe where the joint is fitted. Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

l) Application of mechanical joints and their acceptable use for each service is indicated in Tab 16; dependence upon the class of piping, pipe dimensions, working pressure and temperature is indicated in Tab 17.

m) In some particular cases, sizes in excess of those mentioned above may be accepted by the Society if they are in compliance with a recognised national and/or international standard.

n) Application of various mechanical joints may be accepted as indicated by Tab 16. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

o) Mechanical joints are to be tested in accordance with the provisions of Tab 37.

2.5 Protection against overpressure

2.5.1 General

a) These requirements deal with the protection of piping systems against overpressure, with the exception of heat exchangers and pressure vessels, which are dealt with in Ch 1, Sec 3, [2.4].

b) Safety valves are to be sealed after setting.

2.5.2 Protection of flammable oil systems

Provisions shall be made to prevent overpressure in any flammable oil tank or in any part of the flammable oil systems, including the filling pipes.

2.5.3 Protection of pump and compressor discharges

a) Provisions are to be made so that the discharge pressure of pumps and compressors cannot exceed the pressure for which the pipes located on the discharge of these pumps and compressors are designed.

b) When provided on the pump discharge for this purpose, safety valves are to lead back to the pump suction.

c) The discharge capacity of the safety valves installed on pumps and compressors is to be such that the pressure at the discharge side cannot exceed by more than 10% the design pressure of the discharge pipe in the event of operation with closed discharge.

2.5.4 Protection of pipes

a) Pipes likely to be subjected to a pressure exceeding their normal working pressure are to be provided with safety valves or equivalent overpressure protecting devices.

b) In particular, pipes located on the low pressure side of pressure reducing valves are to be provided with safety valves unless they are designed for the maximum pressure on the high pressure side of the pressure reducing valve. See also [1.3.2] and [2.9.1].

c) The discharge capacity of the devices fitted on pipes for preventing overpressure is to be such that the pressure in these pipes cannot exceed the design pressure by more than 10%.

Figure 2 : Examples of mechanical joints

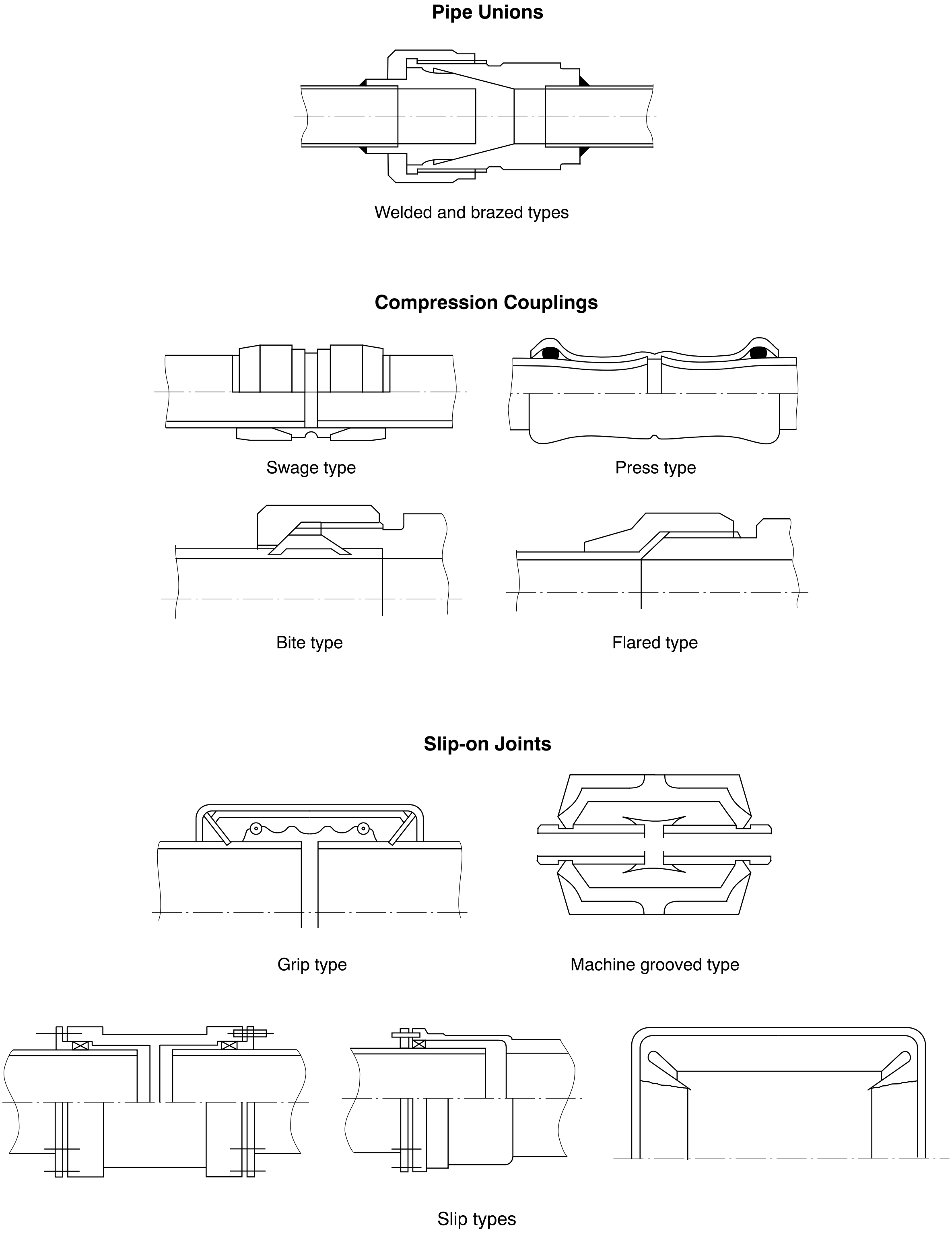


Table 16 : Application of mechanical joints

Systems		Kind of connections		
		Pipe unions	Compression couplings **(5)**	Slip-on joints
Flammable fluids (flash point > 60°C)				
1	JP5-NATO(F44) lines	+	+	+ **(2) (3)**
2	Fuel oil lines	+	+	+ **(2) (3)**
3	Lubricating oil lines	+	+	+ **(2) (3)**
4	Hydraulic oil	+	+	+ **(2) (3)**
5	Thermal oil	+	+	+ **(2) (3)**
Sea water				
6	Bilge lines	+	+	+ **(1)**
7	Fire main and water spray	+	+	+**(3)**
8	Foam system	+	+	+**(3)**
9	Sprinkler system	+	+	+ **(3)**
10	Ballast system	+	+	+ **(1)**
11	Cooling water system	+	+	+ **(1)**
12	Tank cleaning services	+	+	+
13	Non-essential systems	+	+	+
Fresh water				
14	Cooling water system	+	+	+ **(1)**
15	Condensate return	+	+	+ **(1)**
16	Non-essential systems	+	+	+
Sanitary/Drains/Scuppers				
17	Deck drains (internal)	+	+	+ **(4)**
18	Sanitary drains	+	+	+
19	Scuppers and discharge (overboard)	+	+	–
Sounding/Vent				
20	Water tanks/Dry spaces	+	+	+
21	Oil tanks (flash point > 60°C)	+	+	+ **(2) (3)**
Miscellaneous				
22	Starting/Control air **(1)**	+	+	–
23	Service air (non-essential)	+	+	+
24	Brine	+	+	+
24	CO_2 system **(1)**	+	+	–
25	Steam	+	+	–

Note 1:
+ : Application is allowed
– : Application is not allowed.
(1) Inside machinery spaces of category A - only approved fire resistant types.
(2) Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
(3) Approved fire resistant types.
(4) Above freeboard deck only.
(5) If compression couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for slip-on joints.

Table 17 : Application of mechanical joints depending upon the class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe Unions			
Welded and brazed types	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Compression Couplings			
Swage type	+	+	+
Bite type Flared type	+ (OD ≤ 60,3 mm) + (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm) + (OD ≤ 60,3 mm)	+ +
Press type	–	–	+
Slip-on Joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
Note 1: + : Application is allowed – : Application is not allowed.			

2.6 Flexible hoses and expansion joints

2.6.1 General

a) Definitions:
   - Flexible hose assembly: short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.
   - Expansion joint: an assembly designed to safely absorb the heat-induced expansion and contraction, mainly to allow axial relative movement between pipes and the ship's structure as required in [5.6].

b) Flexible hoses and expansion joints are to be of a type approved by the Society. Unless otherwise specified, they are to comply with the requirements of this sub-article.

c) The requirements of this sub-article apply to flexible hoses and expansion joints of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporarily connected flexible hoses or hoses of portable equipment.

d) Unless otherwise specified, the requirements of this sub-article do not apply for flexible hose assemblies and expansion joints intended to be used in fire-extinguishing systems.

e) Flexible hose assemblies and expansion joints intended for piping systems with a design temperature below the ambient temperature are subject to special consideration by the Society.

2.6.2 General conditions of use applicable to flexible hoses and expansion joints

a) Unless otherwise specified, the Society may permit the use of flexible hoses and expansion joints, made of both metallic and non-metallic materials, provided they are approved for the intended service. They may be accepted for use in oil fuel, JP5-NATO (F44), lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, Class III steam systems and exhaust gas systems where they comply with the requirements of this sub-article.

b) For steam systems, the flexible hose assemblies and expansion joints are to be of metallic construction.

c) The position of flexible hose assemblies and expansion joints is to be clearly shown on the drawings listed in [1.2.1] and [1.2.2] when submitted to the Society.

d) Flexible hose assembly or an expansion joint is to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any requirements of the Society.

e) The arrangement and installation of the flexible hose assemblies and expansion joints are also to comply with [5.9.3].

f) The distance between pipe flanges is to be between the manufactured contraction length and extension length of relevant flexible hose.

2.6.3 Specific conditions of use applicable to flexible hoses

a) Flexible hose assembly is not accepted in high pressure fuel oil injection systems.

b) Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1,5 m in length.

2.6.4 General requirements for the design of flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be designed and constructed in accordance with recognised National or International standards acceptable to the Society.

b) Acceptance of a flexible hose assembly or an expansion joint is subject to satisfactory prototype testing in accordance with the provisions of [19.2].

c) The material, design and construction are to be at least suitable for:
- marine environment and external contact with hydrocarbons
- internal contact and resistance to the fluid they are to convey
- maximal pressure and temperature of fluid they are to convey
- maximum expected forces due to vibrations
- maximum expected impulse peak pressure.

The metallic materials are to comply with [2.1.2].

d) Where rubber materials are intended for use in bilge, ballast, compressed air, oil fuel, JP5-NATO (F44), lubricating, hydraulic and thermal oil systems, the construction is to incorporate a single, double, or more, closely woven integral wire braid or other suitable material reinforcement acceptable to the Society.

Flexible hoses and expansion joints of plastic materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid, are to have suitable material reinforcement, as far as practicable.

Rubber or plastic material hoses and expansion joints used in oil supply lines to burners are to have external wire braid protection in addition to the reinforcement mentioned above.

e) Flexible hose assemblies and expansion joints constructed of non-metallic materials, which are intended for installation in piping systems for flammable media or in sea water systems where failure may result in flooding, are to be of fire-resistant type except in cases where such hoses are installed on open decks as defined in Ch 4, Sec 5, [1.2.3], item b) (5) and not used for fuel oil or JP5-NATO (F44) lines.

Fire resistance is to be demonstrated by testing in accordance with standard specified in Tab 33 and Tab 35.

f) Flexible hoses and expansion joints are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with [2.4.5] as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose or expansion joint with particular reference to pressure and impulse tests.

2.6.5 Specific requirements for the design of flexible hoses

The hose clamps and similar types of end attachments are not acceptable for use in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0,5 MPa and provided that there are double clamps at each end connection.

2.6.6 Marking

Flexible hoses or expansion joints are to be permanently marked by the manufacturer with the following details:
- manufacturer's name or trademark
- date of manufacture (month/year)
- designation type reference
- nominal diameter
- pressure rating
- temperature rating.

Where a flexible hose assembly or an expansion joint is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

2.7 Valves and accessories

2.7.1 General

a) Valves and accessories are normally to be built in accordance with a recognized standard.

Failing this, they are to be approved by the Society when they are fitted:
- in a class I piping system, or
- in a class II piping system with a diameter exceeding 100 mm, or
- on the ship side, on the collision bulkhead or on fuel or JP5-NATO (F44) tanks under static pressure.

b) Shut-off valves are to be provided where necessary to isolate pumps, heat exchangers, pressure vessels, etc., from the rest of the piping system, and in particular:
- to allow the isolation of duplicate components without interrupting the fluid circulation
- for maintenance or repair purposes.

2.7.2 Design of valves and accessories

a) Materials of valve and accessory bodies are to comply with [2.1].

b) Connections of valves and accessories with pipes are to comply with [2.4].

c) All valves and accessories are to be so designed as to prevent the loosening of covers and glands when they are operated.

d) Valves are to be so designed as to shut with a right-hand (clockwise) motion of the wheels.

e) Valves are to be provided with local indicators showing whether they are open or shut, unless this is readily apparent.

2.7.3 Valves with remote control

a) All valves which are provided with remote control are also to be designed for local manual operation.

b) The remote control system and means of local operation are to be independent. In this respect, arrangement of the local operation by means of a fixed hand pump will be specially considered by the Society.

c) In the case of valves which are to be provided with remote control in accordance with the Rules, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

d) Power failure of the remote control system is not to cause an undesired change of the valve position.

2.8 Sea inlets and overboard discharges

2.8.1 General

Except where expressly stated in Article [8], the requirements of this sub-article do not apply to scuppers and sanitary discharges.

2.8.2 Design of sea inlets and overboard discharges

a) All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing accidental ingress of water into the ship.

b) Sea inlets and overboard discharges are to be fitted with valves complying with [2.7] and [2.8.3].

c) Sea inlets and discharges related to the operation of main and auxiliary machinery are to be fitted with readily accessible valves between the pipes and the shell plating or between the pipes and fabricated boxes attached to the shell plating. The valves may be controlled locally and are to be provided with indicators showing whether they are open or closed.

d) Sea inlets are to be so designed and arranged as to limit turbulence and to avoid the ingress of air due to motion of the ship.

e) Sea inlets are to be fitted with gratings complying with [2.8.4].

f) Provisions are to be made for clearing sea inlet gratings.

g) Sea chests are to be suitably protected against corrosion.

2.8.3 Valves

a) Sea inlet and overboard discharge valves are to be secured:
   - directly on the shell plating, or
   - on sea chests built on the shell plating, with scantlings in compliance with Part B of the Rules, or
   - on extra-reinforced and short distance pieces attached to the shell (see Tab 5).

b) The bodies of the valves and distance pieces are to have a spigot passing through the plating without projecting beyond the external surface of such plating or of the doubling plates and stiffening rings, if any.

c) Valves are to be secured by means of:
   - bolts screwed through the plating with a countersunk head, or
   - studs screwed in heavy pads themselves secured to the hull or chest plating, without penetration of the plating by the stud holes.

d) The use of butterfly valves will be specially considered by the Society. In any event, butterfly valves not fitted with flanges are not to be used for water inlets or overboard discharges unless provisions are made to allow disassembling at sea of the pipes served by these valves without any risk of flooding.

e) The materials of the valve bodies and connecting pieces are to comply with Tab 4.

2.8.4 Gratings

a) Gratings are to have a free flow area not less than twice the total section of the pipes connected to the inlet.

b) When gratings are secured by means of screws with a countersunk head, the tapped holes provided for such screws are not to pass through the plating or doubling plates outside distance pieces or chests.

c) Screws used for fixing gratings are not to be located in the corners of openings in the hull or of doubling plates.

d) In the case of large sea inlets, the screws used for fixing the gratings are to be locked and protected from corrosion.

e) When gratings are cleared by use of compressed air or steam devices, the chests, distance pieces and valves of sea inlets and outlets thus arranged are to be so constructed as to withstand the maximum pressure to which they may be subjected when such devices are operating.

2.8.5 Ship side connections for blow-down of boilers

a) Blow-down pipes of boilers are to be provided with cocks or valves placed as near the end of the pipes as possible, while remaining readily accessible and located above the engine room floor.

b) Blow-down valves are to be so designed that it is easy to ascertain whether they are open or shut. Where cocks are used, the control keys are to be such that they cannot be taken off unless the cocks are shut. Where valves are used, the control-wheels are to be permanently fixed to the spindle.

c) A protection ring is to be fitted on the shell plating, outside, at the end of the blow-down pipes. The spigot of the valve referred to in [2.8.3], item b), is to pass through this ring.

2.9 Control and monitoring

2.9.1 General

a) Local indicators are to be provided for at least the following parameters:
   - pressure, in pressure vessels, at pump or compressor discharge, at the inlet of the equipment served, on the low pressure side of pressure reducing valves
   - temperatures, in tanks and vessels, at heat exchanger inlet and outlet
   - levels, in tanks and vessels containing liquids.

b) Safeguards are to be provided where an automatic action is necessary to restore acceptable values for a faulty parameter.

c) Automatic controls are to be provided where it is necessary to maintain parameters related to piping systems at a pre-set value.

2.9.2 Level gauges

Level gauges used in flammable oil systems are to be of a type approved by the Society and are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel.

Level gauges, when allowed, are to be made of heat-resistant material and efficiently protected against shocks.

3 Welding of steel piping

3.1 Application

3.1.1

a) The following requirements apply to welded joints belonging to class I or II piping systems.
   At the discretion of the Society they may also be requested for class III piping systems.

b) This article does not apply to refrigerated spaces installation piping systems operating at temperatures lower than minus 40°C.

c) The requirements for qualification of welding procedures are given in NR216 Materials and Welding.

3.2 General

3.2.1 Welding processes

a) Welded joints of pipes are to be made by means of electric arc or oxyacetylene welding, or any other previously approved process.

b) When the design pressure exceeds 0,7 MPa, oxyacetylene welding is not permitted for pipes with an external diameter greater than 100 mm or a thickness exceeding 6 mm.

3.2.2 Location of joints

The location of welded joints is to be such that as many as possible can be made in a workshop. The location of welded joints to be made on board is to be so determined as to permit their joining and inspection in satisfactory conditions.

3.3 Design of welded joints

3.3.1 Types of joints

a) Except for the fixing of flanges on pipes in the cases mentioned in Fig 1 and for the fixing of branch pipes, joints between pipes and between pipes and fittings are to be of the butt-welded type. However, for class I pipes with internal diameter not exceeding 50 mm and for class II pipes, socket welded connections of approved types may be used.

b) For butt-welded joints between pipes or between pipes and flanges or other fittings, correctly adjusted backing rings may be used; such rings are to be either of the same grade of steel as the elements to be welded or of such a grade as not to adversely influence the weld; if the backing ring cannot be removed after welding, it is to be correctly profiled.

3.3.2 Assembly of pipes of unequal thickness

If the difference of thickness between pipes to be butt-welded exceeds 10% of the thickness of the thinner pipe plus 1 mm, subject to a maximum of 4 mm, the thicker pipe is to be thinned down to the thickness of the thinner pipe on a length at least equal to 4 times the offset, including the width of the weld if so desired.

3.3.3 Accessories

a) When accessories such as valves are connected by welding to pipes, they are to be provided with necks of sufficient length to prevent abnormal deformations during the execution of welding or heat treatment.

b) For the fixing by welding of branch pipes on pipes, it is necessary to provide either a thickness increase as indicated in [2.2.5] or a reinforcement by doubling plate or equivalent.

3.4 Preparation of elements to be welded and execution of welding

3.4.1 General

Attention is drawn to the provisions of Ch 1, Sec 3, which apply to the welding of pressure pipes.

3.4.2 Edge preparation for welded joints

The preparation of the edges is preferably to be carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching, grinding or chipping back to sound metal.

3.4.3 Abutting of parts to be welded

a) The elements to be welded are to be so abutted that surface misalignments are as small as possible.

b) As a general rule, for elements which are butt-welded without a backing ring the misalignment between internal walls is not to exceed the lesser of:

   - the value given in Tab 18 as a function of thickness t and internal diameter d of these elements, and
   - t / 4.

   Where necessary, the pipe ends are to be bored or slightly expanded so as to comply with these values; the thickness obtained is not to be less than the Rule thickness.

c) In the case of welding with a backing ring, smaller values of misalignment are to be obtained so that the space between the backing ring and the internal walls of the two elements to be assembled is as small as possible; normally this space is not to exceed 0,5 mm.

d) The elements to be welded are to be adequately secured so as to prevent modifications of their relative position and deformations during welding.

e) Tack welds should be made with an electrode suitable for the base metal; tack welds which form part of the finished weld should be made using approved procedures.

   When welding materials requiring preheating are employed, the same preheating should be applied during tack welding.

3.4.4 Protection against adverse weather conditions

a) Pressure pipes are to be welded, both on board and in the shop, away from draughts and sudden temperature variations.

b) Unless special justification is given, no welding is to be performed if the temperature of the base metal is lower than 0°C.

3.4.5 Preheating

a) Preheating is to be performed as indicated in Tab 19, depending on the type of steel, the chemical composition and the pipe thickness.

b) The temperatures given in Tab 19 are based on the use of low hydrogen processes. Where low hydrogen processes are not used, the Society reserves the right to require higher preheating temperatures.

3.5 Post-weld heat treatment

3.5.1 General

a) As far as practicable, the heat treatment is to be carried out in a furnace. Where this is impracticable, and more particularly in the case of welding on board, the treatment is to be performed locally by heating uniformly a circular strip, extending on at least 75 mm on both sides of the welded joint; all precautions are to be taken to permit accurate checking of the temperature and slow cooling after treatment.

b) For austenitic and austenitic ferritic steels, post-weld head treatment is generally not required.

3.5.2 Heat treatment after welding other than oxyacetylene welding

a) Stress relieving heat treatment after welding other than oxyacetylene welding is to be performed as indicated in Tab 20, depending on the type of steel and thickness of the pipes.

b) The stress relieving heat treatment is to consist in heating slowly and uniformly to a temperature within the range indicated in the Table, soaking at this temperature for a suitable period, normally 2 min. per mm of thickness with a minimum of half an hour, cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling in still atmosphere.

c) In any event, the heat treatment temperature is not to be higher than $(T_T - 20)$°C, where T_T is the temperature of the final tempering treatment of the material.

3.5.3 Heat treatment after oxyacetylene welding

Stress relieving heat treatment after oxyacetylene welding is to be performed as indicated in Tab 21, depending on the type of steel.

Table 18 : Maximum value of misalignment

d, in mm	t, in mm		
	$t \leq 6$	$6 < t \leq 10$	$10 < t$
$d < 150$	1,0	1,0	1,0
$150 \leq d < 300$	1,0	1,5	1,5
$300 \leq d$	1,0	1,5	2,0

Table 19 : Preheating temperature

Type of steel		Thickness of thicker part, in mm	Minimum preheating temperature, in °C
C and C-Mn steels	$C + \frac{Mn}{6} \leq 0{,}40$	$t \geq 20$**(2)**	50
	$C + \frac{Mn}{6} > 0{,}40$	$t \geq 20$ **(2)**	100
0,3 Mo		$t \geq 13$ **(2)**	100
1 Cr 0,5 Mo		$t < 13$ $t \geq 13$	100 150
2,25 Cr 1 Mo **(1)**		$t < 13$ $t \geq 13$	150 200
0,5 Cr 0,5 Mo V **(1)**		$t < 13$ $t \geq 13$	150 200

(1) For 2,25 Cr 1 Mo and 0,5 Cr 0,5 Mo V grades with thicknesses up to 6 mm, preheating may be omitted if the results of hardness tests carried out on welding procedure qualification are considered acceptable by the Society.
(2) For welding in ambient temperature below 0°C, the minimum preheating temperature is required independent of the thickness unless specially approved by the Society.

Table 20 : Heat treatment temperature

Type of steel	Thickness of thicker part, in mm	Stress relief treatment temperature, in °C
C and C-Mn steels	$t \geq 15$ **(1)** **(3)**	550 to 620
0,3 Mo	$t \geq 15$ **(1)**	580 to 640
1 Cr 0,5 Mo	$t \geq 8$	620 to 680
2,25 Cr 1 Mo 0,5 Cr 0,5 Mo V	any **(2)**	650 to 720

(1) Where steels with specified Charpy V notch impact properties at low temperature are used, the thickness above which post-weld heat treatment is to be applied may be increased, subject to the special agreement of the Society.
(2) For 2,25Cr 1Mo and 0,5Cr 0,5Mo V grade steels, heat treatment may be omitted for pipes having thickness lower than 8 mm, diameter not exceeding 100 mm and service temperature not exceeding 450°C.
(3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness, subject to the special agreement of the Society.

Table 21 : Heat treatment after oxyacetylene welding

Type of steel	Heat treatment and temperature, in °C
C and C-Mn	Normalizing 880 to 940
0,3 Mo	Normalizing 900 to 940
1Cr-0,5Mo	Normalizing 900 to 960 Tempering 640 to 720
2,25Cr-1Mo	Normalizing 900 to 960 Tempering 650 to 780
0,5Cr-0,5Mo-0,25V	Normalizing 930 to 980 Tempering 670 to 720

3.6 Inspection of welded joints

3.6.1 General

a) The inspection of pressure pipe welded joints is to be performed at the various stages of the fabrication further to the qualifications defined in [3.1.1], item c).

b) The examination mainly concerns those parts to be welded further to their preparation, the welded joints once they have been made and the conditions for carrying out possible heat treatments.

c) The required examinations are to be carried out by qualified operators in accordance with procedures and techniques to the Surveyor’s satisfaction.

3.6.2 Visual examination

Welded joints, including the inside wherever possible, are to be visually examined.

3.6.3 Non-destructive examinations

a) Non-destructive tests for class I pipes are to be performed as follows:
   - butt-welded joints of pipes with an external diameter exceeding 75 mm are to be subjected to full X-ray examination or equivalent
   - welded joints other than butt-welded joints and which cannot be radiographed are to be examined by magnetic particle or liquid penetrant tests
   - fillet welds of flange connections are to be examined by magnetic particle tests or by other appropriate non-destructive tests.

b) Non-destructive tests for class II pipes are to be performed as follows:
   - butt-welded joints of pipes with an external diameter exceeding 100 mm are to be subjected to at least 10% random radiographic examination or equivalent
   - welded joints other than butt-welded joints are to be examined by magnetic particle tests or by other appropriate non-destructive tests
   - fillet welds of flange connections may be required to be examined by magnetic particle tests or by other appropriate non-destructive tests, at the discretion of the Surveyor.

3.6.4 Defects and acceptance criteria

a) Joints for which non-destructive examinations reveal unacceptable defects are to be re-welded and subsequently to undergo a new non-destructive examination. The Surveyor may require that the number of joints to be subjected to non-destructive examination is larger than that resulting from the provisions of [3.6.3].

b) The acceptance criteria of defects are:
   - for class I pipes, those defined in NR216 Materials and Welding for the special quality level
   - for class II pipes, those defined in NR216 Materials and Welding for the normal quality level.

4 Bending of pipes

4.1 Application

4.1.1 This Article applies to pipes made of:

- alloy or non-alloy steels
- copper and copper alloys
- stainless steel.

4.2 Bending process

4.2.1 General

The bending process is to be such as not to have a detrimental influence on the characteristics of the materials or on the strength of the pipes.

4.2.2 Bending radius

Unless otherwise justified, the bending radius measured on the centreline of the pipe is not to be less than:

- twice the external diameter for copper and copper alloy, C steel and stainless steel pipes
- 3 times the external diameter for cold bent steel pipes.

4.2.3 Acceptance criteria

a) The pipes are to be bent in such a way that, in each transverse section, the difference between the maximum and minimum diameters after bending does not exceed 10% of the mean diameter; higher values, but not exceeding 15%, may be allowed in the case of pipes which are not subjected in service to appreciable bending stresses due to thermal expansion or contraction.

b) The bending is to be such that the depth of the corrugations is as small as possible and does not exceed:
- 5% of the corrugation length for class I and class II piping systems
- 9% of the corrugation length for class III piping system.

4.2.4 Hot bending

a) In the case of hot bending, all arrangements are to be made to permit careful checking of the metal temperature and to prevent rapid cooling, especially for alloy steels.

b) Hot bending is to be generally carried out in the temperature range 850°C-1000°C for all steel grades; however, a decreased temperature down to 750°C may be accepted during the forming process.

4.3 Heat treatment after bending

4.3.1 Copper and copper alloy

Copper and copper alloy pipes are to be suitably annealed after cold bending if their external diameter exceeds 50 mm.

4.3.2 Steel

a) After hot bending carried out within the temperature range specified in [4.2.4], the following applies:
- for C, C-Mn and C-Mo steels, no subsequent heat treatment is required,
- for Cr-Mo and Cr-Mo-V steels, a subsequent stress relieving heat treatment in accordance with Tab 20 is required.

b) After hot bending performed outside the temperature range specified in [4.2.4], a subsequent new heat treatment in accordance with Tab 21 is required for all grades.

c) Unless otherwise agreed, after cold bending at a radius lower than 4 times the external diameter of the pipe, a heat treatment in accordance with Tab 21 is required.

5 Arrangement and installation of piping systems

5.1 General

5.1.1 Unless otherwise specified, piping and pumping systems covered by the Rules are to be permanently fixed on board ship.

5.2 Location of tanks and piping system components

5.2.1 Flammable oil systems

Location of tanks and piping system components conveying flammable fluids under pressure is to comply with [5.10].

5.2.2 Piping systems with open ends

Attention is to be paid to the requirements for the location of open-ended pipes on board ships having to comply with the provisions of [5.5].

5.2.3 Pipe lines located inside tanks

a) The passage of pipes through tanks, when permitted, normally requires special arrangements such as reinforced thickness or tunnels, in particular for:
- bilge pipes
- ballast pipes
- scuppers and sanitary discharges
- air, sounding and overflow pipes
- fuel oil and JP5-NATO (F44) pipes.

b) Junctions of pipes inside tanks are to be made by welding or welded flange connections. See also [2.4.3].

5.2.4 Overboard discharges

Overboard discharges are to be so located as to prevent any discharge of water into the lifeboats while they are being lowered.

5.2.5 Piping and electrical apparatus

As far as possible, pipes are not to pass near switchboards or other electrical apparatus. If this requirement is impossible to satisfy, gutterways or masks are to be provided wherever deemed necessary to prevent projections of liquid or steam on live parts.

5.3 Passage through watertight bulkheads or decks

5.3.1 Penetration of watertight bulkheads and decks

a) Where penetrations of watertight bulkheads and internal decks are necessary for piping, arrangements are to be made to maintain the watertight integrity.

b) Lead or other heat sensitive materials are not to be used in piping systems which penetrate watertight subdivision bulkheads or decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkhead or decks.

   This applies in particular to the following systems:
   - bilge system
   - ballast system
   - scuppers and sanitary discharge systems.

c) Where bolted connections are used when passing through watertight bulkheads or decks, the bolts are not to be screwed through the plating. Where welded connections are used, they are to be welded on both sides of the bulkhead or deck.

d) In case of penetrations of watertight bulkheads or decks by plastic pipes, case by case considerations will be made by the Society in agreement with the Naval Authority and based on Ch 1, App 2, [4.7.2].

5.3.2 Passage through the collision bulkhead

a) A maximum of two pipes may pass through the collision bulkhead below the bulkhead deck, unless otherwise justified. Such pipes are to be fitted with suitable valves operable from above the bulkhead deck and the valve chest is to be secured at the bulkhead inside the fore peak. Such valves may be fitted on the after side of the collision bulkhead provided that they are readily accessible under all service conditions and the space in which they are located is not a cargo space or similar space. All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

b) The remote operation device of the valve referred to in a) is to include an indicator to show whether the valve is open or shut.

5.4 Independence of lines

5.4.1 As a general rule, bilge and ballast lines are to be entirely independent and distinct from lines conveying lubricating oil, fuel oil and JP5-NATO(F44), with the exception of:

- pipes located between collecting boxes and pump suctions
- pipes located between pumps and overboard discharges
- pipes supplying compartments likely to be used alternatively for ballast or fuel oil, provided such pipes are fitted with blind flanges or other appropriate change-over devices, in order to avoid any mishandling.

5.5 Prevention of progressive flooding

5.5.1 Principle

a) In order to comply with the subdivision and damage stability requirements of Pt B, Ch 3, Sec 3, provision is to be made to prevent any progressive flooding of a dry compartment served by any open-ended pipe, in the event that such pipe is damaged or broken in any other compartment by collision or grounding.

b) For this purpose, if pipes are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired. Refer to Pt B, Ch 3, Sec 3.

5.5.2 Extent of damage

For the definition of the assumed transverse extent of damage, reference is to be made to Pt B, Ch 3, Sec 3.

5.6 Provision for expansion

5.6.1 General

Piping systems are to be so designed and pipes so fixed as to allow for relative movement between pipes and the ship’s structure, having due regard to:

- the temperature of the fluid conveyed
- the coefficient of thermal expansion of the pipes material
- the deformation of the ship’s hull.

5.6.2 Fitting of expansion devices

All pipes subject to thermal expansion and those which, due to their length, may be affected by deformation of the hull, are to be fitted with expansion pieces or loops.

5.7 Supporting of the pipes

5.7.1 General

Unless otherwise specified, the fluid lines referred to in this Section are to consist of pipes connected to the ship's structure by means of collars or similar devices.

5.7.2 Arrangement of supports

Shipyards are to take care that:

a) The arrangement of supports and collars is to be such that pipes and flanges are not subjected to abnormal bending stresses, taking into account their own mass, the metal they are made of, and the nature and characteristics of the fluid they convey, as well as the contractions and expansions to which they are subjected.

b) Heavy components in the piping system, such as valves, are to be independently supported.

5.8 Protection of pipes

5.8.1 Protection of sea water pipes from mechanical damage

Seawater pipes in vehicle and ro-ro spaces are to be protected from impact of cargo where they are liable to be damaged.

For ships having a **SEA-KEEP** additional class notation, requirements of Pt E, Ch 9, Sec 3 also apply.

5.8.2 Protection against corrosion and erosion

a) Pipes are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

b) The layout and arrangement of sea water pipes are to be such as to prevent sharp bends and abrupt changes in section as well as zones where water may stagnate. The inner surface of pipes is to be as smooth as possible, especially in way of joints. Where pipes are protected against corrosion by means of galvanizing or other inner coating, arrangements are to be made so that this coating is continuous, as far as possible, in particular in way of joints.

c) Provided that due consideration is given to water velocity with regards to maximum allowed noise levels, such velocity is not to exceed 3 m/s in continuously used sea water systems.

d) Arrangements are to be made to avoid galvanic corrosion.

5.8.3 Protection against frosting

Pipes are to be adequately insulated against cold wherever deemed necessary to prevent frost.

This applies specifically to pipes passing through refrigerated spaces and which are not intended to ensure the refrigeration of such spaces.

Were the pipes are normally kept empty and without risk of frost of condensate or were it is proven that the flow of internal fluid is sufficient to prevent frost the present requirement of insulation could be withdrawn.

5.8.4 Protection of high temperature pipes and components

a) All pipes and other components where the temperature may exceed 220°C are to be efficiently insulated. Where necessary, precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b) Particular attention is to be paid to lagging in way of flanges.

5.9 Valves, accessories and fittings

5.9.1 General

Cocks, valves and other accessories are generally to be arranged so that they are easily visible and accessible for manoeuvring, control and maintenance. They are to be installed in such a way as to operate properly.

5.9.2 Valves and accessories

a) In machinery spaces and tunnels, the cocks, valves and other accessories of the fluid lines referred to in this Section are to be placed:
   - above the floor, or
   - when this is not possible, immediately under the floor, provided provision is made for their easy access and control in service.

b) Control-wheels of low inlet valves are to rise at least 0,45 m above the lowest floor.

5.9.3 Flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be so arranged as to be accessible at all times.

b) Flexible hoses and expansion joints are to be as short as possible.

c) The radius of curvature of flexible hoses is not to be less than the minimum recommended by the manufacturer.

d) The adjoining pipes are to be suitably aligned, supported, guided and anchored.

e) Isolating valves are to be provided permitting the isolation of flexible hoses intended to convey flammable oil or compressed air.

f) Expansion joints are to be protected against over extension or over compression.

g) Where they are likely to suffer external damage, flexible hoses and expansion joints are to be provided with adequate protection.

5.9.4 Thermometers

Thermometers and other temperature-detecting elements in fluid systems under pressure are to be provided with pockets built and secured so that the thermometers and detecting elements can be removed while keeping the piping under pressure.

5.9.5 Pressure gauges

Pressure gauges and other similar instruments are to be fitted with an isolating valve or cock at the connection with the main pipe.

5.9.6 Nameplates

a) Accessories such as cocks and valves on the fluid lines referred to in this Section are to be provided with nameplates indicating the apparatus and lines they serve except where, due to their location on board, there is no doubt as to their purpose.

b) Nameplates are to be fitted at the upper part of air and sounding pipes.

5.10 Additional arrangements for flammable fluids

5.10.1 General

The requirements in [5.10.3] and [5.10.4] apply to:

- fuel oil systems and JP5-NATO (F44), in all spaces
- lubricating oil systems, in machinery spaces
- other flammable oil systems, in locations where means of ignition are present.

5.10.2 Prohibition of carriage of flammable oils in forepeak tanks

In all ships fuel oil, JP5-NATO (F44) and lubricating oil and other flammable oils are not to be carried in forepeak tanks or tanks forward of the collision bulkhead.

5.10.3 Prevention of flammable oil leakage ignition

a) As far as practicable, parts of the fuel, JP5-NATO (F44) oil and lubricating oil systems containing heated oil under pressure exceeding 0,18 MPa are to be placed above the platform or in any other position where defects and leakage can readily be observed.

   The machinery spaces in way of such parts are to be adequately illuminated.

b) No flammable oil tanks are to be situated where spillage or leakage therefrom can constitute a hazard by falling on:

   - hot surfaces, including those of boilers, heaters, steam pipes, exhaust manifolds and silencers
   - electrical equipment
   - air intakes
   - other sources of ignition.

c) Parts of flammable oil systems under pressure exceeding 0,18 MPa such as pumps, filters and heaters are to comply with the provisions of item b) above.

d) Flammable oil lines are to be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakages onto hot surfaces, into machinery air intakes, or on other sources of ignition.

e) Any relief valve of fuel oil, JP5-NATO (F44) and lubricating oil systems is to discharge to a safe position, such as an appropriate tank.

5.10.4 Provisions for flammable oil leakage containment

a) Tanks used for the storage of flammable oils together with their fittings are to be so arranged as to prevent spillages due to leakage or overfilling.

b) Drip trays with adequate drainage to contain possible leakage from flammable fluid systems are to be fitted:

   - under independent tanks (refer to Ch 1, App 3, [2.3.2])
   - under burners
   - under purifiers and any other oil processing equipment
   - under pumps, heat exchangers and filters
   - under valves and all accessories subject to oil leakage
   - surrounding internal combustion engines.

c) The coaming height of drip trays is to suit the amount of potential oil spillage.

d) Where boilers are located in machinery spaces on decks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the decks are to be provided with oil-tight coamings at least 200 mm in height.

e) Where drain pipes are provided for collecting leakages, they are to be led to an appropriate drain tank.

5.10.5 Drain tank

a) The drain tank is not to form part of an overflow system and is to be fitted with an overflow alarm device.

b) In ships provided with a double bottom, appropriate precautions are to be taken when the drain tank is constructed in the double bottom, in order to avoid flooding of the machinery space where drip trays are located, in the event of accidentally running aground.

5.10.6 Valves

All valves and cocks forming part of flammable oil systems are to be capable of being operated from readily accessible positions and, in machinery spaces, from above the working platform.

5.10.7 Level switches

Level switches fitted to flammable oil tanks are to be contained in a steel or other fire-resisting enclosure.

6 Bilge systems

6.1 Principle

6.1.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment other than spaces permanently dedicated to the carriage of fresh water, ballast water, fuel oil or JP5-NATO (F44) and for which other efficient means of pumping are provided, under all practical conditions.

To this purpose ships shall be provided with means to cope with drainage of great amount of water in every compartment. In addition propulsion machinery spaces and auxiliary machinery spaces, where substantial oil leakages may occur, shall be provided with bilge means which prevent sea pollution by avoiding overboard discharge of water and oil bilge (see requirements of Annex I of MARPOL 73/78).

6.2 Design of bilge systems

6.2.1 General

a) The bilge pumping installation is to include a bilge draining system serving all watertight spaces, designed to drain the effluents resulting from limited and occasional leakages, and consisting of:

- an oily bilge water draining and treatment system dedicated to machinery spaces, including auxiliary machinery spaces, tunnels and other spaces where oil leakage may occur
- a separate clean bilge water system dedicated to the other spaces. This system may be provided by a bilge main, by independent bilge main sections or by dedicated system.

  Power bilge pumps or ejectors are to serve the bilge main or each independent bilge main section. They may serve several compartments.

  Power bilge pumps or ejectors discharging locally overboard could be provided for dedicated systems.
- it is pointed out that where required the oily bilge water draining and treatment system is not in replacement of the clean bilge water system but in supplement.

b) If deemed acceptable by the Society, bilge pumping arrangements may be dispensed with in specific compartments provided the safety of the ship is not impaired.

6.2.2 Distribution of bilge suctions

a) Complete draining of watertight spaces is to be possible, when the ship is on an even keel and either is upright or has a list of up to 5°.

b) Clean bilge draining system

   At least one suction is to be fitted in all spaces served by the clean bilge draining system.

c) Oily bilge draining and treatment system

   At least two suctions are to be fitted in all spaces served by the oily bilge draining and treatment system.

d) In all cases, arrangements are to be made such as to allow a free and easy flow of water to bilge suctions.

6.2.3 Prevention of communication between spaces Independence of the lines

a) Provisions are to be made to avoid any risk of flooding of one compartment by another one through any bilge circuit.

b) Bilge lines are to be entirely independent and distinct from other lines.

6.3 Drainage arrangements of vehicle and ro-ro spaces and ammunition storages fitted with a fixed pressure water-spraying fire-extinguishing system

6.3.1 Vehicle and ro-ro spaces and ammunition spaces fitted with a fixed pressure water-spraying fire-extinguishing system shall be provided with draining arrangements such as to prevent the build-up of free surface.

Scuppers and discharge shall be provided as stated in [8], in particular in ammunition storages and shall discharge to ship bilge and thereafter drained by flooding power pumps or, if appropriate, equivalent (see [6.6.2]) ejectors.

6.4 Draining of machinery spaces

6.4.1 General

In propulsion machinery spaces and in auxiliary machinery spaces, where substantial oil leakages may occur, the bilge suctions are to be distributed and arranged in accordance with the provisions of [6.2.2].

6.4.2 Additional requirements for spaces containing electric motors

In electrically propelled ships, provision is to be made to prevent accumulation of water under electric generators and motors.

6.5 Draining of dry cofferdams, dry fore and after peaks and dry spaces above fore and after peaks, tunnels and refrigerated spaces

6.5.1 Draining of cofferdams

All cofferdams are to be provided with dedicated power bilge pumps or equivalent ejectors discharging locally overboard unless they are fitted with bilge suctions connected to the bilge main. Such pumps or ejectors may serve several compartments.

6.5.2 Draining of fore and after peaks

a) Where the peaks are not used as tanks the drainage of both peaks shall be realised by a dedicated power bilge pump or ejector discharging overboard locally.

b) Except where permitted in [5.3.2], the collision bulkhead is not to be pierced below the bulkhead deck.

6.5.3 Draining of spaces above fore and after peaks

a) Provision is to be made for the drainage of the chain lockers and watertight compartments above the fore peak tank by power pump suctions

b) In any case, steering gear compartments and other small enclosed spaces located above the peak tank are to be provided with bilge suctions of a dedicated power bilge pump, or an equivalent ejector, fitted above the bulkhead deck.

6.5.4 Draining of tunnels

For the purpose of the present Article [6] tunnels are to be considered as propulsion machinery spaces.

Tunnels are to be drained by means of suctions connected to the oily water bilge system. Such suctions are generally to be located in wells at the aft end of the tunnels.

6.5.5 Draining of refrigerated spaces

Provision is to be made for the continuous drainage of condensate in refrigerated and air cooler spaces. To this end, valves capable of blanking off the water draining lines of such spaces are not to be fitted.

6.6 Bilge pumps

6.6.1 Number and arrangement of pumps

a) The oily bilge pumping system is to be provided with two dedicated power pumps connected to the manifold of that system.

b) If a clean bilge main is fitted, at least two dedicated power pumps are to be connected to the bilge main.

c) If independent bilge main sections are fitted, at least two dedicated power pumps are to be connected to each section.

d) For dedicated bilge system as defined in [6.2.1] one dedicated power pump or ejector is to be connected.

6.6.2 Portable means of pumping

Each safety zone is to comprise at least one portable means of pumping (pump or ejector) allowing the draining of all spaces other than main and auxiliary machinery spaces.

6.6.3 Capacity of the pumps

a) The capacity of each pump serving the oily bilge water system shall be not less than 5 m^3/h.

b) The capacity of each pump, in m^3/h, of the clean water bilge system, where a bilge main is provided, is not to be less than:

   $Q = 0{,}00565\ d^2$

   where:

   d : Internal diameter of the clean water bilge pipe as defined in [6.7.2], item a).

c) Where a bilge main is not provided, the capacity of each clean water dedicated power bilge pump, in m^3/h, is not to be less than:

$$Q = 0{,}00565\ d_1^2$$

where:

d_1 : Internal diameter of the clean water bilge pipe as defined in [6.7.2], item c).

d) The capacity of each dedicated pump of the clean water bilge system, in m^3/h, where several bilge main sections are provided, is not to be less than:

$$Q = 0{,}00565\ d_2^2$$

where:

d_2 : Internal diameter of each clean water bilge pipe as defined in [6.7.2], item b).

6.6.4 Choice of the pumps

a) All bilge pumps, including clean and oily water pumps, are to be of the self-priming type.

Centrifugal pumps are to be fitted with efficient priming means, unless an approved priming system is provided to ensure the priming of pumps under normal operating conditions.

6.7 Size of bilge pipes

6.7.1 Size of oily bilge water pipes

The actual internal diameter of the oily bilge water pipes is to be calculated assuming a water velocity less than 5 m/s. It is in any case not to be less than 40 mm.

6.7.2 Size of clean water bilge pipes

a) The internal diameter of the clean water bilge main, in mm, is to be calculated according to the following formula:

$$d = 25 + 1,68\sqrt{L(B + D)}$$

where:

L : Length between perpendiculars, in m

B : Breath of the ship at draught, in m

D : Moulded depth of the ship to the control deck, in m.

b) Were the bilge system consist of independent sections, the internal diameter of each section, in mm, is to be calculated according to the following formula:

$$d_2 = 25 + 1,68\sqrt{L_2(B + D)}$$

where:

L_2 : Total of length of the compartments served by the section, in m

B, D : As defined in item a).

c) The internal diameter of the clean water bilge pipe, in mm, between dedicated pumps or bilge main and suction in compartments, is to be calculated according to the following formula:

$$d_1 = 25 + 2,16\sqrt{L_1(B + D)}$$

where:

L_1 : Length of the compartment, in m

B, D : As defined in item a).

d_1 is not to be less than 50 mm and need not exceed 100 mm.

6.8 Bilge accessories

6.8.1 Drain valves on watertight bulkheads

a) Drain valves or similar devices shall not be fitted on the collision bulkhead.

b) On other watertight bulkheads, the fitting of drain valves or similar devices is allowed unless practical alternative draining means exist. Such valves are to be easily accessible at all times and are to be normally closed.

6.8.2 Screw-down non-return valves

a) Accessories are to be provided to prevent intercommunication of compartments or lines which are to remain segregated from one another. For this purpose, non-return devices are to be fitted:

- on the pipe connections to bilge distribution boxes or to the alternative valves, if any
- on flexible bilge hose connections
- on the suctions of water bilge ejectors
- in compliance with the provisions for prevention of progressive flooding.

b) Screw-down and other non-return valves are to be of a type recognized by the Society as not offering undue obstruction to the flow of water.

6.8.3 Strainers

The open ends of bilge lines are to be fitted with readily accessible strum boxes or strainers having an open area of not less than twice the area of the suction pipe.

Strum boxes are to be so designed that they can be cleaned without having to remove any joint on the suction pipe.

6.8.4 Bilge wells

a) The wells provided for draining the various compartments are to be made of steel plate and their capacity is to be not less than 0,15 m^3. In small compartments, smaller cylindrical wells may be fitted.

b) Bilge wells are to comply with the relevant provisions of Part B.

6.9 Bilge piping arrangement

6.9.1 Provision for expansion

Where necessary, bilge pipes inside tanks are to be fitted with expansion bends. Sliding joints are not permitted for this purpose.

6.9.2 Connections

Connections used for bilge pipes passing through tanks are to be welded joints or reinforced welded flange connections.

6.9.3 Access to valves and distribution boxes

All distribution boxes and manually operated valves in connection with the bilge pumping arrangement shall be in positions which are accessible under normal circumstances.

6.9.4 Location of bilge pumps and pipes

Bilge pumps and piping system are not to be situated at a distance less than B/5 from the ship side, where B is the ship's width.

7 Ballast systems

7.1 Design of ballast systems

7.1.1 Ballast system and independence of ballast lines

The ship shall be provided with ballast systems if so requested by the Naval Authority.

Ballast lines are to be entirely independent and distinct from other lines except where allowed in [5.4] and in [7.2.1].

7.2 Ballast pumping arrangement

7.2.1 Filling and suction pipes

a) All tanks including aft and fore peak and double bottom tanks intended for ballast water are to be provided with suitable filling and suction pipes connected to power driven pumps of adequate capacity.

   Alternatively, ballast tanks can be filled by the fire main and drained by an ejector supplied by the fire main.

   Alternatively, ballast tanks can possibly be filled by gravity subject to additional valve on direct filling pipe.

b) Suctions are to be so positioned that the transfer of sea water can be suitably carried out in the normal operating conditions of the ship. In particular, two suctions may be required in long compartments.

7.2.2 Piping

In no case the internal diameter of ballast piping is to be less than 50 mm.

7.2.3 Passage of ballast pipes through tanks

If not contained in pipe tunnels, the parts of ballast pipes through tanks intended to contain fresh water or fuel oil shall have increased thickness, as per Tab 5 for steel pipes, and shall consist of either a single piece or several pieces assembled by welding or by devices deemed equivalent for the application considered. Parts of ballast pipes passing through JP5-NATO (F44) tanks, if not contained in pipe tunnel, shall be of jacketed type provided with means for ascertaining leakages.

8 Scuppers and sanitary discharges

8.1 Application

8.1.1

a) This Article applies to scuppers of any type of ships.

b) Discharges in connection with machinery operation are dealt with in [2.8].

8.1.2 Ships to be assigned the additional class notation **CBRN** or **CBRN-AIRBLAST RESISTANCE** are to comply with the requirements of Pt E, Ch 8, Sec 4 in addition to the requirements of the present Article.

8.2 Principle

8.2.1 Scuppers

a) The scupper installation is to be so designed as to allow overboard gravity draining of any water introduced in all spaces, compartments, open decks and areas located above the damage control deck.

b) The number of scuppers openings in the shell plating is to be reduced to a minimum by making each discharge, sufficient in number and suitable in size, are to be provided to permit the drainage of water likely to accumulate in the spaces which are not located in the ship's bottom.

c) The number of scuppers openings in the shell plating is to be reduced to a minimum by making each discharge serve as many pipes as possible. Alternative satisfactory solutions may be accepted.

d) The scupper piping system is to be designed and arranged so as to ensure quick draining of the concerned space considering a permanent list of 5° and in all normal trim conditions of the ship.

8.2.2 Sanitary discharges

The sewage piping system is to be designed taking into consideration the possible generation of toxic and flammable gases (such as hydrogen sulfide, methane, ammonia) during the sewage treatment.

Air pipes from the sewage and grey water systems are to be independent of all other air pipes and to be led to the outside of the ship, away from any air intake.

8.3 Drainage from spaces below the bulkhead deck or within enclosed superstructures and deckhouses on or above the bulkhead deck

8.3.1 Normal arrangement

Scuppers from spaces below the bulkhead deck or from within superstructures and deckhouses on or above the bulkhead deck the deck fitted with doors complying with the provisions of Pt B, Ch 8, Sec 6 are to be led to the bilge. As an alternative, [8.6] and [8.7] are to be complied with.

Scuppers of open deck shall be led overboard.

8.4 Drainage of enclosed vehicle and ro-ro spaces situated on the bulkhead deck

8.4.1 General

Means of drainage are to be provided for enclosed vehicle and ro-ro spaces situated on the bulkhead deck. The Society may allow the absence of means of drainage in any of the above spaces if it is satisfied that, due to the size or internal subdivision of such space, the safety of the ship is not impaired.

8.4.2 Cases where the bulkhead deck side line is not immersed when the ship heels more than 5°

Scuppers from vehicle and ro-ro spaces, led through the shell, are to comply with the requirements stated in [8.7]; alternatively drainage is to be led overboard in accordance to [8.4.3].

8.4.3 Cases where the bulkhead deck side line is immersed when the ship heels 5° or less

If scuppers from vehicle and ro-ro spaces are immersed when the ship heels 5° or less, the drainage of such spaces on the bulkhead deck is to be led to a suitable space, or spaces, of appropriate capacity, having a high water level alarm and provided with arrangements for discharge overboard. In addition, it is to be ensured that:

- the number, size and arrangement of the scuppers are such as to prevent unreasonable accumulation of free water
- the pumping arrangements take account of the requirements for any fixed pressure water-spraying fire-extinguishing system
- where the enclosed space is protected by a gas fire-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

8.5 Drainage arrangement of vehicle and ro-ro spaces or ammunition spaces fitted with a fixed pressure water-spraying fire-extinguishing system

8.5.1 Scupper draining

Scuppers from vehicle and ro-ro spaces are not to be led to machinery spaces or other places where sources of ignition may be present.

Scuppers from ammunition spaces are to discharge directly overboard. The discharge pipe is to be fitted with a valve whose opening is to be automatically controlled by the activation of the drenching system. Alternatively, the scupper pipe may be fitted with a spring loaded valve.

Each ammunition space is to have its own drainage system.

8.5.2 Prevention of build-up of free surfaces

In vehicle and ro-ro spaces fitted with a fixed pressure water-spraying fire-extinguishing system, the drainage arrangement is to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water are to be taken into account to the extent deemed necessary by the Society in its approval of the stability information. Refer to Pt B, Ch 3, Sec 3.

In ammunition spaces the adverse effect upon the stability of the added weight and free surface of water, as well as those of the spaces in which the water is collected, are to be accounted in Pt B, Ch 3, Sec 3.

8.6 Arrangement of discharges from spaces below the margin line

8.6.1 Normal arrangement

Each separate discharge led though the shell plating from spaces below the margin line is to be provided with one automatic non-return valve fitted with positive means of closing it from above the damage control deck.

8.6.2 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,01 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve:

- is above the deepest subdivision load line, and
- is always accessible for examination under service conditions.

8.7 Arrangement of discharges from spaces above the margin line

8.7.1 General

The provisions of this sub-article are applicable only to those discharges which remain open during the normal operation of a ship. For discharges which must necessarily be closed at sea, such as gravity drains from topside ballast tanks, a single screw-down valve operated from the deck may be accepted.

8.7.2 Normal arrangement

Normally, each separate discharge led though the shell plating from spaces above the margin line is to be provided with:

- one automatic non-return valve fitted with positive means of closing it from a position above the damage control deck, or
- one automatic non-return valve and one sluice valve controlled from above the damage control deck.

8.7.3 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,01 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that:

- the inboard valve is above the level of the deepest subdivision waterline so as to always be accessible for examination under service conditions, or
- where this is not practicable, a locally controlled sluice valve is interposed between the two automatic non-return valves.

8.7.4 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,02 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,02 L, a single automatic non-return valve without positive means of closing may be accepted subject to the approval of the Society.

8.7.5 Arrangement of discharges through manned machinery spaces

Where sanitary discharges and scuppers lead overboard through the shell in way of manned machinery spaces, the fitting at the shell of a locally operated positive closing valve together with a non-return valve inboard may be accepted. The operating position of the valve will be given special consideration by the Society.

8.7.6 Arrangement of discharges through the shell more than 450 mm below the watertight deck or less than 600 mm above the deepest subdivision waterline

Scupper and discharge pipes originating at any level and penetrating the shell either more than 450 mm below the watertight deck or less than 600 mm above the deepest subdivision waterline are to be provided with a non-return valve at the shell. Unless required by [8.7.2] to [8.7.4], this valve may be omitted if the piping is of substantial thickness, as per Tab 23.

8.7.7 Arrangement of discharges through the shell less than 450 mm below the watertight deck and more than 600 mm above the deepest subdivision waterline

Scupper and discharge pipes penetrating the shell less than 450 mm below the damage control deck and more than 600 mm above the deepest subdivision waterline are not required to be provided with a non-return valve at the shell.

8.8 Summary table of overboard discharge arrangements

8.8.1 The various arrangements acceptable for scuppers and sanitary overboard discharges are summarized in Fig 3.

8.9 Valves and pipes

8.9.1 Materials

a) All shell fittings and valves are to be of steel, bronze or other ductile material. Valves of ordinary cast iron or similar material are not acceptable. All scupper and discharge pipes are to be of steel or other ductile material. Refer to [2.1].

b) Plastic shall not be used for scuppers and discharge piping.

c) For the pipe likely to contain flammable oils, the provisions of Ch 4, Sec 10, [3.2.1] are also to be fulfilled.

8.9.2 Thickness of pipes

a) The thickness of scupper and discharge pipes led to the bilge or to draining tanks, or pipes other than in item b) is not to be less than that required in [2.2].

b) The thickness of scupper and discharge pipes led to the shell is not to be less than the minimum thickness given in Tab 22 and Tab 23.

8.9.3 Scupper size

Internal diameters of scupper pipes are not to be less than 40 mm.

8.9.4 Operation of the valves

Where valves are required to have positive means of closing, such means is to be readily accessible and provided with an indicator showing whether the valve is open or closed.

Figure 3 : Overboard discharge arrangement

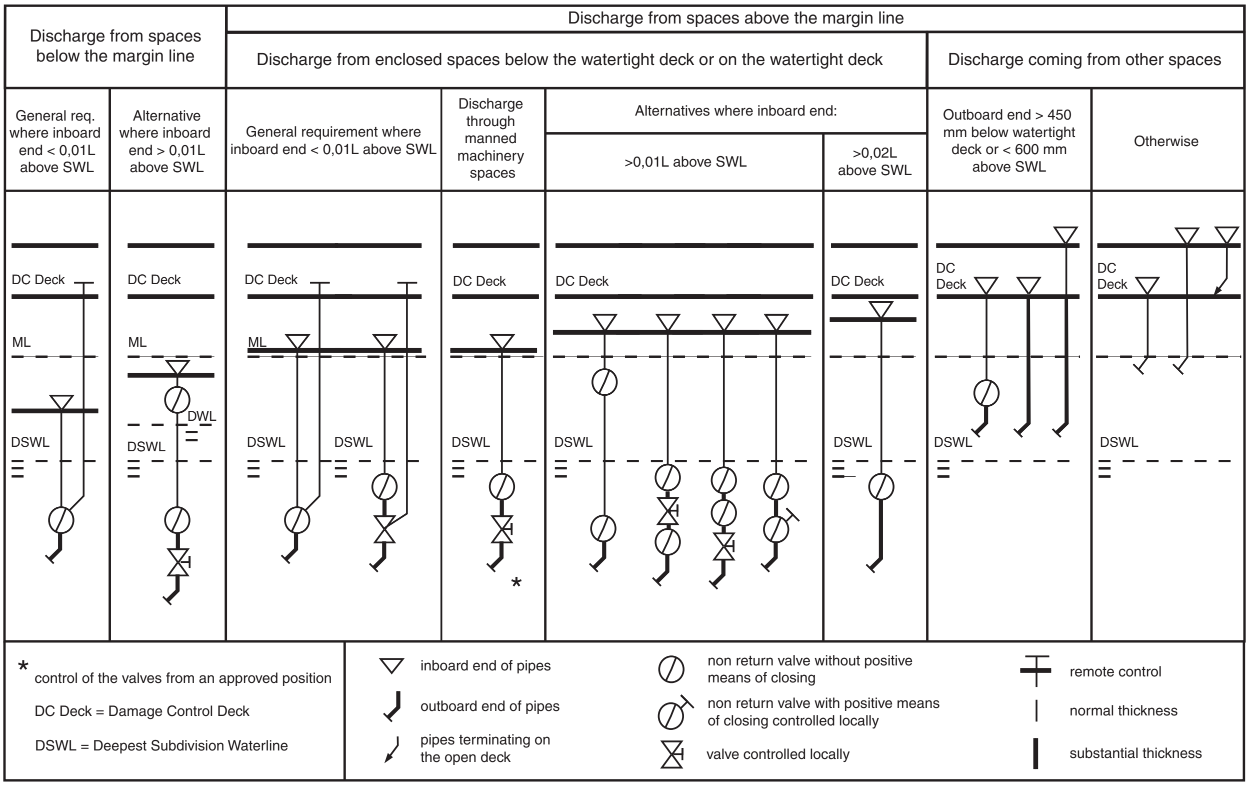


Table 22 : Thickness of scupper and discharge pipes led to the shell, according to their location

Applicable requirement ->	[8.6.1]	[8.7.1]	[8.7.2]	[8.7.3]	[8.7.4]	[8.7.5]	[8.7.6] with valve	[8.7.6] without valve	[8.7.7]
Pipe location									
Between the shell and the first valve	Thickness according to Tab 23, column 1, or 0,7 times that of the shell side plating, whichever is the greater **(1)**							NA	NA
Beyond the first valve and the inboard end	Thickness according to [2.2]							NA	NA
Below the bulkhead deck	NA							Thickness according to Tab 23, column 1**(1)**	Thickness according t Tab 23, column 2**(1)**
Above the bulkhead deck	NA							Thickness according to [2.2]	Thickness according to [2.2]

(1) However, this thickness is not required to exceed that of the plating.
Note 1: NA = Not Applicable.

Table 23 : Minimum thickness of scupper and discharge pipes led to the shell

External diameter of the pipe d, in mm	Column 1 substantial thickness, in mm	Column 2 normal thickness, in mm
d ≤ 80,0	7,00	4,50
155	9,25	4,50
180	10,00	5,00
220	12,50	5,80
230 ≤ d	12,50	6,00

Note 1: Intermediate sizes may be determined by interpolation.
Note 2: In any case it is not required a thickness greater than the shell plating

8.10 Arrangement of scuppers

8.10.1 Overboard discharges and valve connections

a) Overboard discharges are to have pipe spigots extending through the shell plate and welded to it, and are to be provided at the internal end with a flange for connection to the valve or pipe flange.

b) Valves may also be connected to the hull plating in accordance with the provisions of [2.8.3], item c).

8.10.2 Passage through vehicle and ro-ro spaces

Where scupper and sanitary discharge pipes are led through vehicle and ro-ro spaces, the pipes and the valves with their controls are to be adequately protected by strong casings or guards.

8.10.3 Passage through tanks

a) As a rule, scupper and sanitary discharge pipes are not to pass through fuel oil tanks or JP5-NATO (F44) tanks.

b) Where scupper and discharge pipes pass unavoidably through fuel oil tanks and are led through the shell within the tanks, the thickness of the piping is not to be less than that given in Tab 23 column 1 (substantial thickness). It is not needed, however, to exceed the Rule thickness of the shell plating or the tank thickness in case of only passing through.

c) Scupper and sanitary discharge pipes shall not pass through fresh and drinking water tanks.

d) Scupper and sanitary discharge pipes shall not pass through JP5-NATO (F44) tanks unless of jacketed type provided with means for ascertain leakages.

8.10.4 Passage through ammunition spaces

Except where not practicable, scuppers pipes are not to pass through ammunition spaces

8.10.5 Discharge in refrigerated spaces

No scupper pipe from non-refrigerated spaces is to discharge in refrigerated spaces.

8.10.6 Discharge from galleys and their stores

Discharges from galleys and their stores are to be kept separate from other discharges and be drained overboard or in separate drainage tanks; alternatively, discharges are to be provided with adequate devices against odours and overflow.

8.10.7 Discharge from aircrafts-related areas

Scuppers of the spaces of the aircrafts-related areas likely to contain burning fuel are to be independent from the scupper network serving the spaces located outside the citadel. In addition, drainage facilities from aircraft-related areas are to comply with the following requirements, as applicable:

- drainage facilities from helidecks and flight decks: Ch 4, Sec 10, [3.2], Pt D, Ch 2, Sec 5, [8.1.1] and Pt D, Ch 5, Sec 6 [5.1.2]
- drainage facilities from aircraft hangars: Ch 4, Sec 10, [3.2.2], Pt D, Ch 2, Sec 5, [6.1.5] and Pt D, Ch 5, Sec 6, [8.1.5].

8.10.8 Discharge from aft spaces

Spaces located aft of the aft peak bulkhead not intended to be used as tanks are to be drained in compliance with [6].

8.10.9 Scupper tank

a) The scupper tank air pipe is to be led to above the bulkhead deck.

b) Provision is to be made to ascertain the level of water in the scupper tank.

9 Air, sounding and overflow pipes

9.1 Air pipes

9.1.1 Principle

Air pipes are to be fitted to all tanks, double bottoms, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements, in order to allow the passage of air or liquid so as to prevent excessive pressure or vacuum in the tanks or compartments, in particular in those which are fitted with piping installations. Their open ends are to be so arranged as to prevent the free entry of sea water in the compartments.

Note 1: Air pipes may be dispensed with in tunnels, cofferdams and other void spaces provided they do not contain any bilge suction.

Air pipes of JP5-NATO(F44) installations are to be independent of air pipes for spaces belonging to other types of system.

In addition, air pipes are to be fitted in ammunition spaces located below the waterline and fitted with fixed water spraying system in accordance with Ch 4, Sec 6, [6.1]. These air pipes are to be fitted with a flame arrester and with a pressure relief valve adjusted to 10mbar.

Note 2: Other means to avoid over pressurisation of the ammunition space may be accepted to the satisfaction of the Society.

9.1.2 Number and position of air pipes

a) Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate at any point in the compartments can freely evacuate.

b) Air pipes are to be fitted opposite the filling pipes and/or at the highest parts of the compartments, the ship being assumed to be on an even keel.

c) Except for supply ship, in general only one air pipe may be fitted for each compartment. When the top of the compartment is of irregular form, the position of air pipes will be given special consideration by the Society.

d) Where only one air pipe is provided, it is not to be used as a filling pipe.

9.1.3 Location of open ends of air pipes

a) Air pipes of double bottom compartments, tunnels, deep tanks and other compartments which can come into contact with the sea or be flooded in the event of hull damage are to be led to above the bulkhead deck.

b) Air pipes of tanks intended to be pumped up are to be led to the open above the bulkhead deck.

c) Air pipes other than those of fuel oil tanks, JP5-NATO (F44) tanks and of any other oil tanks may be led to enclosed vehicle or ro-ro spaces, situated above the bulkhead deck, provided that such spaces are fitted with scuppers discharging overboard, which are capable of draining all the water which may enter through the air pipes without giving rise to any water accumulation.

d) Air pipes of tanks other than oil tanks, JP5-NATO (F44) tanks and of any other oil tank may discharge through the side of the superstructure.

e) The air pipe of the scupper tank is to be led to above bulkhead deck.

f) The location of air pipes for flammable oil tanks is also to comply with [9.1.7].

9.1.4 Height of air pipes

Air pipes are to extend above the V-line, as defined in Pt B, Ch 3, App 4.

9.1.5 Fitting of closing appliances

a) Permanently attached appliances are to be provided for closing the openings of air pipes in order to prevent the free entry of water into the spaces concerned, except for pipes of tanks fitted with cross-flooding connections.

b) Automatic closing appliances are to be fitted in the following cases:
- in positions of [9.1.3] item c)
- where air pipes have a height lower than that required in [9.1.4].

See also Pt B, Ch 3, Sec 3, [2.2.2].

c) Automatic closing appliances are to be of a type approved by the Society. Requirements for type tests are given in [19.3.1].

9.1.6 Design of closing appliances

a) When closing appliances are requested to be of an automatic type, they are to comply with the following:
- They are to be so designed that they withstand both ambient and working conditions up to an inclination of –40° to +40° without failure or damage.
- They are to be so designed as to allow inspection of the closure and the inside of the casing as well as changing of the seals.
- Where they are of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.
- Efficient seating arrangements are to be provided for the closures.
- They are to be self-draining.
- The clear area through an air pipe closing appliance is to be at least equal to the area of the inlet.
- The maximum allowable tolerances for wall thickness of floats is not to exceed ±10% of the nominal thickness.
- Their casings are to be of approved metallic materials adequately protected against corrosion.
- Closures and seats made of non-metallic materials are to be compatible with the media to be carried in the tank and with sea water at ambient temperatures between –25°C and +85°C.

b) Where closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out. For this purpose, a hole of approximately 10 mm in diameter may be provided in the bend of the air pipe or at any other suitable position in the closing appliance.

c) Wooden plugs and trailing canvas are not permitted.

9.1.7 Special arrangements for air pipes of flammable oil tanks

a) Air pipes from fuel oil, JP5-NATO (F44) and thermal oil tanks are to discharge to a safe position on the open deck where no danger will be incurred from issuing oil or gases.

   Air vents are to be fitted with wire gauze diaphragms made of corrosion resistant material and readily removable for cleaning and replacement. The clear area of such diaphragms is not to be less than the cross-sectional area of the pipe.

b) Air pipes of lubricating or hydraulic oil storage tanks not subject to flooding in the event of hull damage may be led to machinery spaces, provided that in the case of overflowing the oil cannot come into contact with electrical equipment, hot surfaces or other sources of ignition.

c) Air pipes of fuel oil, JP5-NATO (F44), service, settling and lubrication oil, tanks likely to be damaged by impact forces are to be adequately reinforced.

9.1.8 Construction of air pipes made of steel

a) Where air pipes to ballast and other tanks extend above the bulkhead deck or superstructure deck (see [9.1.4]), the exposed parts of the pipes are to be of substantial construction, with a minimum wall thickness of at least:
- 6,0 mm for pipes of 80 mm or smaller external diameter
- 8,5 mm for pipes of 165 mm or greater external diameter.

   Intermediate minimum thicknesses may be determined by linear interpolation.

   For stainless steel the above thickness may be respectively 3,0 mm and 4,0 mm.

Note 1: When the air pipes are protected against sea impacts, thicknesses in accordance with Tab 5 may be accepted.

b) Air pipes with height exceeding 900 mm are to be additionally supported.

c) In each compartment likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

d) The internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

9.2 Sounding pipes

9.2.1 Principle

a) Sounding devices are to be fitted to tanks intended to contain liquids as well as to other tanks, double bottoms, cofferdams, bilges and all compartments which are not readily accessible at all times.

b) For service tanks, the following systems may be accepted in lieu of sounding pipes:
- a level gauge of an approved type efficiently protected against shocks, or
- a remote level gauging system of an approved type, provided an emergency means of sounding is available in the event of failure affecting such system.

9.2.2 Position of sounding pipes

Sounding pipes are to be located as close as possible to suction pipes.

9.2.3 Termination of sounding pipes

a) As a general rule, sounding pipes are to end above the bulkhead deck in easily accessible places and are to be fitted with efficient, permanently attached, metallic closing appliances.

b) In machinery spaces where the provisions of a) cannot be satisfied, short sounding pipes led to readily accessible positions above the floor and fitted with efficient closing appliances may be accepted.

In ships required to be fitted with a double bottom, such closing appliances are to be of the self-closing type.

9.2.4 Special arrangements for sounding pipes of flammable oil tanks

a) Where sounding pipes are used in flammable (except lubricating, sludge, dirty bilge, oil leakage and similar) oil systems, they may terminate below the open deck where no risk of ignition of spillage from the sounding pipe might arise. In particular, they are not to terminate in crew spaces dedicated to off-duty activities. As a general rule, they are not to terminate in machinery spaces.

b) The Society may permit termination in machinery spaces of sounding pipes for lubricating oil, fuel oil leakage, sludge and dirty bilge tanks, provided that the terminations of sounding pipes are fitted with appropriate means of closure.

9.2.5 Closing appliances

a) Self-closing appliances are to be fitted with cylindrical plugs having counterweights such as to ensure automatic closing.

b) Closing appliances not required to be of the self-closing type may consist of a metallic screw cap secured to the pipe by means of a chain or a shut-off valve.

9.2.6 Construction of sounding pipes

a) Sounding pipes are normally to be straight. If it is necessary to provide bends in such pipes, the curvature is to be as small as possible to permit the ready passage of the sounding apparatus.

b) The sounding arrangement of compartments by means of bent pipes passing through other compartments will be given special consideration by the Society. Such an arrangement is normally accepted only if the compartments passed through are cofferdams or are intended to contain the same liquid as the compartments served by the sounding pipes.

c) Bent portions of sounding pipes are to have reinforced thickness and be suitably supported.

d) The internal diameter of sounding pipes is not to be less than 32 mm. Where sounding pipes pass through refrigerated spaces, or through the insulation of refrigerated spaces in which the temperature may be below 0°C, their internal diameter is to be at least 60 mm.

e) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull. When sounding pipes with closed lower ends are used, the closing plate is to have reinforced scantlings.

9.3 Overflow pipes

9.3.1 Principle

Overflow pipes of JP5-NATO(F44) installations are to be independent of overflow pipes for tanks belonging to other types of system.

Overflow pipes are to be fitted to tanks:

- which can be filled by pumping and are designed for a hydrostatic pressure lower than that corresponding to the height of the air pipe, or
- where the cross-sectional area of air pipes is less than that prescribed in [9.1.8], item d).

9.3.2 Design of overflow systems

a) Overflow pipes are to be led:

  - either outside, or
  - in the case of fuel oil or JP5-NATO (F44) or lubricating oil, to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. For JP5-NATO(F44) a dedicated tank is to be provided.

Note 1: As an alternative to the overflow tank, for JP5-NATO (F44), an isolating valve on the tank filling line arranged for automatic closing in case of high level can be accepted. The filling line is to fitted with a protection device against overpressure, which may be located outside the ship (on the refuelling installation).

b) Where tanks containing the same liquid are connected to a common overflow system, the arrangement is to be such as to prevent any risk of:

- intercommunication between the various tanks due to movements of liquid when emptying or filling, or due to the inclination of the ship
- overfilling of any tank from another assumed flooded due to hull damage.

For this purpose, overflow pipes are to be led to a high enough point above the bulkhead deck. Safety devices protecting from a risk of hydrostatic overpressure in overflow pipes could be accepted subject to an alarm of discharging in the dripping pan.

c) Arrangements are to be made so that a compartment cannot be flooded from the sea through the overflow in the event of another compartment connected to the same overflow main being bilged. To this end, the openings of overflow pipes discharging overboard are as a rule to be placed above the maximum draft of the ship and are to be fitted where necessary with non-return valves on the plating, or, alternatively, overflow pipes from tanks are to be led to a point above the maximum draft of the ship.

d) Where tanks alternately containing fuel oil and ballast water are connected to a common overflow system, arrangements are to be made to prevent the ballast water overflowing into the tanks containing fuel oil and vice-versa.

9.3.3 Overflow tanks

a) Overflow tanks are to be fitted with an air pipe complying with [9.1] which may serve as an overflow pipe for the same tank. When the vent pipe reaches a height exceeding the design head of the overflow tank, suitable means are to be provided to limit the actual hydrostatic head on the tank.

Such means are to discharge to a position which is safe in the opinion of the Society.

b) An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight-flow glass is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight-flow glasses are only to be placed on vertical pipes and in readily visible positions.

9.3.4 Specific requirements for construction of overflow pipes

a) The internal diameter of overflow pipes is not to be less than 50 mm.

b) In each compartment which can be pumped up, the total cross-sectional area of overflow pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

c) The cross-sectional area of the overflow main is not to be less than the aggregate cross-sectional area of the two largest pipes discharging into the main.

9.4 Constructional requirements applying to sounding, air and overflow pipes

9.4.1 Materials

a) Sounding, air and overflow pipes are to be made of steel or any other material approved for the application considered.

b) Exposed parts of sounding, air and overflow pipes are to be made of approved metallic materials.

9.4.2 Minimum thickness of steel pipes

The minimum thickness of sounding, air and overflow steel pipes is given in Tab 24.

Table 24 : Minimum wall thickness of sounding, air and overflow pipes

External diameter, in mm	Minimum wall thickness, in mm **(1)(2)**
up to 168,3	4,5
177,8	5,0
193,7	5,4
219,1	5,9
above 244,5	6,3

(1) Applies only to structural tanks.
(2) However the wall thickness may not be greater than that it would be required for the tank filling pipes.
For independent tanks, refer to Tab 5.

9.4.3 Passage of pipes through certain spaces

a) Air pipes and sounding pipes led through refrigerated spaces are to be suitably insulated.

b) When sounding, air and overflow pipes made of steel are permitted to pass through ballast tanks or fuel oil tanks, they are to be of reinforced thickness, in accordance with Tab 5. However pipes passing through JP5-NATO(F44) tanks are only permitted if they are of jacketed type with means for ascertain leakages.

c) Sounding, air and overflow pipes are to be adequately protected against impact of product handling.

9.4.4 Self-draining of pipes

Air pipes and overflow pipes are to be so arranged as to be self-draining when the ship is on an even keel.

9.4.5 Name plates

Nameplates are to be fixed at the upper part of air pipes and sounding pipes.

10 Cooling systems

10.1 Application

10.1.1 This article applies to all cooling systems using the following cooling media:

- sea water
- fresh water
- lubricating oil.

Air cooling systems will be given special consideration.

10.2 Principle

10.2.1 General

Sea water and fresh water cooling systems are to be so arranged as to maintain the temperature of the cooled media (lubricating oil, hydraulic oil, charge air, etc.) for propulsion machinery and essential equipment within the manufacturers' recommended limits during all operations, including starting and manoeuvring, under the inclination angles and the ambient conditions specified in Ch 1, Sec 1.

10.2.2 Availability of the cooling system

The cooling system is to be so designed that, in the event of one essential component being inoperative, the cooling of propulsion machinery is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

10.3 Design of sea water cooling systems

10.3.1 General

a) Sea water cooling of the propulsion engines, auxiliary engines and other essential equipment is to be capable of being supplied by two different means.

b) Where required, standby pumps are not to be connected to the sea inlet serving the other sea water pumps, unless permitted under [10.7.1], item b).

10.3.2 Centralised cooling systems

a) In the case of centralized cooling systems, i.e. systems serving a group of propulsion engines and/or auxiliary engines, reduction gears, compressors and other essential equipment, the following sea water pumps and heat exchangers are to be arranged:
   - one main cooling water pump, which may be driven by the engines, of a capacity sufficient to provide cooling water to all the equipment served
   - one independently driven standby pump of at least the same capacity
   - two heat exchangers, each having at least 50% of the total capacity necessary to provide cooling water to all the equipment served.

b) Where the cooling system is served by a group of identical pumps, the capacity of the standby pump needs only to be equivalent to that of each of these pumps.

c) Ballast pumps or other suitable sea water pumps of appropriate capacity may be used as standby pumps, provided arrangements are made against overpressure in the cooling system.

d) In ships having one or more propulsion engines, each with an output not exceeding 375 kW, the independent standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected to the cooling circuit.

e) In cases of centralized cooling systems serving only a group of auxiliary engines, the second means of cooling may consist of a connection to a cooling water pump serving the propulsion plant, provided such pump is of sufficient capacity to provide cooling water to both propulsion plant and auxiliary engines.

10.3.3 Individual cooling of propulsion engines

a) Individual cooling systems of propulsion engines are to include at least:
- one main cooling water pump, which can be driven by the engine
- one independently driven standby pump
- two heat exchangers having an aggregate capacity of at least 100% of that required by the engine.

Where the output of the engine does not exceed 375 kW, the following arrangements may be accepted:
- one main cooling water pump, which can be driven by the engine
- one spare pump of appropriate capacity ready to be connected to the cooling circuit
- one heat exchanger of appropriate capacity.

b) Where, in ships having more than one engine per propeller or having several propellers, each engine is served by its own cooling circuit, the second means requested in [10.3.1] is to be provided, consisting of:
- a connection to an independently driven pump, such as a ballast pump or any other suitable sea water pump of sufficient capacity provided arrangements against overpressure in the cooling system are made. (see [10.7.4], item b)), or
- a complete spare pump identical to those serving the engines and ready to be connected to the cooling circuit.

This second means may be omitted, however, when safety justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with one cooling circuit disabled.

10.3.4 Individual cooling of auxiliary engines

Where each auxiliary engine is served by its own cooling circuit, no second means of cooling is required.

10.3.5 Cooling of steam plants

a) Steam plants are to be fitted with:
- a main circulating pump
- a standby pump capable of ensuring the circulation in the main condenser in the event of failure of the main circulating pump.

b) Where the installation includes more than one propulsive unit, the standby pump is not required, provided a branch pipe is fitted between the discharges of the circulating pumps of each unit.

c) In lieu of the main circulating pump, a sea inlet scoop system may be accepted, provided that an additional means is fitted to ensure the circulation of sea water to the condenser when the ship is manoeuvring. Such means may be:
- an additional independent pump, or
- a connection to an available pump of sufficient capacity.

10.3.6 Cooling of other essential equipment

a) The second means of cooling required in [10.3.1] for essential equipment may consist of a connection to a ballast pump or other suitable sea water pump of sufficient capacity, provided arrangements are made against overpressure in the cooling system (see [10.7.4], item b)).

b) However, where such essential equipment is duplicate, this second means may be omitted when justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with the cooling circuit of one set of equipment disabled.

10.4 Design of fresh water cooling systems

10.4.1 General

Fresh water cooling systems are to be designed according to the applicable requirements of [10.3].

10.4.2 Cooling systems

a) Fresh water cooling systems of essential equipment are to include at least:
- one main cooling water pump, which can be driven by the equipment
- one independently driven standby pump.

b) The standby pump may be omitted provided an emergency connection to a suitable sea water system is fitted and arranged with a suitable change-over device. Provisions against overpressure in the cooling system are to be made in accordance with [10.7.4], item b).

c) The standby pump may also be omitted in the case of redundancy of the cooled equipment.

10.4.3 Expansion tanks

Fresh water expansion tanks are to be provided with at least:
- a de-aerating device
- a water level indicator
- a filling connection
- a drain.

10.4.4 Protection of contamination by oil

Suitable means are to be provided in fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water by fuel oil or lubricating oil.

If cooling water is used for heating of oil, the heating coils are to be located on the pressure side of the cooling pumps and connected by welding, with no detachable connections where mixing of oil and water may occur. Alternatively a primary and secondary system arrangement may be used.

10.5 Design of oil cooling systems

10.5.1 General

Oil cooling systems are to be designed according to the applicable requirements of [10.3].

10.5.2 Second means of cooling

The second means of cooling requested in [10.3.1] may consist of a satisfactory connection to a lubricating oil pump of sufficient capacity. Arrangements are to be made against overpressure in the cooling system.

10.6 Control and monitoring

10.6.1 Alarms are to be provided for water cooling systems in accordance with Tab 25, in addition to the requirements stated for diesel engines in Ch 1, Sec 2.

10.7 Arrangement of cooling systems

10.7.1 Sea inlets

a) Cooling systems serving propulsion machinery and essential equipment are to be supplied by at least two sea inlets complying with [2.8].

b) The two sea inlets may be connected by a cross-over.

c) The sea inlets are to be so designed as to remain submerged under all normal navigating conditions.

In general, one low sea inlet and one high sea inlet are to be arranged.

d) One of the sea inlets may be that of the fire pump.

10.7.2 Coolers

a) Coolers are to be fitted with isolating valves at the inlets and outlets.

b) Coolers external to the hull (chest coolers and keel coolers) are to be fitted with isolating valves at the shell.

10.7.3 Filters

a) Where propulsion engines and auxiliary engines for essential services are directly cooled by sea water, both in normal service and in emergency operating conditions, filters are to be fitted on the suction of cooling pumps.

b) These filters are to be so arranged that they can be cleaned without interrupting the cooling water supply.

Table 25 : Cooling systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water pump pressure or flow	L	local					
Fresh water pump pressure or flow	L	local					
Level in cooling water expansion tank	L	local					

10.7.4 Pumps

a) Cooling pumps for which the discharge pressure may exceed the design pressure of the piping system are to be fitted with relief valves in accordance with [2.5].

b) Where general service pumps, ballast pumps or other pumps may be connected to a cooling system, arrangements are to be made, in accordance with [2.5], to avoid overpressure in any part of the cooling system.

10.7.5 Air venting

Cocks are to be installed at the highest points of the pipes conveying cooling water to the water jackets for venting air or gases likely to accumulate therein. In the case of closed fresh water cooling systems, the cock is to be connected to the expansion tank.

11 Fuel oil and JP5-NATO (F44) systems

11.1 Application

11.1.1 Scope

This Article applies to all fuel oil systems supplying any kind of installation and all JP5-NATO (F44) systems.

Dedicated systems and arrangements shall be provided for each JP5-NATO (F44) fuel system (e.g. one dedicated system for refuelling and one dedicated system for carrying).

11.1.2 Additional requirements applying to fuel oil and JP5-NATO (F44) systems

Additional requirements are given:

- for independent fuel oil tanks: in Ch 1, App 3
- for fuel oil supply equipment forming part of engines, gas turbines, boilers and incinerators: in the corresponding sections of Part C, Chapter 1
- for the installation of purifiers: in Part C, Chapter 4
- for the location and scantling of tanks forming part of the ship's structure: in Part B, Chapter 2 and Part B, Chapter 7
- for helicopter refuelling facilities: in Ch 4, Sec 10, [4]
- for **aircraft carriers**: in Part D, Chapter 2
- for **amphibious vessels**: in Part D, Chapter 5.

11.2 Principle

11.2.1 General

a) Fuel oil and JP5-NATO (F44) systems are to be so designed as to ensure the proper characteristics (purity, viscosity, pressure) of the fuel oil supply to ship's engines or of aircrafts or helicopters and boilers.

b) Fuel oil and JP5-NATO (F44) systems are to be so designed as to prevent:
   - overflow or spillage of fuel oil and JP5-NATO (F44) from tanks, pipes, fittings, etc.
   - fuel oil from coming into contact with sources of ignition
   - overheating and seizure of fuel oil and JP5-NATO (F44).

c) Fuel oils used for engines and boilers are to have a flashpoint complying with the provisions of Ch 1, Sec 1, [2.9].

11.2.2 Availability of fuel systems

a) Fuel oil systems are to be so designed that, in the event that any one essential auxiliary of such systems becomes inoperative, the fuel oil supply to boilers and engines can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) Fuel oil tanks are to be so arranged that, in the event of damage to any one tank, complete loss of the fuel supply to essential services does not occur.

11.3 General

11.3.1 Arrangement of fuel oil systems

a) In a ship in which fuel oil is used, or JP5-NATO (F44) is carried or used for refuelling, the arrangements for the storage, distribution and utilization of the fuel oil or JP5-NATO (F44) are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.10] are to be complied with.

11.3.2 Provision to prevent overpressure

Provisions are to be made to prevent overpressure in any oil or JP5-NATO (F44) tank or in any part of the fuel oil and JP5-NATO (F44) systems. Any relief valve is to discharge to a safe position.

11.3.3 Ventilation

The ventilation of machinery spaces is to be sufficient under all normal conditions to prevent accumulation of oil vapour.

11.3.4 Access

Spaces where fuel oil or JP5-NATO (F44) are handled are to be readily accessible.

11.4 Design of fuel oil and JP5-NATO (F44) filling and transfer systems

11.4.1 General

A system of pumps and piping for filling and transferring fuel oil or JP5-NATO (F44) is to be provided. Provisions are to be made to allow the transfer of fuel oil or JP5-NATO (F44) from any storage tank to another tank.

11.4.2 Filling systems

a) Filling pipes of fuel oil or JP5-NATO (F44) tanks are to terminate on open deck or in filling stations isolated from other spaces and efficiently ventilated. Suitable coamings and drains are to be provided to collect any leakage resulting from filling operations.

b) Arrangements are to be made to avoid overpressure in the filling lines which are served by pumps on board. Where safety valves are provided for this purpose, they are to discharge to the overflow tank referred to in [9.3.3] or to other safe positions deemed satisfactory.

11.4.3 Independence of fuel oil and JP5-NATO (F44) transfer lines

The fuel oil transfer piping system is to be completely separate from the other piping systems of the ship. This requirement is also to be complied with by JP5-NATO (F44) transfer piping system.

Note 1: A fuel oil tank may be used to carry JP5/NATO (F44) provided arrangements are made to avoid any inadvertent filling of other fuel oil tanks, and with particular care for quality control (filtration, fuel oil and water content) before refuelling of aircrafts.

11.4.4 Transfer pumps

a) Fuel oil system is to include at least two means of transfer. One of these means is to be a power pump. The other may consist of a standby pump.

b) Where necessary, transfer pumps are to be fitted on their discharge side with a relief valve leading back to the suction of the pump or to any other place deemed satisfactory.

c) No stand-by pump is required for JP5-NATO (F44).

11.5 Arrangement of fuel oil, bunkers and JP5-NATO (F44) tanks

11.5.1 Location of fuel oil and JP5-NATO (F44) tanks

a) No fuel oil tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

b) Fuel oil tanks and bunkers are not to be situated immediately above boilers or in locations where they could be subjected to high temperatures, unless specially agreed by the Society. In general, the distance between fuel oil tanks and boilers is not to be less than 450 mm. Where boilers are situated above double bottom fuel oil tanks, the distance between the double bottom tank top and the lower metallic part of the boilers is not to be less than:

- 750 mm for water tube boilers
- 600 mm for cylindrical boilers.

c) As far as practicable, fuel oil tanks are to be part of the ship’s structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Note 1: Machinery spaces of category A are defined in Ch 4, Sec 1.

Note 2: Service tanks may be located within machinery spaces provided the following conditions are met:

- the tank is fitted with a quick draining system connected to a suitable tank and operable from an accessible position outside the concerned space.
- a water extinguishing system is provided in case of fire in way of the tank as mentioned in Ch 4, Sec 6, [4.1.1]. See also Ch 4, Sec 13, [7.1.1].

d) The location of fuel oil tanks is to be in compliance with the requirements of Part B, Chapter 2, particularly as regards the installation of cofferdams, the separation between fuel oil tanks or bunkers and the other spaces of the ship, and the protection of these tanks and bunkers against any abnormal rise in temperature.

11.5.2 Use of free-standing fuel oil tanks

a) In general the use of free-standing fuel oil tanks is to be avoided except on supply ships, where their use is permitted in category A machinery spaces.

b) For the design and the installation of independent tanks, refer to Ch 1, App 3.

11.6 Design of fuel oil tanks and bunkers and JP5-NATO (F44) tanks

11.6.1 General

Tanks such as collector tanks, de-aerator tanks etc. are to be considered as fuel oil tanks for the purpose of application of this sub-article, and in particular regarding the valve requirements.

Tanks with a volume lower than 500 l will be given special consideration by the Society.

11.6.2 Scantlings

a) The scantlings of fuel oil tanks and bunkers and JP5-NATO (F44) tanks forming part of the ship's structure are to comply with the requirements stated in Part B, Chapter 7.

b) Scantlings of fuel oil tanks and bunkers which are not part of the ship's structure are to comply with Ch 1, App 3. For cases which are not contained in the Tables of that appendix, scantlings will be given special consideration by the Society.

11.6.3 Filling and suction pipes

a) All suction pipes from JP5-NATO (F44) tanks, fuel oil tanks and bunkers, including those in the double bottom, are to be provided with valves.

b) For storage tanks, filling pipes may also be used for suction purposes.

c) Where the filling pipes to JP5-NATO (F44) tanks, fuel oil bunkers and tanks are not led to the upper part of the such bunkers and tanks, they are to be provided with non-return valves at their ends, unless they are fitted with valves arranged in accordance with the requirements stated in [11.6.4].

11.6.4 Remote control of valves

a) Every fuel oil and JP5-NATO (F44) pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank situated above the double bottom, is to be fitted with a cock or valve directly on the tank or directly on plating of last tank, capable of being closed from a safe position outside the space in which such tanks are situated in the event of a fire occurring in such space.

Note 1: For the location of the remote controls, refer to [11.10.3], item c).

b) Such valves and cocks are also to include local control and indicators are to be provided on the remote and local controls to show whether they are open or shut (see [2.7.3]).

c) Where fuel oil tanks are situated outside boiler and machinery spaces, the remote control required in a) may be transferred to a valve located inside the boiler or machinery spaces on the suction pipes from these tanks.

d) In the special case of storage tanks situated in any shaft or pipe tunnel or similar space, valves are to be fitted on the tank but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

11.6.5 Drain pipes

Where fitted, drain pipes are to be provided with self-closing valves or cocks. See also [11.5.1], item c), Note 2.

11.6.6 Air and overflow pipes

Air and overflow pipes are to comply with [9.1] and [9.3].

11.6.7 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of fuel oil and JP5-NATO (F44) contained in any fuel oil tank and JP5-NATO (F44) tank are to be provided.

b) Sounding pipes of fuel oil and JP5-NATO (F44) tanks are to comply with the provisions of [9.2].

c) Gauge cocks for ascertaining the level in the tanks are not to be used.

11.7 Design of fuel oil heating systems

11.7.1 Fuel oil heaters

a) Where steam heaters or heaters using other heating media are provided in fuel oil system, they are to be fitted with at least a high temperature alarm or a low flow alarm in addition to a temperature control, except where temperatures dangerous for the ignition of the fuel oil cannot be reached.

b) When electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In all cases a safety temperature switch is to be fitted in order to avoid a surface temperature of 220°C and above. It is to be:
   - independent from the automatic control sensor
   - designed to cut off the electrical power supply in the event of excessive temperature
   - provided with manual reset.

c) Fuel oil heaters are to be fitted with relief valves leading back to the pump suction concerned or to any other place deemed satisfactory.

11.8 Design of fuel oil and JP5-NATO (F44) treatment systems

11.8.1 General

Fuel oils and JP5-NATO (F44) used for the engines of the ship, of the aircrafts or of the helicopters are to be purified and filtered according to the relevant manufacturer’s requirements.

11.8.2 Drains

a) Storage tanks and, where provided, settling tanks, are to be provided with drains permitting the evacuation of water and impurities likely to accumulate in the lower part of such tanks.

b) Efficient means are to be provided for draining oily water escaping from the drains.

11.8.3 Treatment installation

a) Where fuel oil needs to be treated, at least two means of treatment are to be installed on board, each means is to be capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the ship's engines.

b) For JP5 NATO (F44), one means of treatment may be accepted.

c) Subject to special consideration by the Society, the capacity of the standby purifier fuel oil may be less than that required in item a), depending on the arrangements made for the fuel oil service tanks to satisfy the requirement in [11.9.2].

d) The standby purifier may also be used for other ship's services.

e) Each purifier is to be provided with an alarm in case of failures likely to affect the quality of the purified fuel oil or JP5-NATO (F44).

f) Fuel oil purifiers and JP5-NATO (F44) purifiers are to be installed as required in Part C, Chapter 4.

11.9 Design of fuel supply systems

11.9.1 General

When necessary, arrangements are to be made for cooling the marine diesel oil from engine return lines.

11.9.2 Fuel oil service tanks

a) The propulsion plant and the generator plant are to be supplied by at least two service tanks, which may be common to both plants.

b) The aggregate capacity of the service tanks is to allow at least 3 hours operation at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

11.9.3 Fuel oil supply to internal combustion engines

a) The suctions of engine fuel pumps are to be so arranged as to prevent the pumping of water and sludge likely to accumulate after decanting at the lower part of service tanks.

b) Internal combustion engines intended for main propulsion are to be fitted with at least two filters, or similar devices, so arranged that one of the filters can be overhauled while the other is in use.

Note 1: Where the propulsion plant consists of:

- two or more engines, each one with its own filter, or
- one engine with an output not exceeding 375 kW,

the second filter may be replaced by a readily accessible and easily replaceable spare filter.

c) Oil filters fitted in parallel are to be so arranged as to minimize the possibility of a filter under pressure being opened by mistake.

Filter chambers are to be provided with suitable means for:

- ventilating when put into operation
- de-pressurizing before being opened.

Valves or cocks used for this purpose are to be fitted with drain pipes led to a safe location.

d) Excess fuel oil from pumps or injectors is to be led back to the service or settling tanks, or to other tanks intended for this purpose.

e) For high pressure fuel oil pipes, refer to Ch 1, Sec 2.

11.10 Control and monitoring

11.10.1 Monitoring

Alarms and safeguards are to be provided for fuel oil and for JP5-NATO (F44) systems in accordance with Tab 26.

11.10.2 Automatic controls

Automatic temperature control is to be provided for all heaters.

11.10.3 Remote controls

a) The remote control arrangement of valves fitted on fuel oil and on JP5-NATO (F44) tanks is to comply with [11.6.4].

b) The power supply to:

- transfer pumps and other pumps of the fuel oil and JP5-NATO (F44) system
- fuel oil and JP5-NATO (F44) purifiers, and other treatment equipment,

is to be capable of being stopped from a position within the space containing the pumps and from another position located outside such space and always accessible in the event of fire within the space.

Note 1: Locally controlled pneumatic pumps are not required to be provided with a remote control system.

c) Remote control of the valve fitted to the emergency generator fuel tank is to be in a separate location from that of other valves fitted to tanks in the engine room.

d) The positions of the remote controls are also to comply with Part C, Chapter 3.

Table 26 : Fuel oil and JP5-NATO (F44) systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil and JP5-NATO (F44) overflow tank level	H **(1)** HH			X **(2)** X**(2)**			
Sludge tank level		local					
Fuel oil level in daily service tank and JP5-NATO (F44) service tank	L+H **(1)**	local					
(1) Or sightglasses on the overflow pipe **(2)** Filling valve shut down **Note 1:** Blank box means no provision.							

11.11 Construction of fuel oil and JP5-NATO (F44) piping systems

11.11.1 Materials

a) Fuel oil pipes and their valves are to be of steel or other approved material, except that the use of flexible pipes may be accepted provided they comply with [2.6.3].

For JP5-NATO (F44), such pipes and valves located on the refuelling line (i.e. downstream the treatment equipment) are to be of stainless steel.

b) For valves fitted to fuel oil tanks and which are under a static pressure head, steel or nodular cast iron may be accepted.

c) Internal galvanisation of fuel oil pipes and tank or bunker walls are not allowed.

11.12 Arrangement of fuel oil and JP5-NATO (F44) piping systems

11.12.1 Passage of fuel oil or JP5-NATO (F44) pipes through tanks

a) Fuel oil pipes are not to pass through tanks containing fresh water or other flammable oil, unless they are contained within tunnels.

JP5-NATO (F44) pipes are not allowed to pass through tanks containing other fluids.

b) Transfer pipes of fuel oil passing through ballast tanks are to have a reinforced thickness complying with Tab 5, however the thickness of the pipe need not to exceed the Rule thickness of tank plate.

11.12.2 Passage of pipes through fuel oil or JP5-NATO (F44) tanks

Fresh water pipes are not to pass through fuel oil tanks, unless such pipes are contained within tunnels.

JP5-NATO (F44) tanks are not to be passed through by any other piping system.

11.12.3 Segregation of fuel oil purifiers

Purifiers fuel oil or JP5-NATO (F44) are to be in accordance with Ch 4, Sec 6, [4.1.2].

12 Lubricating oil systems

12.1 Application

12.1.1 This Article applies to lubricating oil systems serving diesel engines, steam and gas turbines, reverse and reduction gears, clutches and controllable pitch propellers, for lubrication or control purposes.

This Article also applies to separate oil systems intended for the cooling of engine pistons

12.2 Principle

12.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the engines, turbines and other equipment, including electric motors, intended for propulsion:
   - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
   - for all the inclinations angles stated in Ch 1, Sec 1

b) Lubricating oil systems are to be so designed as to ensure sufficient heat transfer and appropriate filtration of the oil.

c) Lubricating oil systems are to be so designed as to prevent oil from entering into contact with sources of ignition.

12.2.2 Availability

a) Lubricating oil systems serving propulsion plants are to be so designed that, in the event that any one pump is inoperative, the lubrication of the engines and other equipment is maintained. Reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) For auxiliary engines fitted with their own lubrication system, no additional pump is required.

c) Main engines are to be provided with at least two power lubricating pumps, of such a capacity as to maintain normal lubrication with any one pump out of action.

d) In the case of propulsion plants comprising more than one engine, each with its own lubricating pump, one of the pumps mentioned in item a) may be a spare pump.

12.3 General

12.3.1 Arrangement of lubricating oil systems

The provisions of [5.10] are to be complied with, where applicable.

12.3.2 Filtration

a) In forced lubrication systems, a device is to be fitted which efficiently filters the lubricating oil in the circuit.

b) The filters provided for this purpose for main machinery and machinery driving electric propulsion generators are to be so arranged that they can be easily cleaned without stopping the supply of filtered lubricating oil to the machines.

c) The fineness of the filter mesh is to comply with the requirements of the engine or turbine manufacturers.

d) Where filters are fitted on the discharge side of lubricating oil pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

12.3.3 Purification

Where provided, lubricating oil purifiers are to comply with [11.8.3] item d) and item e).

12.3.4 Heaters

Lubricating oil heaters are to comply with [11.7.1].

12.4 Design of lubricating oil tanks

12.4.1 Remote control of valves

Lubricating oil tanks with a capacity of 500 litres and above are to be fitted with remote controlled valves in accordance with the provisions of [11.6.4].

Suction valves and draining valves from storage tanks need not be arranged with remote controls provided they are kept closed except during transfer operations.

12.4.2 Filling and suction pipes

Filling and suction pipes are to comply with the provisions of [11.6.3].

12.4.3 Air and overflow pipes

Air and overflow pipes are to comply with the provisions of [9.1] and [9.3].

12.4.4 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of lubricating oil contained in the tanks are to be provided.

b) Sounding pipes are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

12.4.5 Oil collecting tanks for engines

a) In ships required to be fitted with a double bottom, wells for lubricating oil under main engines may be permitted by the Society provided it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with Pt B, Ch 4, Sec 4.

b) Where, in ships required to be fitted with a double bottom, oil collecting tanks extend to the outer bottom, a valve is to be fitted on the oil drain pipe, located between the engine sump and the oil drain tank. This valve is to be capable of being closed from a readily accessible position located above the working platform.

Alternative arrangements will be given special consideration.

c) Oil collecting pipes from the engine sump to the oil collecting tank are to be submerged at their outlet ends.

12.5 Control and monitoring

12.5.1 In addition to the requirements in Ch 1, Sec 2 for diesel engines, in Ch 1, Sec 4 for steam turbines, in Ch 1, Sec 5 for gas turbines and in Ch 1, Sec 6 for gears, alarms are to be provided for lubricating oil systems in accordance with Tab 27.

Table 27 : Lubricating oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sludge tank level		local					
Note 1: Blank box means no provision.							

12.6 Construction of lubricating oil piping systems

12.6.1 Materials

Materials used for oil piping system in machinery spaces are to comply with the provisions of [11.11.1].

12.6.2 Sight-flow glasses

The use of sight-flow glasses in lubricating systems is permitted, provided that they are shown by testing to have a suitable degree of fire resistance.

13 Hydraulic systems

13.1 Application

13.1.1 Hydraulic installations intended for essential services

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services, including:

- actuating systems of controllable pitch propellers. Additional requirements are also given in Ch 1, Sec 8, [2.6.2]
- actuating systems of clutches
- actuating systems of thrusters
- actuating systems of steering gear. Additional requirements are also given in Ch 1, Sec 12, [2.6]
- actuating systems of lifting appliances
- manoeuvring systems of hatch covers
- manoeuvring systems of stern, bow and side doors and bow visors
- manoeuvring systems of mobile ramps, movable platforms, elevators and telescopic wheelhouses
- starting systems of diesel engines and gas turbines
- remote control of valves
- stabilizing installations.

The provisions of [5.10] are to be complied with.

13.1.2 Hydraulic installations located in spaces containing sources of ignition

Hydraulic power installations not serving essential services but located in spaces where sources of ignition are present are to comply with the provisions of [5.10], [13.3.2], [13.3.3], [13.4.4] [13.4.5].

13.1.3 Low pressure or low power hydraulic installations

Hydraulic power installations with a design pressure of less than 2,5 MPa and hydraulic power packs of less than 5 kW will be given special consideration by the Society.

13.1.4 Very high pressure hydraulic installations

Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by the Society.

13.2 Principle

13.2.1 General

Hydraulic systems are to be so designed as to:

- avoid any overload of the system
- maintain the actuated equipment in the requested position (or the driven equipment at the requested speed)
- avoid overheating of the hydraulic oil
- prevent hydraulic oil from coming into contact with sources of ignition.

13.2.2 Availability

a) Hydraulic systems are to be so designed that, in the event that any one essential component becomes inoperative, the hydraulic power supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired. Such reduction of capability is not acceptable for steering gear.

b) When a hydraulic power system is simultaneously serving one essential system and other systems, it is to be ensured that:
   - any operation of such other systems, or
   - any failure in the whole installation external to the essential system,

   does not affect the operation of the essential system.

c) Provision of item b) applies in particular to steering gear.

d) Hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, hatch covers, lifts, etc., are to be so designed that a single failure of any component of the system may not result in a sudden undue displacement of the load or in any other situation detrimental to the safety of the ship and persons on board.

13.3 General

13.3.1 Definitions

a) A power unit is the assembly formed by the hydraulic pump and its driving motor.

b) An actuator is a component which directly converts hydraulic pressure into mechanical action.

13.3.2 Limitations of use of hydraulic oils

a) Oils used for hydraulic power installations are to have a flashpoint not lower than 150°C and be suitable for the entire service temperature range.

b) The hydraulic oil is to be replaced in accordance with the specification of the installation manufacturer.

13.3.3 Location of hydraulic power units

a) Whenever practicable, hydraulic power units are to be located outside main engine room.

b) Where this requirement is not complied with, shields or similar devices are to be provided around the units in order to avoid an accidental oil spray or mist on heated surfaces which may ignite oil.

13.4 Design of hydraulic systems

13.4.1 Power units

Low power hydraulic installations not supplying essential services may be fitted with a single power unit, provided that alternative means, such as a hand pump, are available on board.

13.4.2 Pressure reduction units

Pressure reduction units used in hydraulic power installations are to be duplicated.

13.4.3 Filtering equipment

a) A device is to be fitted which efficiently filters the hydraulic oil in the circuit.

b) Where filters are fitted on the discharge side of hydraulic pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

13.4.4 Provision for cooling

Where necessary, appropriate cooling devices are to be provided.

13.4.5 Provision against overpressure

a) Safety valves of sufficient capacity are to be provided at the high pressure side of the installation.

b) Safety valves are to discharge to the low pressure side of the installation or to the service tank.

13.4.6 Provision for venting

Cocks are to be provided in suitable positions to vent the air from the circuit.

13.4.7 Provision for drainage

Provisions are to be made to allow the drainage of the hydraulic oil contained in the installation to a suitable collecting tank.

13.5 Design of hydraulic tanks and other components

13.5.1 Hydraulic oil service tanks

a) Service tanks intended for hydraulic power installations supplying essential services are to be provided with at least:
- a level gauge complying with [2.9.2]
- a temperature indicator
- a level switch complying with [13.6.2].

b) The free volume in the service tank is to be at least 10% of the tank capacity.

13.5.2 Hydraulic oil storage tanks

Hydraulic power installations supplying essential services are to include a storage means of sufficient capacity to refill the whole installation should the need arise in case of necessity.

13.5.3 Hydraulic accumulators

The hydraulic side of the accumulators which can be isolated is to be provided with a relief valve.

13.6 Control and monitoring

13.6.1 Indicators

Arrangements are to be made for connecting a pressure gauge where necessary in the piping system.

13.6.2 Monitoring

Alarms and safeguards for hydraulic power installations intended for essential services, except steering gear, for which the provisions of Ch 1, Sec 12 apply, are to be provided in accordance with Tab 28.

Note 1: Tab 28 does not apply to steering gear.

Table 28 : Hydraulic oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Pump pressure	L						
Service tank level	L**(1)**						

(1) The low level alarm is to be activated before the quantity of lost oil reaches 100 liters or 50% of the circuit volume, whichever is the less.

Note 1: Blank box means no provision.

13.7 Construction of hydraulic oil piping systems

13.7.1 Materials

a) Pipes are to be made of seamless steel or seamless stainless steel. The use of welded steel pipes will be given special consideration by the Society.

b) Casings of pumps, valves and fittings are to be made of steel or other ductile material.

13.7.2 Pipe connections

Where flanged connections are used they are to be of the recess type or of another approved type offering suitable protection against projections.

14 Steam systems

14.1 Application

14.1.1 Scope

This Article applies to all steam systems intended for essential and non-essential services.

Steam systems with a design pressure of 10 MPa or more will be given special consideration.

14.2 Principle

14.2.1 Availability

a) Where a single boiler is installed, the steam system may supply only non-essential services.

b) Where more than one boiler is installed, the steam piping system is to be so designed that, in the event that any one boiler is out of action, the steam supply to essential services can be maintained.

14.3 Design of steam lines

14.3.1 General

a) Every steam pipe and every connected fitting through which steam may pass is to be designed, constructed and installed such as to withstand the maximum working stresses to which it may be subjected.

b) When the design temperature of the steam piping system exceeds 400°C, calculations of thermal stresses are to be submitted to the Society as specified in [2.3].

c) Steam connections on boilers and safety valves are to comply with the applicable requirements of Ch 1, Sec 3.

14.3.2 Provision against overpressure

a) If a steam pipe or fitting may receive steam from any source at a higher pressure than that for which it is designed, a suitable reducing valve, relief valve and pressure gauge are to be fitted.

b) When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valves are designed, means to relieve the excess pressure are to be provided.

14.3.3 Provision for dumping

In order to avoid overpressure in steam lines due to excessive steam production, in particular in systems where the steam production cannot be adjusted, provisions are to be made to allow the excess steam to be discharged to the condenser by means of an appropriate dump valve.

14.3.4 Provision for draining

Means are to be provided for draining every steam pipe in which dangerous water hammer action might otherwise occur.

14.3.5 Steam heating pipes

a) When heating coils are fitted in compartments likely to contain either fuel oil or liquid or dry cargoes, arrangements such as blind flanges are to be provided in order to disconnect such coils in the event of carriage of dry or liquid cargoes which are not to be heated.

b) The number of joints on heating coils is to be reduced to the minimum consistent with dismantling requirements.

14.3.6 Steam lines in cargo holds

a) Live and exhaust steam pipes are generally not to pass through cargo holds, unless special provisions are made with the Society's agreement.

b) Where steam pipes pass through cargo holds in pipe tunnels, provision is to be made to ensure the suitable thermal insulation of such tunnels.

c) When a steam smothering system is provided for cargo holds, provision is to be made to prevent spurious damage of the cargo by steam or condensate leakage.

14.3.7 Steam lines in accommodation spaces

Steam lines are not to pass through accommodation spaces, unless they are intended for heating purposes.

14.3.8 Turbine connections

a) A sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary.

b) Bled steam connections are to be fitted with non-return valves or other approved means to prevent steam and water returning to the turbines.

14.3.9 Strainers

a) Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or, alternatively, at the inlets to manoeuvring valves.

b) Where required by the manufacturer of the auxiliaries, steam strainers are also to be fitted in the steam lines supplying these auxiliaries.

15 Boiler feed water and condensate systems

15.1 Application

15.1.1 This Article applies to:

- feed water systems of oil fired and exhaust gas boilers
- steam drain and condensate systems.

15.2 Principle

15.2.1 General

Boiler feed water and condensate systems are to be so designed that:

- reserve feed water is available in sufficient quantity to compensate for losses
- feed water is free from contamination by oils or chlorides
- feed water for propulsion systems is suitably de-aerated.

15.2.2 Availability

a) Feed water systems are to be so designed that, in the event of failure of any one component, the steam supply to essential services can be maintained or restored.

b) Condensate systems are to be so designed that, in the event of failure of:
   - one condensate pump, or
   - the arrangements to maintain vacuum in the condenser,

   the steam supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted.

15.3 Design of boiler feed water systems

15.3.1 Number of feed water systems

a) Every steam generating system which supplies essential services is to be provided with not less than two separate feed water systems from and including the feed pumps, noting that a single penetration of the steam drum is acceptable.

b) The requirement stated in a) may be dispensed with for boilers heated exclusively by engine exhaust gases or by steam for which one feed system is considered as sufficient, provided an alternative supply of steam is available on board.

c) Each boiler is to be provided with feed regulators as specified in Ch 1, Sec 3, [5].

15.3.2 Feed pumps

a) The following pumps are to be provided:
   - at least one main feed pump of sufficient capacity to supply the boilers under nominal conditions, and
   - one standby feed pump.

b) The capacity of the standby pump may be less than that of the main feed pumps provided it is demonstrated that, taking into account the reduction of the propulsion capability, the ship remains safely operable.

c) Main feed pumps may be either independent or driven by the main turbines. The standby feed pump is to be independent.

d) In twin-screw ships in which there is only one independent feed pump, each main turbine is to be fitted with a driven pump. Where all feed pumps are independent, they are to be so arranged as to be capable of dealing with the feed water necessary to supply steam either to both turbines or to one turbine only.

e) Independent feed pumps for main boilers are to be fitted with a delivery control and regulating system.

f) Unless overpressure is prevented by the feed pump characteristics, means are to be provided which will prevent overpressure in the feed water system.

g) The pressure head of feed pumps is to take into account the maximum service pressure in the boiler as well as the pressure losses in the discharge piping. The suction head of feed pumps is to be such as to prevent cavitation as far as possible.

h) Feed pumps and pipes are to be provided with valves so arranged that any one pump can be overhauled while the boilers are operating at full load.

15.3.3 Harbour feed pumps

a) Where main turbine driven pumps are provided and there is only one independent pump, a harbour feed pump or an ejector is to be fitted in addition to provide the second means for feeding the boilers which are in use when the main turbine is not working.

b) The harbour feed pump may be used for the general service of the ship, but in no case is this pump to be used to convey liquid fuel, lubricating oil or oily water.

c) The suction pipes of the harbour feed pump from the hotwell, from reserve feed water tanks and from filters are to be fitted with non-return valves.

15.3.4 Feed water tanks

a) All ships fitted with main boilers or auxiliary boilers for essential services are to be provided with reserve feed water tanks.

b) Boilers are to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

c) Feed water tanks are not to be located adjacent to fuel oil tanks. Fuel oil pipes are not to pass through feed water tanks.

d) For main boilers, one or more evaporators are to be provided, the capacity of which is to compensate for the losses of feed water due to the operation of the machines, in particular where the fuel supplied to the boilers is atomized by means of steam.

15.3.5 Provision for de-aerating feed water

A de-aerator is to be provided to ensure the de-aeration of the feed water intended for main boilers before it enters such boilers.

15.4 Design of condensate systems

15.4.1 Condensers

a) Appropriate arrangements, such as air ejectors, are to be provided to maintain vacuum in the main condenser or restore it to the required value.

b) Cooling of the main condenser is to comply with the provisions of [10.3.5].

15.4.2 Condensate pumps

a) Condensate pumps are to include at least:
   - one main condensate pump of sufficient capacity to transfer the maximum amount of condensate produced under nominal conditions, and
   - one independently driven standby condensate pump.

b) The standby condensate pump may be used for other purposes.

15.4.3 Condensate observation tanks

Any condensate from the steam heating pipes provided for fuel oil tanks and bunkers, cargo tanks and fuel oil or lubricating oil heaters is to be led to an observation tank or some other device of similar efficiency located in a well-lighted and readily accessible position.

15.5 Control and monitoring

15.5.1 General

The provisions of this sub-article apply only to feed water and condensate systems intended for propulsion.

15.5.2 Monitoring

Alarms and safeguards are to be provided for feed water and condensate systems in accordance with Tab 29.

15.5.3 Automatic controls

Automatic level control is to be provided for:

- de-aerators
- condensers.

Table 29 : Boiler feed and condensate system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water flow or equivalent	L						
Condenser pressure	H	local					
	HH			X			
Water level in main condenser (unless justified)	H	local					
Feed water salinity	H	local					
Feed water pump delivery pressure	L	local					
						X	
Feed water tank level	L						

15.6 Arrangement of feed water and condensate piping

15.6.1

a) Feed water pipes are not to pass through fuel oil or lubricating oil tanks.

b) Pipes connected to feed water tanks are to be so arranged as to prevent the contamination of feed water by fuel oil, lubricating oil or chlorides.

16 Compressed air systems

16.1 Application

16.1.1 This Article applies to compressed air systems intended for essential services, and in particular to:

- starting of engines
- control and monitoring
- breathable air systems.

16.2 Principle

16.2.1 General

a) Compressed air systems are to be so designed that the compressed air delivered to the consumers:
   - is free from oil and water
   - does not have an excessive temperature.

b) Compressed air systems are to be so designed as to prevent overpressure in any part of the systems.

16.2.2 Availability

a) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air receiver intended for starting, control purposes or other essential services, the air supply to such services can be maintained.

b) At the specific request of the Naval Authority, it may be required that the compressed air system for starting main engines and auxiliary engines for essential services is to be so arranged that it is possible to ensure the initial charge of air receiver(s) without the aid of a power source outside the ship. Equivalent solutions allowing the starting of the engines may be accepted by the Society on a case by case basis.

c) If the air receivers are used for engine starting as in [16.3] the total capacity of air receivers hall take into account the air to be delivered to other consumers such as control systems, ship systems, etc., which are connected to the air receivers.

16.3 Design of starting air systems

16.3.1 Number and capacity of air compressors

a) Where main and auxiliary engines are arranged for starting by compressed air, two or more air compressors are to be fitted with a total capacity sufficient to supply within one hour the quantity of air needed to satisfy the provisions of Ch 1, Sec 2, [3.1.1]. This capacity is to be approximately equally divided between the number of compressors fitted, excluding the emergency compressor fitted in pursuance of [16.3.2].

b) At least one of the compressors is to be independent of the engines for which starting air is supplied and is to have a capacity of not less than 50% of the total required in item a).

16.3.2 Initial charge of starting air receivers

a) Where, for the purpose of [16.2.2], an emergency air compressor is fitted, its driving engine is to be capable of being started by hand-operated devices. Independent electrical starting batteries may also be accepted.

b) A hand compressor may be used for the purpose of [16.2.2] only if it is capable of charging within one hour an air receiver of sufficient capacity to provide 3 consecutive starts of a propulsion engine or of an engine capable of supplying the energy required for operating one of the main compressors.

16.3.3 Number and capacity of air receivers

a) Where main engines are arranged for starting by compressed air, at least two air receivers are to be fitted of approximately equal capacity and capable of being used independently.

b) The total capacity of air receivers is to be sufficient to provide without replenishment the number of starts required in Ch 1, Sec 2, [3.1.1].

16.3.4 Air supply for starting the emergency generating set

Starting air systems serving main or auxiliary engines may be used for starting the emergency generator under the conditions specified in Ch 1, Sec 2, [3.1.3].

16.4 Design of control and monitoring air systems

16.4.1 Air supply

a) The control and monitoring air supply to essential services is to be available from two sources of a sufficient capacity to allow normal operation with one source out of service.

b) At least one air vessel fitted with a non-return valve is to be provided for control and monitoring purposes.

Note 1: The Society may accept, as an alternative to the above clause, provisions allowing the configuration of the compressed air installation in such a way as that the control and monitoring air circuit can be isolated from the rest of the installation.

c) Pressure reduction units used in control and monitoring air systems intended for essential services are to be duplicated, unless an alternative air supply is provided.

d) Failure of the control air supply is not to cause any sudden change of the controlled equipment which may be detrimental to the safety of the ship.

16.4.2 Pressure control

Arrangements are to be made to maintain the air pressure at a suitable value in order to ensure satisfactory operation of the installation.

16.4.3 Air treatment

In addition to the provisions of [16.8.3], arrangements are to be made to ensure cooling, filtering and drying of the air prior to its introduction in the monitoring and control circuits.

16.5 Design of air compressors

16.5.1 Prevention of excessive temperature of discharged air

Air compressors are to be so designed that the temperature of discharged air cannot exceed 95°C. For this purpose, the air compressors are to provided where necessary with:

- suitable cooling means
- fusible plugs or alarm devices set at a temperature not exceeding 120°.

16.5.2 Prevention of overpressure

a) Air compressors are to be fitted with a relief valve complying with [2.5.3].

b) Means are to be provided to prevent overpressure wherever water jackets or casings of air compressors may be subjected to dangerous overpressure due to leakage from air pressure parts.

c) Water space casings of intermediate coolers of air compressors are to be protected against any overpressure which might occur in the event of rupture of air cooler tubes.

16.5.3 Crankcase relief valves

Air compressors having a crankcase volume of at least 0,6 m^3 are to be fitted with crankcases explosion relief valves satisfying the provisions of Ch 1, Sec 2, [2.4.4].

16.5.4 Provision for draining

Air compressors are to be fitted with a drain valve.

16.6 Control and monitoring of compressed air systems

16.6.1 Monitoring

Alarms and safeguards are to be provided for compressed air systems in accordance with Tab 30.

16.6.2 Automatic controls

Automatic pressure control is to be provided for maintaining the air pressure in the air receivers within the required limits.

16.7 Materials

16.7.1 Pipes and valves bodies in control and monitoring air systems and other air systems intended for non-essential services may be made of plastic in accordance with the provisions of Ch 1, App 2.

16.8 Arrangement of compressed air piping systems

16.8.1 Prevention of overpressure

Means are to be provided to prevent overpressure in any part of compressed air systems. Suitable pressure relief arrangements are to be provided for all systems discharging in a safe position.

16.8.2 Air supply to compressors

a) Provisions are to be made to reduce to a minimum the entry of oil into air pressure systems.

b) Air compressors are to be located in spaces provided with sufficient ventilation.

Table 30 : Compressed air systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Compressor lubricating oil pressure (except where splash lubrication)	L						
Air pressure after reducing valves **(1)**	L+H	local					
Starting air pressure before main shut-off valve	L	local + R					
Air vessel pressure **(2)**	L+H	local					
Note 1: Blank box means no provisions. **(1)** Applicable to the pressure reducing valves referred to in [15.4.1] c). **(2)** Applicable to air vessel group where the air vessels are normally in communication.							

16.8.3 Air treatment and draining

a) Provisions are be made to drain air pressure systems.

b) Efficient oil and water separators, or filters, are to be provided on the discharge of compressors, and drains are to be installed on compressed air pipes wherever deemed necessary.

16.8.4 Lines between compressors, receivers and engines

All discharge pipes from starting air compressors are to be lead directly to the starting air receivers, and all starting air pipes from the air receivers to main or auxiliary engines are to be entirely separate from the compressor discharge pipe system.

Note 1: Air vessels may be arranged as buffer vessels (common filling and discharge line) provided that a non return valve is fitted between the engine and the compressor, in addition to that required in Ch 1, Sec 2, [3.1.1], item c).

16.8.5 Protective devices for starting air mains

Non-return valves and other safety devices are to be provided on the starting air mains of each engine in accordance with the provisions of Ch 1, Sec 2, [3.1.1].

16.9 Compressed breathable air systems

16.9.1 Number of refilling air breathable stations and station arrangement

A refilling station for breathing apparatus of fire-fighter's outfits is to be provided in each safety zone. The station is to be provided with an electric driven compressor capable of refilling the number of bottles mentioned in the ship specification at 30 MPa in less than one hour. Arrangements are to be made for refilling other equipment such as breathing apparatuses for CBRN protection purposes or divers apparatus.

Where necessary, pressure reducing devices are to be provided.

Ships to be assigned the additional class notation **CBRN** or **CRBN-AIRBLAST RESISTANCE** are to comply with the provisions of Pt E, Ch 8, Sec 3, [5] in addition to those of the present requirement.

16.9.2 Breathable air properties

The breathable air properties shall comply with standards to be stated by the Naval Authority.

16.9.3 Air compressors

a) The air inlet of the compressors is to be positioned so that particulate matters are minimized and the content of water and oil in the suctioned air remains below 50 mg/Nm^3. For ships to be assigned the **CBRN** or **CBRN-AIRBLAST RESISTANCE** additional class notation, these criteria are to be fulfilled in CBRN mode as well.

b) All compressors shall be so designed and constructed that prevention of overpressure and excessive temperature and shall comply with the requirements of [16.5.1] and [16.5.2].

c) The compressors shall also be provided with filter and valves at the air inlet, valve at air outlet, automatic drain valve and safety valve at stages as well as automatic condensate baffle separators after stages.

d) Furthermore, for the electric compressor, at least the followings operations are to be provided from the control panel required in [16.9.5]:
   - emergency shut down
   - automatic stop at a delivered preset pressure
   - emergency stop in case of compressed air high temperature

and the following monitors:

- lubricating oil level
- delivered air pressure.

16.9.4 Air filtering systems

The air filtering systems shall be consistent with the air breathable properties stated by the Naval Authority.

16.9.5 Air breathable monitor and control panels

Air process, air properties as well as filling/refilling process shall be controlled and monitored.

16.9.6 Prevention of over pressure

The requirements in [16.8.1] shall be complied with.

16.9.7 Metallic materials

All metallic materials which are used in the construction of pipes for breathable systems shall be AISI 316, or other stainless steel with a nickel content not less than 10% and a yielding strength R_S not less than 250 Mpa, or Monel 400.

16.9.8 Class of components of breathable air systems and tests

For pipes, fittings, containers, filter and absorption devices containers and compressors, class shall be in accordance with the present Ch 1, Sec 10 and, where appropriate, with Ch 1, Sec 3.

The tests of such components shall be in accordance with [19].

17 Combustion air and exhaust gas systems

17.1 General

17.1.1 Application

This Article applies to:

- combustion air intake systems that may be provided for machinery required to run in CBRN condition
- exhaust gas pipes from engines and gas turbines, and
- smoke ducts from boilers and incinerators.

17.1.2 Principle

Combustion air systems are to be designed so as to:

- prevent CBRN contamination in manned spaces
- prevent water from entering engines.

Exhaust gas systems are to be designed so as to:

- limit the risk of fire
- prevent gases from entering manned spaces
- prevent water from entering engines.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 2, [6] for ships to be assigned the **CBRN** additional class notation.

17.1.3 Exhaust gas pollution prevention systems

Additional requirements for the installation of exhaust gas pollution prevention systems and storage and use of chemical treatment fluids consumed in the associated process are given in Ch 1, Sec 11.

17.2 Design of combustion air and exhaust systems

17.2.1 General

Combustion air and exhaust systems are to be so arranged as to minimise the intake of exhaust gases into manned spaces, air conditioning systems and engine intakes.

17.2.2 Limitation of exhaust line surface temperature

a) Exhaust gas pipes and silencers are to be either water cooled or efficiently insulated where:
   - their surface temperature may exceed 220°C, or
   - they pass through spaces of the ship where a temperature rise may be dangerous.

b) The insulation of exhaust systems is to comply with the provisions of Ch 1, Sec 1, [3.7.1].

17.2.3 Limitation of pressure losses

Combustion air and exhaust gas systems are to be so designed that pressure losses in the intake and exhaust lines do not exceed the maximum values permitted by the engine or boiler manufacturers.

17.2.4 Intercommunication of engine exhaust gas lines or boiler smoke ducts

Exhaust gas from different engines is not to be led to a common exhaust main, exhaust gas boiler or economizer, unless each exhaust pipe is provided with a suitable isolating device.

17.2.5 Air intake and exhaust gas pipe terminations

a) Where exhaust pipes are led overboard close to the load waterline, means are to be provided to prevent water from entering the engine or the ship.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

c) Air intake systems are to be so arranged to prevent water and waterspray from entering the air duct.

d) Air intake systems are to be protected against entering of dust as per requirement of engine manufacturer.

17.3 Materials

17.3.1 General

Materials of exhaust gas pipes and fittings are to be resistant to exhaust gases and suitable for the maximum temperature expected.

17.4 Arrangement of combustion air and exhaust piping systems

17.4.1 Provision for thermal expansion

a) Exhaust pipes and smoke ducts are to be so designed that any expansion or contraction does not cause abnormal stresses in the piping system, and in particular in the connection with engine turbochargers.

b) The devices used for supporting the pipes are to allow their expansion or contraction.

17.4.2 Provision for displacement

Where engine are elastic mounted, the devices used for supporting the combustion air, if any, and exhaust pipes or ducts are to be so designed that any displacement does not cause abnormal stresses in the piping system and in particular in the connection with engine turbochargers.

17.4.3 Provision for draining

a) Drains are to be provided where necessary in combustion air and exhaust systems in order to prevent water flowing into the engine.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18 Oxyacetylene welding systems

18.1 Application

18.1.1 This Article applies to centralized fixed plants for oxyacetylene welding installed on ships. It may also be applied, at the discretion of the Society, to other plants using liquefied gas, such as propane.

While it is to be noted that oxyacetylene welding systems are generally not in use in naval ships the following provisions apply if this system are present.

18.2 Definitions

18.2.1 Centralised plants for oxyacetylene welding

A centralized plant for oxyacetylene welding is a fixed plant consisting of a gas bottle room, distribution stations and distribution piping, where the total number of acetylene and oxygen bottles exceeds 4.

18.2.2 Acetylene

Acetylene (C_2H_2) is assumed to be contained in pressurized gas bottles with pressure equal to 1,5-1,8 MPa at 15°C.

18.2.3 Oxygen

Oxygen (O_2) is assumed to be contained in pressurized gas bottles, with pressure equal to 15-20 MPa at 15°C.

18.2.4 Gas bottle rooms

A gas bottle room is a room containing acetylene and oxygen bottles, where distribution headers, non-return and stop valves, pressure reducing devices and outlets of supply lines to distribution stations are also installed.

Note 1: Gas bottle rooms may also contain non dangerous equipment.

18.2.5 Distribution stations

Distribution stations are adequately protected areas or cabinets equipped with stop valves, pressure regulating devices, pressure gauges, non-return valves and oxygen as well as acetylene hose connections for the welding torch.

18.3 Design of oxyacetylene welding systems

18.3.1 General

Except on pontoons and service working ships, no more than two distribution stations are normally permitted.

18.3.2 Acetylene and oxygen bottles

a) The bottles are to be tested by the Society or by a body recognized by the Society.

b) Bottles with a capacity exceeding 50 liters are not permitted.

c) Bottles supplying the plant and spare bottles are to be installed in the gas bottle room. Installation within accommodation spaces, service spaces, control stations and machinery spaces is not permitted.

d) Bottles are to be installed in a vertical position and are to be safely secured. The securing system is to be such as to allow the ready and easy removal of the bottles.

18.3.3 Piping systems

a) Acetylene and oxygen piping systems are to comply with the following provisions:
   - all valves and fittings as well as welding torches and associated supply hoses are to be adapted to this specific service and suitable for the conditions expected in the different parts of the system
   - acetylene piping is to be of stainless steel and seamless drawn
   - oxygen piping is to be of copper or stainless steel and seamless drawn
   - the connections between the various pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted
   - only a minimum number of unavoidable connections are permitted provided they are located in a clearly visible position.

b) High pressure lines (i.e. lines between bottles and pressure reducing devices) are to be installed inside the gas bottle room and are to comply with the following provisions:
   - acetylene and oxygen piping and associated fittings are to be suitable for a design pressure of 29,5 MPa
   - a non-return valve is to be installed on the connection of each acetylene and oxygen bottle to the header
   - stop valves are to be provided on the bottles and kept shut when distribution stations are not working.

c) Low pressure lines (i.e. lines between pressure reducing devices and distribution stations) are to comply with the following provisions:
   - steel piping is to have a thickness of not less than:
     - 2,5 mm when installed in the open air
     - 2 mm otherwise.
   - stainless steel piping is to have a thickness of not less than 1,7 mm.
   - supply lines to each distribution station are to include, at the station inlet:
     - a stop valve to be kept shut when the station is not working
     - devices to protect the supply lines from back flow of gas or flame passage.

d) Safety valves are to be provided on the low pressure side of the pressure reducing devices and led to the open air above the deck in a safe location where the gas can easily be spread and where no source of ignition is present.

18.4 Arrangement of oxyacetylene welding systems

18.4.1 Gas bottle rooms

a) The gas bottle room is to be located in an independent space over the highest continuous deck and provided with direct access from outside. The limiting bulkheads and decks are to be gas-tight and made of steel.

Note 1: Alternatively, the bottles may be stored in an open area.

b) When the total number of gas bottles, including possible spare bottles which are not connected to the plant, does not exceed 8, acetylene and oxygen bottles may be installed in the same room. Otherwise, acetylene and oxygen bottles are to be separated by a gas-tight bulkhead.

c) The bottle room is to be adequately ventilated. See also Ch 4, Sec 5, [6.8.6].

d) Flammable oil or gas piping, except that related to the oxyacetylene welding plant, is not to be led through this room.

18.4.2 Distribution stations

Distribution stations are to be located in the engine room or in the workshop, in a well-ventilated position and protected against possible mechanical damage.

18.4.3 Piping

a) Piping is not to be led through accommodation or service spaces.

b) Piping is to be protected against any possible mechanical damage.

c) In way of deck or bulkhead penetrations, piping is to be suitably enclosed in sleeves so arranged as to prevent any fretting of the pipe with the sleeve.

18.4.4 Signboards

Signboards are to be posted on board the ship in accordance with Tab 31.

Table 31 : Signboards

Location of the signboard	Signboard to be posted
In the gas bottle room	Diagram of the oxyacetylene plant
	"No smoking"
In way of: • bottle stop valves • distribution station stop valves	"To be kept shut when distribution stations are not working"
In way of the pressure reducing devices	Indication of the maximum allowable pressure at the pressure reducing device outlet
In way of the safety valve discharge outlet	"No smoking"

19 Certification, inspection and testing of piping systems

19.1 Application

19.1.1 This Article defines the certification and workshop inspection and testing programme to be performed on:

- the various components of piping systems
- the materials used for their manufacture.

On board testing is dealt with in Ch 1, Sec 16.

19.2 Type tests of flexible hoses and expansion joints

19.2.1 General

a) Prototype test programmes are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

b) Prototype test programmes are to be made in accordance with recognised standards which are suitable for the intended service of the flexible hose or of an expansion joint.

c) Tests are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to the installation.

d) All flexible hose assemblies or expansion joints are to be satisfactorily prototype burst tested to an international standard (see Note 1) to demonstrate that they are able to withstand a pressure not less than 4 times their design pressure without indication of failure or leakage.

Note 1: The international standards (e.g. EN or SAE standards) for burst testing of non-metallic hoses require the pressure to be increased until burst without any holding period. Burst is to occur at a pressure greater than 4 times the maximum working pressure.

19.2.2 Flexible hoses

a) For flexible hoses which are to comply with [2.6], prototype tests are to be carried out for each size of hose assembly. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:

   - the smallest diameter
   - the largest diameter
   - intermediate diameters selected based on the principle that prototype tests carried out for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0,5 D and 2 D.

   For fire resistance tests the specimens are to be selected in accordance with ISO 15540:2016.

b) The flexible hoses subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [19.2.1], including, but not limited to, the scope of testing specified in Tab 32 for metallic flexible hoses and in Tab 33 for non-metallic flexible hoses.

Table 32 : Type tests and procedures for metallic flexible hoses depending on the application

	Burst	Pliability (bending)	Cycle test: U bend (Hoses up to 100 DN)	Cycle test: Cantilever bend (Hoses above DN 100)	Pressure and elongation	Impulse	Vibration
	ISO 10380:2012**(1)**					**(2)**	Ch 3, Sec 6, Tab 1 **(1)**
Fuel Oil	X	X	X	X	X	**(3)**	**(4)**
Lubricating Oil	X	X	X	X	X	**(3)**	**(4)**
Hydraulic Oil	X	X	X	X	X	**(3)**	**(4)**
Thermal Oil	X	X	X	X	X	**(3)**	**(4)**
Fresh water	X	X	X	X	X	**(3)**	**(4)**
Sea water	X	X	X	X	X	**(3)**	**(4)**
Compressed air	X	X	X	X	X	**(3)**	**(4)**
Bilge	X	X	X	X	X	**(3)**	**(4)**
Exhaust Gas	X	X	X	X	X	**(3)**	**(4)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) Impulse pressure is to be raised from 0 to 1,5 times the design pressure with a frequency equal to 30-100 cycles per minute for at least 150 000 cycles.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 33 : Type tests and procedures for non-metallic flexible hoses depending on the application

	Burst	Fire resistance	Visual inspection and dimensional check	Change in length	Resistance against liquid	Cover adhesion	Ozone resistance **(2)**	Impulse	Vibration	Vacuum	Cold flexibility
	EN ISO 1402:2021 **(1)**	EN ISO 15540:2016 / EN ISO 15541:2016 **(1)**	EN ISO 4671:2022 **(1)**	EN ISO 1402:2021 **(1)**	ISO 1817:2022 **(1)**	EN ISO 8033:2016 **(1)**	ISO 7326:2016 **(1)**	EN ISO 6802:2018 / EN ISO 6803:2017 **(1)**	Ch 3, Sec 6, Tab 1 **(1)**	EN ISO 7233:2016 **(1)**	EN ISO 10619-2:2021 **(1)**
Fuel Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Fresh water	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Sea water	X	X	X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Compressed air	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Bilge	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Exhaust Gas	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For rubber hoses only.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.
(5) For suction hoses only.
(6) For piping systems subject to low temperature (< 0°C).

19.2.3 Expansion Joints

a) For the expansion joints which are to comply with [2.6], relevant type approval tests are to be carried out on a representative sampling on each type and for each pressure range.

b) The expansion joints subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [19.2.1], including, but not limited to, the scope of testing specified in Tab 34 for metallic expansion joints and in Tab 35 for non-metallic expansion joints.

d) Exemptions from prototype burst test may be granted for expansion joints of large diameter used on sea water lines and to large diameter expansion joints used on exhaust gas lines, except for those which are fitted directly on engines. Testing may be limited to pressure test.

Table 34 : Type tests and procedures to be performed for metallic expansion joints

	Burst	Hydrostatic	Cyclic expansion **(2)**	Vibration
	see [19.2.1] d)**(1)**	see [19.6.6]**(1)**	EJMA Code **(3)(1)**	Ch 3, Sec 6, Tab 1**(1)**
Fuel Oil	X		X	**(4)**
Lubricating Oil	X		X	**(4)**
Hydraulic Oil	X		X	**(4)**
Thermal Oil	X		X	**(4)**
Fresh water	X		X	**(4)**
Sea water	X		X	**(4)**
Compressed air	X		X	**(4)**
Bilge	X		X	**(4)**
Exhaust Gas		X	X	**(4)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For piping systems subject to expansion cycles.
(3) Type test is an alternative. A test procedure is to be submitted to the Society for approval.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 35 : Type tests and procedures for non-metallic expansion joints

	Burst	Fire resistance	Resistance against liquid	Cyclic expansion**(2)**	Ozone resistance	Impulse	Vibration
	[19.2.1] d)**(1)**	EN ISO 15540:2016 / EN ISO 15541:2016**(1)**	ISO 1817:2022**(1)**	**(3)(1)**	ISO 7326:2016**(1)**	EN ISO 6802:2018 / EN ISO 6803:2017**(1)**	Ch 3, Sec 6, Tab 1**(1)**
Fuel Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Fresh water	X			X	**(4)**	**(5)**	**(6)**
Sea water	X	X		X	**(4)**	**(5)**	**(6)**
Compressed air	X			X	**(4)**	**(5)**	**(6)**
Bilge	X			X	**(4)**	**(5)**	**(6)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For piping systems subject to expansion cycles.
(3) Test procedure is to be submitted to the Society for approval
(4) For rubber expansion joints only.
(5) For piping systems subject to pressure pulsation.
(6) Where fitted to engines, pumps, compressors or other sources of high vibrations

19.3 Type tests of air pipe closing devices

19.3.1 Type approval tests are to be carried out on each type and size of air pipe closing device, in accordance with Tab 36 and the "Rules for type approval and testing of air pipe closing devices".

19.4 Type tests of mechanical pipe joints

19.4.1 Type approval tests of mechanical pipe joints are to be carried out in accordance with the provisions of Tab 37.

Table 36 : Type tests to be performed for air pipe closing appliances

Test to be performed	Type of air closing appliance	
	Float type	Other types
Tightness test **(1)**	X	X
Flow characteristic determination **(2)**	X	X
Impact test of floats	X	
Pressure loading test of floats	X **(3)**	

(1) The tightness test is to be carried out during immerging/ emerging in water, in the normal position and at an inclination of 40 degrees.
(2) Pressure drop is to be measured versus flow rate using water.
(3) only for non-metallic floats.
Note 1: X = required.

Table 37 : Type tests to be performed for mechanical joints

Tests		Types of mechanical joints		
		Compression couplings and pipes unions	Slip-on joints	
			Grip type & machine grooved type	Slip type
1	Tightness test	+	+	+
2	Vibration (fatigue) test	+	+	–
3	Pressure pulsation test **(1)**	+	+	–
4	Burst pressure test	+	+	+
5	Pull-out test	+	+	–
6	Fire endurance test	+	+	+
7	Vacuum test	+ **(3)**	+	+
8	Repeated assembly test	+ **(2)**	+	–

Abbreviations:
+ : test is required
– : test is not required.
(1) For use in those systems where pressure pulsation other than water hammer is expected
(2) Except press type
(3) Except joints with metal-to-metal tightening surfaces.

19.5 Testing of materials

19.5.1 General

a) Detailed specifications for material tests are given in NR216 Materials and Welding.

b) Requirements for the inspection of welded joints are given in NR216 Materials and Welding.

19.5.2 Tests for materials

a) Where required in Tab 38, materials used for pipes, valves and other accessories are to be subjected to the following tests:

- tensile test at ambient temperature
- flattening test or bend test, as applicable

- tensile test at the design temperature, except if one of the following conditions is met:
  - the design temperature is below 200°C
  - the mechanical properties of the material at high temperature have been approved
  - the scantling of the pipes is based on reduced values of the permissible stress.

b) Plastic materials are to be subjected to the tests specified in Ch 1, App 2, however installation shall be avoided if not agreed by the Society and the Naval Authority.

19.6 Hydrostatic testing of piping systems and their components

19.6.1 General

Pneumatic tests are to be avoided wherever possible. Where such testing is absolutely necessary in lieu of the hydraulic pressure test, the relevant procedure is to be submitted to the Society for acceptance prior to testing.

19.6.2 Hydrostatic pressure tests of piping

a) Hydrostatic pressure tests are to be carried out to the Surveyor's satisfaction for:
- all class I and II pipes and their integral fittings
- all steam pipes, feed water pipes, compressed air pipes, and fuel oil and other flammable oil pipes with a design pressure greater than 0,35 MPa and their associated integral fittings.

b) These tests are to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

Note 1: Classes of pipes are defined in [1.5.2].

c) Pressure testing of small bore pipes (less than 15 mm) may be waived except for fuel oil system, JP5-NATO (F44) system, aircraft/helicopter refuelling system and compressed air system at the discretion of the Surveyor, depending on the application.

d) Where the design temperature does not exceed 300°C, the test pressure is to be equal to 1,5 p.

e) Where the design temperature exceeds 300°C, the test pressure is to be as follows:
- for carbon and carbon-manganese steel pipes, the test pressure is to be equal to 2 p
- for alloy steel pipes, the test pressure P_H is to be determined by the following formula, but need not exceed 2 p:

$$p_H = 1,5 \frac{K_{100}}{K_T} p$$

where:

K_{100} : Permissible stress for 100°C, as stated in Tab 10

K_T : Permissible stress for the design temperature, as stated in Tab 10.

Note 2: Where alloy steels not included in Tab 10 are used, the permissible stresses will be given special consideration.

f) Where it is necessary to avoid excessive stress in way of bends, branches, etc., the Society may give special consideration to the reduction of the test pressure to a value not less than p_H equal to1,5 p. The membrane stress is in no case to exceed 90% of the yield stress at the testing temperature.

g) While satisfying the condition stated in b), the test pressure of pipes located on the discharge side of centrifugal pumps driven by steam turbines is not to be less than the maximum pressure liable to be developed by such pumps with closed discharge at the operating speed of their overspeed device.

h) When the hydrostatic test of piping is carried out on board, these tests, except for class I, may be carried out in conjunction with the tests required in [19.6.7].

19.6.3 Hydrostatic tests of valves, fittings and heat exchangers

a) Valves and fittings non-integral with the piping system and intended for class I and II pipes are to be subjected to hydrostatic tests in accordance with standards recognized by the Society, at a pressure not less than 1,5 times the design pressure p defined in [1.3.2].

b) Valves and distance pieces intended to be fitted on the ship side below the maximum ship draft are to be subjected to hydrostatic tests under a pressure not less than 0,5 MPa.

c) The shells of appliances such as heaters, coolers and heat exchangers which may be considered as pressure vessels are to be tested under the conditions specified in Ch 1, Sec 3.

d) The nests of tubes or coils of heaters, coolers and heat exchangers are to be submitted to a hydraulic test under the same pressure as the fluid lines they serve.

e) For coolers of internal combustion engines, see Ch 1, Sec 2.

19.6.4 Hydrostatic tests of fuel oil and JP5-NATO (F44) bunkers and tanks not forming part of the ship's structure

Fuel oil, JP5-NATO (F44) and bunkers tanks not forming part of the ship's structure are to be subjected to a hydrostatic test under a pressure corresponding to the maximum liquid level in such spaces or in the air or overflow pipes, with a minimum of 2,40 m above the top.

19.6.5 Hydrostatic tests of pumps and compressors

a) Cylinders, covers and casings of pumps and compressors are to be subjected to a hydrostatic test under a pressure at least equal to the test pressure p_H , in MPa, determined by the following formulae:

- $p_H = 1,5\ p$ where $p \leq 4$
- $p_H = 1,4\ p + 0,4$ where $4 < p \leq 25$
- $p_H = p + 10,4$ where $p > 25$

where:

p : Design pressure, in MPa, as defined in [1.3.2].

p_H is not to be less than 0,4 MPa.

b) While satisfying the condition stated in a), the test pressure for centrifugal pumps driven by steam turbines is not to be less than 1,05 times the maximum pressure likely to be recorded with closed discharge at the operating speed of the overspeed device.

c) Intermediate coolers of compressors are to undergo a hydrostatic test under a pressure at least equal to the pressure p_H defined in a). When determining p_H, the pressure p to be considered is that which may result from accidental communication between the cooler and the adjoining stage of higher pressure, allowance being made for any safety device fitted on the cooler.

d) The test pressure for water spaces of compressors and their intermediate coolers is not to be less than 1,5 times the design pressure in the space concerned, subject to a minimum of 0,2 MPa.

e) For air compressors and pumps driven by diesel engines, see Ch 1, Sec 2.

19.6.6 Hydrostatic test of flexible hoses and expansion joints

a) Each flexible hose or expansion joint, together with its connections, is to undergo a hydrostatic test under a pressure at least equal to 1,5 times the maximum service pressure.

b) During the test, the flexible hose or expansion joint is to be repeatedly deformed from its geometrical axis.

19.6.7 Pressure tests of piping after assembly on board

After assembly on board, the following tightness tests are to be carried out in the presence of the Surveyor.

In general, all the piping systems covered by these requirements are to be checked for leakage under operational conditions and, if necessary, using special techniques other than hydrostatic testing. In particular, heating coils in tanks and liquid lines are to be tested to not less than 1,5 times the design pressure but in no case less than 0,4 MPa.

Bilge and drainage systems are to be tested against air suction along the relevant lines which are to be provided with the necessary fittings for such purpose.

19.7 Testing of piping system components during manufacturing

19.7.1 Pumps

a) Bilge and fire pumps are to undergo a performance test.

b) Rotors of centrifugal feed pumps for main boilers are to undergo a balancing test.

c) All pumps are to undergo to vibration according to a recognized standard.

19.7.2 Centrifugal separators

Centrifugal separators used for fuel oil, JP5-NATO (F44) and lubricating oil are to undergo a running test, normally with a fuel water mixture.

19.8 Inspection and testing of piping systems

19.8.1 The inspections and tests required for piping systems and their components are summarised in Tab 38.

Table 38 : Inspection and testing at works for piping systems and their components

Item **(6)**		Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
		Tests required**(8)**	Type of material certificate **(2)**	During manufacturing (NDT)	After completion	Type of product certificate **(2)**
Valves, pipes and fittings **(9)**	a) class I, ND ≥ 50 mm or class II, ND ≥ 100 mm	[19.5.2]	C	[3.6.2] **(5)** [3.6.3]	[19.6.3]	C **(3)**
	b) class I, ND < 50 mm or class II, ND < 100 mm	[19.5.2]	W	[3.6.2] **(5)** [3.6.3]	[19.6.3]	C **(3)**
Flexible hoses and expansion joints		[19.5.2]	W		[19.6.6]	C **(3)**
Pumps and air compressors within piping systems covered by Sections of this Chapter **(7)**	a) all	NR216 Materials and Welding			[19.6.5]	C **(3)**
	b) bilge and fire pumps	NR216 Materials and Welding			[19.6.5] [19.7.1] a)	C **(3)**
	c) feed pumps for main boilers: - casing and bolts - main parts - rotor	NR216 Materials and Welding **(10)**	C **(10)**	[3.6.2] **(5)** [3.6.3]	[19.6.5] [19.7.1] b)	C **(3)**
	d) forced circulation pumps for main boiler: - casing and bolts	NR216 Materials and Welding	C	[3.6.2] **(5)** [3.6.3]	[19.6.5]	C **(3)**
Centrifugal separators					[19.7.2]	C **(3)**
Prefabricated pipe lines	a) class I and II with: - ND ≥ 65 mm, or - t ≥ 10 mm			[3.6.2] **(5)** [3.6.3]	[19.6.2]	C **(3)**
	b) class I and II with: - ND < 65 mm, or - t < 10 mm			[3.6.2] **(5)** [3.6.3]	[19.6.2]	W
	c) class III **(4)**				[19.6.2]	W

(1) [x.y.z] = test required, as per referent regulation.
(2) C = class certificate ; W = works' certificate.
(3) or alternative type of certificate, depending on the Survey Scheme. See Part A.
(4) where required by [19.6.2].
(5) if of welded construction, for welded connections.
(6) ND = nominal diameter of the corresponding pipe.
(7) for other pumps and compressors, see also additional Rules relevant for related systems.
(8) The material generally shall comply with [2.1.2] and Tab 5. Detail requirements where specified, are given by NR216 Materials and Welding.
(9) Attention is to be drawn to Tab 3 (valves and fittings fitted to the ship side are considered class II, as well as valves on the collision bulkheads, on fuel oil tanks or on lubricating oil tanks under static pressure).
(10) Applies only for casing and bolts.

Section 11 Exhaust Gas Pollution Prevention System

1 General

1.1 Application

1.1.1 This Section applies to installation, storage of chemical treatment fluids, piping system and equipment dedicated to NOx reducing system.

1.1.2 The requirements of this Section are additional to those of Ch 1, Sec 10, [17].

1.1.3

a) Requirements for exhaust gas pipes from engines, gas turbines, boilers and incinerators are given in Ch 1, Sec 10, [17].

b) General requirements applying to the installation of NOx reducing equipment and systems are contained in Article [2] for their installation.

c) Requirements for the storage and use of Urea as reductant in SCR are given in Article [3].

1.2 Definitions

1.2.1 Chemical treatment fluid

Unless otherwise specified, chemical treatment fluid means any chemical consumed in a process for the treatment of exhaust gas.

1.2.2 SCR

Equipment used to reduce NOx emission from the exhaust of marine engines using Selective Catalytic Reduction process.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	General arrangement of the exhaust gas pollution prevention system
2	A	Diagrams of sea water and / or fresh water piping systems **(3)**
3	A	Diagram of chemical piping system, including filling, storage and dosing **(3)**
4	I	Risk analysis report covering a failure of the exhaust gas pollution prevention system, a leakage of washwater, sludge or chemical, or a fire, as applicable following [3.1]

(1) A = to be submitted for approval ; I = to be submitted for information
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems
(3) Where applicable, depending on the design of the exhaust gas pollution prevention system

2 Installation requirements

2.1 General

2.1.1 Exhaust gas pollution prevention systems are to be designed, arranged and installed in accordance with the following requirements.

2.2 Design

2.2.1 Attention is drawn on IMO Guidelines regarding the environmental performance of selective catalytic reduction (SCR) systems.

2.2.2 Tank design and construction requirements are given in Pt B, Ch 2, Sec 2, [11].

2.2.3 The chemical treatment fluids tanks are to be included in the ship's stability calculation.

2.3 Availability

2.3.1 The availability of the machinery served by the exhaust gas pollution prevention system is to be substantiated by a risk analysis.

The exhaust gas pollution prevention equipment is to be so arranged that, in the case of failure of such equipment, propulsion power and auxiliary power supplying essential functions are not affected. Where necessary, a bypass is to be installed.

In case of blackout, automatic starting of engines, if provided, is to remain effective as if no exhaust gas pollution prevention system were installed and not detrimental to the exhaust gas pollution prevention installation.

2.4 Arrangement

2.4.1 Exhaust systems connections

As mentioned in Ch 1, Sec 10, [17.2.4], no interconnection is permitted between different exhaust piping systems for engines. In case of one exhaust gas pollution prevention system used for several installations, interconnections may be acceptable with additional devices installed as follows:

- Individual isolating devices for exhaust pipes are to be provided on each individual exhaust pipe; and
- Forced ventilation is to be installed at the outlet of the common exhaust pipe, preventing any backflow of exhaust gases in individual exhaust ducts in any possible working conditions.

  As an alternative to forced ventilation, exhaust systems interconnections might be accepted on a case-by-case basis and considering an exhaust gas back pressure analysis to the satisfaction of the Society.

2.4.2 Bypass

When the exhaust gas pollution prevention system may be by-passed, proper means are to be installed providing double barrier upstream from the exhaust gas pollution prevention system, in order to enable safe inspection in exhaust gas pollution prevention equipment in any working configuration of combustion units.

2.4.3 Filling systems for chemical treatment fluids

Filling systems for chemical treatment fluids are to be located in places where no interference with other ship activities would happen. In case interference is unavoidable, a risk analysis is to be provided in order to evaluate occurrence and level of danger for the crew.

Filling systems are to fulfil the requirements of Ch 1, Sec 10, [11.4.2]. Drainage of drip trays if any and outlet of safety valves are to be led to a tank designed for that purpose.

2.4.4 Materials

Materials used for equipment and piping systems are to be suitable with fluids conveyed, not leading to early corrosion or creating hazardous gases, when in contact with treatment liquid or vapours. This requirement is also valid for drip-trays, fans and ducts being part of exhaust gas pollution prevention system.

2.4.5 Control and monitoring

Alarms and indications are to be provided in accordance with Tab 2.

Information related to exhaust gas pollution prevention device and washwater, discharge measurements is to be made available in a control station.

Table 2 : Control and monitoring for exhaust gas pollution prevention systems

<table>
<tr><td rowspan="2">Symbol convention
H = High, HH = High high, G = group alarm
L = Low, LL = Low low, I = individual alarm
X = function is required, R = remote</td><td colspan="2" rowspan="2">Monitoring</td><td colspan="5">Automatic control</td></tr>
<tr><td colspan="3">System</td><td colspan="2">Auxiliary</td></tr>
<tr><td>Identification of system parameter</td><td>Alarm</td><td>Indication</td><td>Slow-down</td><td>Shut-down</td><td>Control</td><td>Stand by Start</td><td>Stop</td></tr>
<tr><td>Failure of exhaust fans (each fan)</td><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Exhaust temperature before entering in plastic parts or
Cooling medium flow</td><td>H
L</td><td>local
local</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Chemical treatment fluids storage tank level (1)</td><td>H (2)</td><td>local (2)</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="8">(1) Not applicable to process tanks
(2) High level alarm is to be independent from the tank level indicator.</td></tr>
</table>

3 Storage and use of SCR reductant

3.1 Application

3.1.1 The following requirements apply to urea/water solutions used in SCR which are typically carried on board in bulk.

For other reductants falling in the scope of IMDG Code like aqueous ammonia or anhydrous ammonia, the following conditions are to be fulfilled:

- It is to be demonstrated that the use of urea based reductant is not practicable and, in case of use of anhydrous ammonia, that the use of aqueous ammonia is not practicable either

Note 1: It is reminded that use of anhydrous ammonia need the agreement of the Naval Authority

- A risk analysis is to be provided regarding the loading, carriage and use of the product
- Requirements mentioned in [4] are to be fulfilled.

3.2 Storage tank

3.2.1 The storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank.

3.2.2 The storage tank may be located in the engine room.

3.2.3 Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

3.2.4 Where urea based ammonia solution is stored in integral tanks, these tanks are to be coated with appropriate anti-corrosion coating and are not to be located adjacent to any fuel oil or fresh water tank.

3.2.5 Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

3.3 Ventilation

3.3.1 If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be independent from the ventilation systems of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

Alternatively, where a urea storage tank is located within an engine room, a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

3.3.2 The requirements specified in [3.3.1] also apply to closed compartments normally entered:

- when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925°C and with fully welded joints.

3.4 Piping

3.4.1 The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

3.5 Materials

3.5.1 Reductant tanks are to be of steel or other equivalent material with a melting point above 925°C. Pipes/piping systems are to be of steel or other equivalent material with melting point above 925°C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire. In such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test.

Reductant tanks and pipes/piping systems are to be made with a material compatible with the reductant or coated with appropriate anti-corrosion coating.

Copper is to be avoided for equipment and piping systems in contact with fluids containing ammonia.

3.6 Protection of crew members

3.6.1 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash are to be provided, the location and number of these eyewash stations are to be derived from the detailed installation arrangements.

4 Storage and use of other substances mentioned in IMDG Code

4.1 Application

4.1.1 For exhaust gas pollution prevention systems using chemical treatment fluids other than those mentioned in [3], the following requirements are to be followed. Additionally a risk analysis is to be conducted, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas pollution prevention systems, to an extent equivalent to systems complying with Article [3].

4.2 Risk analysis

4.2.1 For compartment containing chemical treatment fluid tanks a risk analysis is to be provided, taking into account normal or abnormal operating conditions (failure, fluid leakage, fire) regarding human health and damage to essential equipment contained in compartment.

4.2.2 In case of use of substances classed in IMO IMDG Code in categories 1, 2.1, 3, 4.1, 4.2, 4.3, 5.1, 6.1, 8 or 9, application of IEC standard 60079-10-1 is required regarding electric installations, hazardous areas definition and ventilation, and a specific risk analysis is to submitted.

4.3 Containment of leakage

4.3.1 In case substances mentioned in IMO IMDG Code are used in exhaust gas pollution prevention systems, drainage and/or bilge pumping of compartments where such systems are located is to be separated from ship bilge system. Retention of potential leakages using drip trays associated to spill kits is to be implemented. Draining pipes from drip trays are to be led to a tank designed for that purpose.

4.4 Storage tank

4.4.1 Chemical treatment fluids tanks are not to be contiguous with tanks containing sea water, fresh water, fuel, lubricating tanks. A ventilated cofferdam between treatment chemical tanks and above mentioned tanks is an acceptable solution. Arrangement of the ventilation system is to be in accordance with [4.5].

Chemical treatment fluids tanks are not to be located in category A machinery spaces unless a specific risk analysis, as required in [4.2], is submitted to the Society for approval.

Chemical treatment fluids tanks when located adjacent to or within a compartment used for other purposes are to be surrounded by coamings delimitating space fitted with a high level alarm.

Bilge system of this compartment may be connected to ship bilge system provided arrangements are made to isolate this bilge suction. An additional fixed pumping system is to be installed in order to pump liquid with chemical substance from bilge and inside drip trays to draining tank. Isolation means and additional pumping system are to be remotely controlled.

4.4.2 Toxic or flammable product pipes, which, if damaged, would allow the product to escape from a tank, are to be fitted with a quick closing valve directly on the tank, capable of being closed from a safe position outside the compartment involved.

4.4.3 Overflow

Overflow pipes of chemical treatment fluids tanks are to be led to a specific tank dedicated for one kind of product. If several chemical treatment fluids tanks exist for a same product, overflow tank may be common.

4.4.4 Sounding and air pipes

Sounding pipes and air pipes are to end in an open space above freeboard deck. Means in order to prevent water entry through these pipe ends in any circumstances are to be provided.

4.5 Ventilation

4.5.1 Ventilation of compartments where chemical treatment fluids are stored or used is to be of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be separated from any other ventilation system. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

The ventilation system is to be included in the risk analysis requested in [4.2].

4.6 Piping

4.6.1 Piping systems involved in process are not to pass through accommodations, control stations or service spaces.

Section 12 Steering Gear

1 General

1.1 Application

1.1.1 Scope

Unless otherwise specified, the requirements of this Section apply to the steering gear systems of all mechanically propelled ships, and to the steering mechanism of thrusters used as means of propulsion.

1.1.2 Cross references

In addition to those provided in this Section, steering gear systems are also to comply with the requirements of:

- Ch 1, Sec 16, as regards sea trials
- Pt B, Ch 9, Sec 1, as regards the rudder and the rudder stock

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gear

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

Table 1 : Documents to be submitted for steering gear

No.	I/A **(2)**	Description of the document **(1)**
1	I	Assembly drawing of the steering gear including sliding blocks, guides, stops and other similar components
2	I	General description of the installation and of its functioning principle
3	I	Operating manuals of the steering gear and of its main components
4	I	Description of the operational modes intended for steering in normal and emergency conditions
5	A	For hydraulic steering gear, the schematic layout of the hydraulic piping of power actuating systems, including the hydraulic fluid refilling system, with indication of: • the design pressure • the maximum working pressure expected in service • the diameter, thickness, material specification and connection details of the pipes • the hydraulic fluid tank capacity • the flashpoint of the hydraulic fluid
6	I	For hydraulic pumps of power units, the assembly longitudinal and transverse sectional drawings and the characteristic curves
7	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of: • the design torque • the maximum working pressure • the relief valve setting pressure
8	I	Constructional drawings of the relief valves for protection of the hydraulic actuators, with indication of: • the setting pressure • the relieving capacity
9	A	Diagrams of the electric power circuits
10	A	Functional diagram of control, monitoring and safety systems including the remote control from the navigating bridge, with indication of the location of control, monitoring and safety devices
11	A	Constructional drawings of the strength parts providing a mechanical transmission of forces to the rudder stock (tiller, quadrant, connecting rods and other similar items), with the calculation notes of the shrink-fit connections
12	I/A	For azimuth thrusters used as steering means, the specification and drawings of the steering mechanism and, where applicable, documents 2 to 6 and 8 to 11 above

(1) Constructional drawings are to be accompanied by the specification of the materials employed and, where applicable, by the welding details and welding procedures.
(2) A = to be submitted for approval ; I = to be submitted for information.

1.2.2 Additional documents

The following additional documents are to be submitted:

- analysis in relation to the risk of single failure, where required by [2.4.2]
- analysis in relation to the risk of hydraulic locking, where required by [2.4.5]
- fatigue analysis and/or fracture mechanics analysis, where required.

1.3 Definitions

1.3.1 Steering system

Steering system means ship's directional control system, including main steering gear, auxiliary steering gear, steering gear control system and rudder if any.

1.3.2 Steering gear control system

Steering gear control system is the equipment by which orders are transmitted from the navigation bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

Steering gear control system is also understood to cover the equipment required to control the steering gear power actuating system.

1.3.3 Main steering gear

Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.3.4 Steering gear power unit

Steering gear power unit is:

- in the case of electric steering gear, an electric motor and its associated electrical equipment
- in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump
- in the case of other hydraulic steering gear, a driving engine and connected pump.

1.3.5 Auxiliary steering gear

Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.6 Power actuating system

Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.7 Rudder actuator

Rudder actuator is the component which directly converts hydraulic pressure into mechanical action to move the rudder.

1.3.8 Maximum ahead service speed

Maximum ahead service speed is the greatest speed which the ship is designed to maintain in service at sea at the deepest seagoing draught.

1.3.9 Maximum astern speed

Maximum astern speed is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest seagoing draught.

1.3.10 Maximum working pressure

Maximum working pressure is the maximum expected pressure in the system when the steering gear is operated to comply with the provisions of [2.2.1] item b).

1.3.11 Hydraulic locking

Hydraulic locking means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "bypass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

1.4 Symbols

1.4.1 The following symbols are used for strength criteria of steering gear components:

V : Maximum service speed, in knots, with the ship on summer load waterline. When the speed is less than 10 knots, V is to be replaced by the value $(V+20)/3$

d_s : Rule diameter of the rudder stock in way of the tiller, in mm, defined in Pt B, Ch 9, Sec 1, [4] and calculated with a material factor $k_1 = 1$

d_{se} : Actual diameter of the upper part of the rudder stock in way of the tiller, in mm
(in the case of a tapered coupling, this diameter is measured at the base of the assembly)

T_R : Rule design torque of the rudder stock given, in kN.m, by the following formula:

$$T_R = 13{,}5 \cdot d_s^3 \cdot 10^{-6}$$

T_E : For hand emergency operation, design torque due to forces induced by the rudder, in kN.m, given by the following formulae:

$$T_E = 0{,}62 \cdot \left(\frac{V_E + 2}{V + 2}\right)^2 \cdot T_R$$

where:

- $V_E = 7$ where $V \le 14$
- $V_E = 0{,}5\ V$ where $V > 14$

T_G : For main hydraulic or electrohydraulic steering gear, torque induced by the main steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 1: for hand-operated main steering gear, the following value is to be used:
$T_G = 1{,}25.T_R$

T_A : For auxiliary hydraulic or electrohydraulic steering gears, torque induced by the auxiliary steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 2: for hand-operated auxiliary steering gear, the following value is to be used:
$T_A = 1{,}25.T_E$

T'_G : For steering gear which can activate the rudder with a reduced number of actuators, the value of T_G in such conditions

σ : Normal stress due to the bending moments and the tensile and compressive forces, in N/mm²

τ : Tangential stress due to the torsional moment and the shear forces, in N/mm²

σ_a : Permissible stress, in N/mm²

σ_c : Combined stress, determined by the following formula:

$$\sigma_c = \sqrt{\sigma^2 + 3\tau^2}$$

R : Value of the minimum specified tensile strength of the material at ambient temperature, in N/mm²

R_e : Value of the minimum specified yield strength of the material at ambient temperature, in N/mm²

R'_e : Design yield strength, in N/mm², determined by the following formulae:

- $R'_e = R_e$, where $R \ge 1{,}4\ R_e$
- $R'_e = 0{,}417\ (R_e + R)$ where $R < 1{,}4\ R_e$

2 Design and construction

2.1 General

2.1.1 Unless expressly provided otherwise, every ship shall be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.

2.2 Strength, performance and power operation of the steering gear

2.2.1 Main steering gear

The main steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

Note 1: “even keel” means that the vessel is an acceptable trim condition

Note 2: “fully submerged” means A_T is greater than $0.95{\cdot}A_F$, where A_T and A_F are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch of the propeller;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition;

c) operated by power where necessary to meet the requirements of b) and in any case when the Society requires a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice, and

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm², i.e. with a material factor $k_1 = 1$.

2.2.2 Auxiliary steering gear

The auxiliary steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

Note 1: “even keel” means that the vessel is an acceptable trim condition.

Note 2: “fully submerged” means A_T is greater than $0.95 \cdot A_F$, where AT and AF are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the auxiliary steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition;

and

c) operated by power where necessary to meet the requirements of b) and in any case when the Society requires a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm², i.e. with a material factor $k_1 = 1$.

2.2.3 Steering gear test with the vessel not at the deepest seagoing draught

In order to meet the performance stated in item b) of [2.2.1] and item b) of [2.2.2] the following requirements are applicable.

When it is justified that the trials cannot practically be performed with the vessel at the deepest seagoing draught, the loading condition can be accepted on the conditions that:

a) The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition P_F has been extrapolated from the maximum measured actuator hydraulic pressure in the trial condition P_T using one of the following methods:

1) P_F is obtained according to the following formula:

$$P_F = P_T \cdot \alpha$$

$$\alpha = 1{,}25\left(\frac{A_F}{A_T}\right)\left(\frac{V_F}{V_T}\right)^2$$

where:

P_F : estimated steering actuator hydraulic pressure in the deepest seagoing draught condition

P_T : maximum measured actuator hydraulic pressure in the trial condition.

α : extrapolation factor

A_F : total immersed projected area of the movable part of the rudder in the deepest seagoing condition

A_T : total immersed projected area of the movable part of the rudder in the trial condition

V_F : contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught

V_T : measured speed of the vessel (considering current) in the trial condition.

Note 1: Above formulae assumes that the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque.

2) The following methodology is applied for determination of P_F:

- The designer or builder uses computational fluid dynamic (CFD) studies or experimental investigations to predict the estimated rudder stock moment at the full sea going draught condition and service speed Q_F

  These calculations or experimental investigations are to be to the satisfaction of the Society.

- the rudder torque at the trial loading condition Q_T have been reliably predicted based on the maximum measured actuator hydraulic pressure in the trial condition P_T
- The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition is obtained according to the following formula:

$$P_F = P_T \frac{Q_F}{Q_T}$$

b) Where constant volume fixed displacement pumps are utilised, the estimated steering actuator hydraulic pressure at the deepest draught P_F is to be less than the specified maximum working pressure of the rudder actuator.

Where a variable delivery pump is utilised, the pump data is to be supplied and interpreted to estimate the delivered flow rate corresponding to the deepest seagoing draught in order to calculate the estimated steering time, not to be greater than to the required time specified in [2.2.1] or [2.2.2], as applicable.

c) In any case for the main steering gear trial, the speed of the ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

2.3 Control of the steering gear

2.3.1 Main and auxiliary steering gear control

Steering gear control shall be provided:

a) for the main steering gear, both on the navigation bridge and in the steering gear compartment

b) where the main steering gear is arranged in accordance with [2.4.2], by two independent control systems, both operable from the navigation bridge and the steering gear compartment. This does not require duplication of the steering wheel or steering lever. Where the control system consists in a hydraulic telemotor, a second independent system need not be fitted, except in auxiliary naval vessel of 10 000 gross tonnage and upwards

The two independent steering gear control systems are to be:

- so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative, and
- in accordance with [2.3.3]

c) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigation bridge and to be independent of the control system for the main steering gear.

Note 1: The term “steering gear control system” is to be understood to cover “the equipment required to control the steering gear power actuating system”.

2.3.2 Control systems operable from the navigating bridge

Any main and auxiliary steering gear control system operable from the navigating bridge shall comply with the following:

- if electrical, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit
- means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigation bridge from the steering gear it serves
- the system shall be capable of being brought into operation from a position on the navigating bridge
- in the event of failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigation bridge, and
- short-circuit protection only shall be provided for steering gear control supply circuits.

2.3.3 Installation

a) Duplicated steering gear control systems with their associated components are to be separated as far as practicable.

b) Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are to be separated as far as practicable.

Where physical separation is not practicable, separation may be achieved by means of a fire-retardant plate.

c) All electrical components of the steering gear control systems are to be duplicated. This does not require duplication of the steering wheel or steering lever.

d) If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the control systems are to be divided accordingly and separated from each other by an isolating plate or air gap.

e) In the case of double follow-up control, the amplifier is to be designed and fed so as to be electrically and mechanically separated. In the case of non-follow-up control and follow-up control, it is to be ensured that the follow-up amplifier is protected selectively.

f) Control circuits for additional control systems, e.g. steering lever or autopilot, are to be designed for all-pole disconnection.

g) The feedback units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

2.4 Availability

2.4.1 Arrangement of main and auxiliary steering gear

The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one will not render the other inoperative.

2.4.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that:

a) the main steering gear is capable of operating the rudder as required in [2.2.1] while any one of the power units is out of operation

b) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

Steering gear other than of the hydraulic type is to achieve standards equivalent to the requirements of this paragraph to the satisfaction of the Society.

2.4.3 Hydraulic power supply

The hydraulic system intended for main and auxiliary steering gear is to be independent of all other hydraulic systems of the ship.

2.4.4 Non-duplicated components

Special consideration is to be given to the suitability of any essential component which is not duplicated.

2.4.5 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

2.4.6 Additional requirements for ships of 70 000 gross tonnage and above

In ships of 70,000 gross tonnage and upwards, the main steering gear shall comprise two or more identical power units complying with the provisions of [2.4.2].

2.5 Mechanical components

2.5.1 General

a) All steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of the Society.

b) Any non-duplicated essential component is, where appropriate, to utilise anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings, which are to be permanently lubricated or provided with lubrication fittings

c) The construction is to be such as to minimise local concentration of stress.

d) All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

Table 2 : Scantling of components protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_G	• if $T_G \le 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T_G \ge 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Normal operation, with a reduced number of actuators	T'_G	• if $T'_G \le 1,25\ T_R$: $\sigma_a = 1,25\ \sigma_0$ • if $1,25\ T_R < T'_G < 1,50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T'_G \ge 1,50\ T_R$: $\sigma_a = 1,50\ \sigma_0$ where $\sigma_0 = 0,55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R'_e$
Emergency operation achieved by hand	T_E	$0,69\ R'_e$

Table 3 : Scantling of components not protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_R	$0,55\ R'_e$
Normal operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0,8\ T_A$	$0,69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0,8\ T'_G$	$0,69\ R'_e$
Emergency operation achieved by hand	T_E	$0,69\ R'_e$

2.5.2 Materials and welds

a) All steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material complying with the requirements of NR216 Materials and Welding. In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

b) The use of grey cast iron is not permitted, except for redundant parts with low stress level, subject to special consideration by the Society. It is not permitted for cylinders.

c) The welding details and welding procedures are to be submitted for approval.

d) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

2.5.3 Scantling of components

The scantling of steering gear components is to be determined considering the design torque M_T and the permissible value σ_a of the combined stress, as given in:

- Tab 2 for components which are protected against overloads induced by the rudder
- Tab 3 for components which are not protected against overloads induced by the rudder.

2.5.4 Tillers, quadrants and rotors

a) The scantling of the tiller is to be determined as follows:
   - the depth H_0 of the boss is not to be less than $0,75.d_s$
   - the radial thickness of the boss in way of the tiller is not to be less than the greater of:
     - $0,3 \cdot d_s \cdot \sqrt{\dfrac{235}{R'_e}}$
     - $0,25 \cdot d_s$
   - the section modulus of the tiller arm in way of the end fixed to the boss is not to be less than the value Z_b, in cm^3, calculated from the following formula:

$$Z_b = \frac{0{,}147 \cdot d_s^3}{1000} \cdot \frac{L'}{L} \cdot \frac{R_e}{R'_e}$$

   where:

   L : Distance from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

L' : Distance between the point of application of the above load and the root section of the tiller arm under consideration (see Fig 1)

- the width and thickness of the tiller arm in way of the point of application of the load are not to be less than one half of those required by the above formula
- in the case of double arm tillers, the section modulus of each arm is not to be less than one half of the section modulus required by the above formula.

b) The scantling of the quadrants is to be determined as specified in a) for the tillers. When quadrants having two or three arms are provided, the section modulus of each arm is not to be less than one half or one third, respectively, of the section modulus required for the tiller.

Arms of loose quadrants not keyed to the rudder stock may be of reduced dimensions to the satisfaction of the Society, and the depth of the boss may be reduced by 10 per cent.

c) Keys are to satisfy the following provisions:

- the key is to be made of steel with a yield stress not less than that of the rudder stock and that of the tiller boss or rotor without being less than 235 N/mm^2
- the width of the key is not to be less than $0,25.d_s$
- the thickness of the key is not to be less than $0,10.d_s$
- the ends of the keyways in the rudder stock and in the tiller (or rotor) are to be rounded and the keyway root fillets are to be provided with small radii of not less than 5 per cent of the key thickness.

d) Bolted tillers and quadrants are to satisfy the following provisions:

- the diameter of the bolts is not to be less than the value d_b, in mm, calculated from the following formula:

$$d_b = 153\sqrt{\frac{T_R}{n(b+0{,}5d_{se})} \cdot \frac{235}{R_{eb}}}$$

where:

n : Number of bolts located on the same side in respect of the stock axis (n is not to be less than 2)

b : Distance between bolts and stock axis, in mm (see Fig 2)

R_{eb} : Yield stress, in N/mm^2, of the bolt material

Figure 1 : Tiller arm

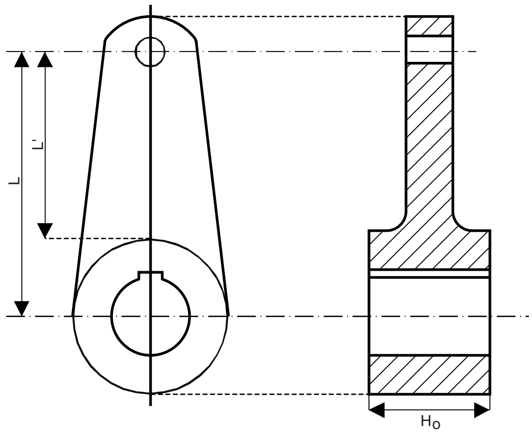
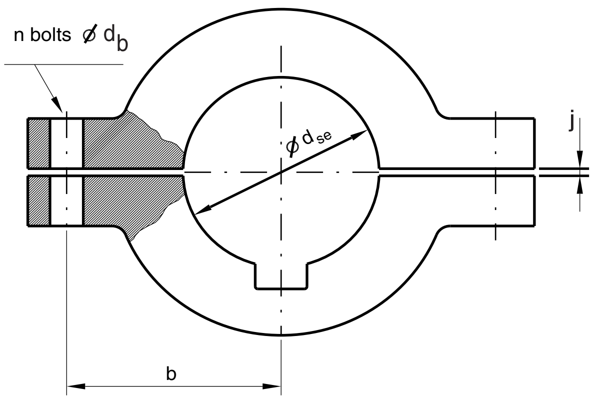


Figure 2 : Bolted tillers



- the thickness of each of the tightening flanges of the two parts of the tiller is not to be less than the following value:

  $$1,85 \cdot d_b \cdot \sqrt{\frac{n \cdot (b - 0,5 \cdot D_e)}{H_0} \cdot \frac{R_{eb}}{R'_e}}$$

  Where:

  D_e : External boss diameter, in mm (average value)

- in order to ensure the efficient tightening of the coupling around the stock, the two parts of the tiller are to bored together with a shim having a thickness not less than the value j, in mm, calculated from the following formula:

  $j = 0,0015 \cdot d_s$

e) Shrink-fit connections of tiller (or rotor) to stock are to satisfy the following provisions:

- the safety factor against slippage is not to be less than:
  - 1 for keyed connections
  - 2 for keyless connections
- the friction coefficient is to be taken equal to:
  - 0,15 for steel and 0,13 for spheroidal graphite cast iron, in the case of hydraulic fit
  - 0,17 in the case of dry shrink fitting
- the combined stress according to the von Mises criterion, due to the maximum pressure induced by the shrink fitting and calculated in way of the most stressed points of the shrunk parts, is not to exceed 80 per cent of the yield stress of the material considered

Note 1: Alternative stress values based on FEM calculations may also be considered by the Society.

- the entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

2.5.5 Piston rods

The scantling of the piston rod is to be determined taking into account the bending moments, if any, in addition to compressive or traction forces and is to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress as per [1.4.1]

σ_a : Permissible stress as per [2.5.3]

b) in respect of the buckling strength:

$$\frac{4}{\pi D_2^2} \cdot \left(\omega F_c + \frac{8M}{D_2}\right) \leq 0,9\sigma_a$$

with:

D_2 : Piston rod diameter, in mm

F_c : Compression force in the rod, in N, when it extends to its maximum stroke

M : Possible bending moment in the piston rod, in N.mm, in way of the fore end of the cylinder rod bearing

$$\omega = \beta + \sqrt{\beta^2 - \alpha}$$

$$\alpha = 0,0072\left(\frac{\ell_s}{D_2}\right)^2 \frac{R'_e}{235}$$

$$\beta = 0,48 + 0,5\alpha + 0,1\sqrt{\alpha}$$

ℓ_s : Length, in mm, of the maximum unsupported reach of the cylinder rod.

2.6 Hydraulic system

2.6.1 General

a) The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in [3], taking into account any pressure which may exist in the low pressure side of the system.

At the discretion of the Society, high cycle and cumulative fatigue analysis may be required for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

b) The power piping for hydraulic steering gear is to be arranged so that transfer between units can be readily effected.

c) Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

d) The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Ch 1, Sec 10 for class I piping systems, and in particular with the requirements of Ch 1, Sec 10, [13], unless otherwise stated.

2.6.2 Materials

a) Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings are to be of steel or other approved ductile material.

b) In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

Grey cast iron may be accepted for valve bodies and redundant parts with low stress level, excluding cylinders, subject to special consideration.

2.6.3 Isolating valves

Shut-off valves, non-return valves or other appropriate devices are to be provided:

- to comply with the availability requirements of [2.4]
- to keep the rudder steady in position in case of emergency.

In particular, for all ships with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

2.6.4 Flexible hoses

a) Flexible hoses may be installed between two points where flexibility is required but are not to be subjected to torsional deflexion (twisting) under normal operation. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

b) Hoses are to be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

c) They are to be of a type approved by the Society.

d) The burst pressure of hoses is to be not less than four times the design pressure.

2.6.5 Relief valves

a) Relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves shall not exceed the design pressure. The valves shall be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

b) The setting pressure of the relief valves is not to be less than 1,25 times the maximum working pressure.

c) The minimum discharge capacity of the relief valve(s) is not to be less than the total capacity of the pumps which can deliver through it (them), increased by 10%. Under such conditions, the rise in pressure is not to exceed 10% of the setting pressure. In this respect, due consideration is to be given to the foreseen extreme ambient conditions in relation to oil viscosity.

2.6.6 Hydraulic oil reservoirs

Hydraulic power-operated steering gear shall be provided with the following:

- a low level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms shall be given on the navigation bridge and in the machinery space where they can be readily observed.
- a fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank shall be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and shall be provided with a contents gauge.

Note 1: For cargo ships of less than 500 tons displacement, the storage means may consist of a readily accessible drum, of sufficient capacity to refill one power actuating system if necessary.

2.6.7 Hydraulic pumps

a) Hydraulic pumps are to be type tested in accordance with the provisions of [6.1.1].

b) Special care is to be given to the alignment of the pump and the driving motor.

2.6.8 Filters

a) Hydraulic power-operated steering gear shall be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

b) Filters of appropriate mesh fineness are to be provided in the piping system, in particular to ensure the protection of the pumps.

2.6.9 Accumulators

Accumulators, if fitted, are to be designed in accordance with Ch 1, Sec 10, [13.5.3].

2.6.10 Rudder actuators

a) Rudder actuators, other than non-duplicated rudder actuators fitted to tankers, chemical carriers and gas carriers of 10000 gross tonnage and above, are to be designed in accordance with the relevant requirements of Ch 1, Sec 3 for class 1 pressure vessels also considering the following provisions.

b) The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R}{A} \quad \text{or} \quad \frac{R_e}{B}$$

where A and B are given in Tab 4.

c) Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal or equivalent type.

d) Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

e) The strength and connection of the cylinder heads (or, in the case of actuators of the rotary type, the fixed vanes) acting as rudder stops are to comply with the provisions of [5.3.1].

Table 4 : Value of coefficients A and B

Coefficient	Steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

2.7 Electrical systems

2.7.1 General design

The electrical systems of the main steering gear and the auxiliary steering gear are to be so arranged that the failure of one will not render the other inoperative.

2.7.2 Power circuit supply

a) Electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard.

b) Auxiliary electric or electrohydraulic steering gear, associated with main electric or electrohydraulic steering gear, may be connected to one of the circuits supplying the main steering gear.

c) The circuits supplying electric or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

d) When, in a ship of less than 1600 gross tonnage, auxiliary steering gear which is required by [2.2.2], item c) to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

e) Where the rudder stock is required to be over 230 millimetres in diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

   This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

   The independent source is to be used only for this purpose.

   The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

f) In every ship of 10 000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

2.7.3 Motors and associated control gear

a) To determine the required characteristics of the electric motors for power units, the breakaway torque and maximum working torque of the steering gear under all operating conditions are to be considered. The ratio of pull-out torque to rated torque is to be at least 1,6.

b) Motors for steering gear power units may be rated for intermittent power demand.

   The rating is to be determined on the basis of the steering gear characteristics of the ship in question; the rating is always to be at least:

   - S3 - 40% for motors of electric steering gear power units
   - S6 - 25% for motors of electrohydraulic steering gear power units and for convertors.

c) Each electric motor of a main or auxiliary steering gear power unit is to be provided with its own separate motor starter gear, located within the steering gear compartment.

2.7.4 Supply of motor control circuits and steering gear control systems

a) Each control for starting and stopping of motors for power units is to be served by its own control circuits supplied from its respective power circuits.

b) Any electrical main and auxiliary steering gear control system operable from the navigating bridge is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit. The power supply systems are to be protected selectively.

c) The remote control of the power unit and the steering gear control systems is to be supplied also by the alternative power source when required by [2.7.2], item e).

2.7.5 Circuit protection

a) Short-circuit protection is to be provided for each control circuit and each power circuit of electric or electrohydraulic main and auxiliary steering gear.

b) No protection other than short-circuit protection is to be provided for steering gear control system supply circuits.

c) Protection against excess current (e.g. by thermal relays), including starting current, if provided for power circuits, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents.

d) Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter.

Note 1: "Normal load" is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions.

e) Where fuses are fitted, their current ratings are to be two step higher than the rated current of the motors. However, in the case of intermittent service motors, the fuse rating is not to exceed 160% of the rated motor current.

f) The instantaneous short-circuit trip of circuit breakers is to be set to a value not greater than 15 times the rated current of the drive motor.

g) The protection of control circuits is to correspond to at least twice the maximum rated current of the circuit, though not, if possible, below 6 A.

2.7.6 Starting and stopping of motors for steering gear power units

a) Motors for power units are to be capable of being started and stopped from a position on the navigation bridge and from a point within the steering gear compartment.

b) Means are to be provided at the position of motor starters for isolating any remote control starting and stopping devices (e.g. by removal of the fuse-links or switching off the automatic circuit breakers).

c) Main and auxiliary steering gear power units are to be arranged to restart automatically when power is restored after a power failure.

2.7.7 Installation

a) Duplicated electric power circuits are to be separated as far as practicable.

b) Cables for duplicated electric power circuits with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

c) Actuators controlling the power systems of the steering gear, e.g. magnetic valves, are to be duplicated and separated.

d) Cables for duplicated steering gear control systems with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

2.8 Alarms and indications

2.8.1 Power units

a) In the event of a power failure to any one of the steering gear power units, an audible and visual alarm shall be given on the navigating bridge.

b) Means for indicating that the motors of electric and electrohydraulic steering gear are running shall be installed on the navigating bridge and at a suitable main machinery control position.

c) Where a three-phase supply is used, an alarm shall be provided that will indicate failure of any one of the supply phases.

d) An overload alarm shall be provided for each motor of electric or electrohydraulic steering gear power units.

e) The alarms required in c) and d) shall be both audible and visual and situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled.

2.8.2 Hydraulic system

a) Hydraulic oil reservoirs are to be provided with the alarms required in [2.6.6].

b) Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on the navigating bridge.

Note 1: This alarm is to be activated when, for example:

- the position of the variable displacement pump control system does not correspond with the given order, or
- an incorrect position in the 3-way valve, or similar, in the constant delivery pump system is detected.

2.8.3 Control system

In the event of a failure of electrical power supply to the steering gear control systems, an audible an visual alarm shall be given on the navigating bridge.

2.8.4 Rudder angle indication

The angular position of the rudder is to be:

a) indicated on the navigating bridge, if the main steering gear is power operated. The rudder angle indication is to be independent of the steering gear control system and be supplied through the emergency switchboard, or by an alternative and independent source of electrical power such as that referred to in [2.7.2], item e);

b) recognisable in the steering gear compartment.

2.8.5 Steering gear failure

The steering gear failures likely to cause uncontrolled movements of rudder are to be clearly identified. In the event of detection of such failure, the rudder is to stop in the current position without manual intervention or, subject to the discretion of the Society, is to return to the midship/neutral position.

For mechanical failures such as sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with [5.5.1].

Additionally, for hydraulic locking failure, refer to [2.8.2] item b).

2.8.6 Summary table

Displays and alarms are to be provided in the locations indicated in Tab 5.

Table 5 : Location of displays and alarms

Item		Display	Alarms (audible and visible)	Location		
				Navigation Bridge	Engine Control Room **(3)**	Steering gear compartment
Indication that electric motor of each power unit is running		X		X	X	
Rudder angle indicator		X		X		X
Power failure of each power unit			X	X	X	
Power failure of each control system			X	X	X	
Overload of electric motor of each power unit			X	X	X	
Phase failure of electric motor of each power unit			X	X	X	
Earth fault on AC and DC circuits			X	X	X	
Control system failures	Loop failures in closed loop systems, coth command and feed back loops **(1)**		X	X	X	
	Data communication errors		X	X	X	
	Programmable system failures (Hardware and software failures)		X	X	X	
	Deviation between rudder order and feedback **(2)**		X	X	X	
Low level of each hydraulic fluid reservoir			X	X	X	
Hydraulic lock			X	X		

(1) Normally short circuit, broken connections and earth faults

(2) Deviation alarm is to be initiated if the rudder's actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures.

(3) Common alarm may be accepted if individual alarms are available locally.

3 Design and construction - Requirements for ships equipped with several rudders

3.1 Principle

3.1.1 General

In addition to the provisions of Article [2], ships equipped with two or more aft rudders are to comply with the provisions of the present Article.

3.1.2 Availability

Where the ship is fitted with two or more rudders, each having its own actuation system, the latter need not be duplicated.

3.1.3 Equivalent rudder stock diameter

Where the rudders are served by a common actuating system, the diameter of the rudder stock referred to in [2.2.1], item c), is to be replaced by the equivalent diameter d obtained from the following formula:

$$d = \sqrt[3]{\sum_j d_j^3}$$

with:

d_j : Rule diameter of the upper part of the rudder stock of each rudder in way of the tiller, excluding strengthening for navigation in ice.

3.2 Synchronisation

3.2.1 General

A system for synchronising the movement of the rudders is to be fitted, either:

- by a mechanical coupling, or
- by other systems giving automatic synchronising adjustment.

3.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) the angular position of each rudder is to be indicated on the navigation bridge

b) the rudder angle indicators are to be independent from each other and, in particular, from the synchronising system

c) in case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained.

4 Design and construction - Requirements for ships equipped with thrusters as steering means

4.1 Principle

4.1.1 General

The main and auxiliary steering gear referred to in Article [3] may consist of thrusters of the following types:

- azimuth thrusters
- water-jets
- cycloidal propellers

complying with the provisions of Ch 1, Sec 13, as far as applicable.

4.1.2 Control system

Where the steering means of the ship consists of two or more thrusters, their control system is to include a device ensuring an automatic synchronisation of the thruster rotation, unless each thruster is so designed as to withstand any additional forces resulting from the thrust exerted by the other thrusters.

4.2 Steering arrangements

4.2.1 General

The requirements in this sub-article apply to ships fitted with alternative propulsion and steering arrangements, such as but not limited to, azimuthing propulsors or water jet propulsion systems.

4.2.2 Steering arrangements for ships fitted with multiple steering-propulsion units

For a ship fitted with multiple steering-propulsion units, such as, but not limited to, azimuthing propulsors or water jet propulsion systems, each of the steering-propulsion units is to be provided with a main steering gear and an auxiliary steering gear or with two or more identical steering actuating systems in compliance with [4.2.7]. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

4.2.3 Steering arrangements for ships fitted with single steering-propulsion unit

For a ship fitted with a single steering-propulsion unit, the steering gear is to be provided with two or more steering actuating systems complying with [4.2.7]. A detailed risk assessment is to be submitted in order to demonstrate that in the case of any single failure in the steering gear, control system and power supply, the ship steering is maintained.

4.2.4 Design of components used in steering arrangements

All components used in steering arrangements for ship directional control are to be of sound reliable construction to the satisfaction of the Administration or recognized organizations acting on its behalf. Special consideration should be given to the suitability of any essential component which is not duplicated. Any such essential component is, where appropriate, to utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which should be permanently lubricated or provided with lubrication fittings.

4.2.5 Main steering arrangements

The main steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at maximum ahead service speed which should be demonstrated
- capable of changing direction of the steering-propulsion unit from one side to the other at declared steering angle limits at an average turning speed of not less than 2,3°/s with the ship running ahead at maximum ahead service speed
- for all ships, operated by power; and
- so designed that they will not be damaged at maximum astern speed; this design requirement need not be proved by trials at maximum astern speed and declared steering angle limits.

Note 1: Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the “declared steering angle limits” are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.6 Auxiliary steering arrangements

The auxiliary steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency
- capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average turning speed, of not less than 0.5°/s; with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
- for all ships, operated by power where necessary to meet the requirements of SOLAS regulation II-1/29.4.2 and in any ship having power of more than 2,500 kW propulsion power per steering-propulsion unit.

Note 1: The definition of “declared steering angle limits”, set out in [4.2.5], applies.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.7 Omission of the auxiliary steering gear

a) For a ship fitted with a single steering-propulsion unit where the main steering gear comprises two or more identical power units and two or more identical steering actuators, an auxiliary steering gear need not be fitted provided that the steering gear:
   - is capable of satisfying the requirements in [4.2.5] while any one of the power units is out of operation
   - is arranged so that after a single failure in its piping system or in one of the power units, steering capability can be maintained or speedily regained.

b) For a ship fitted with multiple steering-propulsion units, where each main steering system comprises two or more identical steering actuating systems, an auxiliary steering gear need not be fitted provided that each steering gear:
   - is capable of satisfying the requirements in [4.2.5] while any one of the steering gear steering actuating systems is out of operation
   - is arranged so that after a single failure in its piping or in one of the steering actuating systems, steering capability can be maintained or speedily regained; and
   - the above capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units.

Note 1: For the purposes of alternative steering arrangements, the steering gear power unit should be considered as defined in [1.3.4]. For electric steering gears, refer to [1.3.4]; electric steering motors should be considered as part of the power unit and actuator.

4.2.8 Case of the steering-propulsion units having a residual steering capability when propulsion power is lost

This requirement applies to steering-propulsion units having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power exceeds 2,500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of [2.2.2], item b), and also its associated control system and the steering gear response indicator, is to be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power is to be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

4.2.9 Additional requirement for ships fitted with multiple electric or electrohydraulic steering systems

For a ship fitted with multiple electric or electrohydraulic steering systems, the requirements of [2.7.2], items a), b) and c), are to be applied to each of the steering systems.

4.3 Use of water-jets

4.3.1 The use of water-jets as steering means will be given special consideration by the Society.

5 Arrangement and installation

5.1 Steering gear room arrangement

5.1.1 The steering gear compartment shall be:

a) readily accessible and, as far as practicable, separated from machinery spaces, and

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

5.2 Rudder actuator installation

5.2.1

a) Rudder actuators are to be installed on foundations of strong construction so designed as to allow the transmission to the ship structure of the forces resulting from the torque applied by the rudder and/or by the actuator, considering the strength criteria defined in [2.5.3] and [5.3.1]. The structure of the ship in way of the foundations is to be suitably strengthened.

b) Where the rudder actuators are bolted to the hull, the grade of the bolts used is not to be less than 8.8. Unless the bolts are adjusted and fitted with a controlled tightening, strong shocks are to be fitted in order to prevent any lateral displacement of the rudder actuator.

5.3 Overload protections

5.3.1 Mechanical rudder stops

a) The steering gear is to be provided with strong rudder stops capable of mechanically stopping the rotation of the rudder at an angle slightly greater than its maximum working angle. Alternatively, these stops may be fitted on the ship to act on another point of the mechanical transmission system between the rudder actuator and the rudder blade. These stops may be built in with the actuator design.

b) The scantlings of the rudder stops and of the components transmitting to the ship's structure the forces applied on these stops are to be determined for the greater value of the torques T_R or T_G.

   Where $T_G \geq 1,5 T_R$, the rudder stops are to be fitted between the rudder actuator and the rudder stock, unless the rudder stock as well as all the components transmitting mechanical forces between the rudder actuator and the rudder blade are suitably strengthened.

5.3.2 Rudder angle limiters

a) Power-operated steering gear is to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

b) For power-operated steering gears and where the rudder may be oriented to more than 35° at very reduced speed, it is recommended to fit a limit system 35° for full speed. A notice is to be displayed at all steering wheel stations indicating that rudder angles of more than 35° are to be used only at very reduced speed.

5.3.3 Relief valves

Relief valves are to be fitted in accordance with [2.6.5].

5.3.4 Buffers

Buffers are to be provided on all ships fitted with mechanical steering gear. They may be omitted on hydraulic gear equipped with relief valves or with calibrated bypasses.

5.4 Means of communication

5.4.1 A means of communication is to be provided between the navigation bridge and the steering gear compartment.

If electrical, it is to be fed through the emergency switchboard or to be sound powered.

5.5 Operating instructions

5.5.1 For steering gear comprising two identical power units intended for simultaneous operation, both normally provided with their own (partly or mutually) separate control systems, the following standard notice is either to be placed on a signboard fitted at a suitable place on the steering control post on the bridge or incorporated into the operation manual:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO THE HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

6 Certification, inspection and testing

6.1 Type tests of hydraulic pumps

6.1.1 Each type of power unit pump is to be subjected in the workshop to a type test of not less than 100 hours' duration.

The test arrangements are to be such that the pump may run both:

- in idling conditions, and
- at maximum delivery capacity at maximum working pressure.

During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board.

During the test, no abnormal heating, excessive vibration or other irregularities are permitted.

After the test, the pump is to be disassembled and inspected.

Note 1: Type tests may be waived for a power unit which has been proven to be reliable in marine service.

6.2 Testing of materials

6.2.1 Components subject to pressure or transmitting mechanical forces

a) Materials of components subject to pressure or transmitting mechanical forces, specifically:
   - cylindrical shells of hydraulic cylinders, rams and piston rods
   - tillers, quadrants
   - rotors and rotor housings for rotary vane steering gear
   - hydraulic pump casings
   - and hydraulic accumulators, if any,

   are to be duly tested, including examination for internal defects, in accordance with the requirements of NR216 Materials and Welding.

b) A works' certificate may be accepted for low stressed parts, provided that all characteristics for which verification is required are guaranteed by such certificate.

6.2.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Ch 1, Sec 10, [19.5].

6.3 Inspection and tests during manufacturing

6.3.1 Components subject to pressure or transmitting mechanical forces

a) The mechanical components referred to in [6.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, pump casings and accumulators, refer to Ch 1, Sec 3.

b) Defects may be repaired by welding only on forged parts or steel castings of weldable quality. Such repairs are to be conducted under the supervision of the Surveyor in accordance with the applicable requirements of NR216 Materials and Welding.

6.3.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Ch 1, Sec 10, [19], for a class I piping system.

6.4 Inspection and tests after completion

6.4.1 Hydrostatic tests

a) Hydraulic cylinder shells and accumulators are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 3.

b) Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 10, [19.6].

6.4.2 Shipboard tests

After installation on board the ship, the steering gear is to be subjected to the tests detailed in Ch 1, Sec 16, [3.9].

6.4.3 Sea trials

For the requirements of sea trials, refer to Ch 1, Sec 16.

Section 13 Thrusters

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the following types of thrusters:

- transverse thrusters intended for manoeuvring developing power equal to 500 kW or more
- thrusters intended for propulsion, steering and dynamic positioning developing power equal to 220 kW or more; for power less than 220 kW the requirements apply only to the propeller and relevant shaft.

1.1.2 Thrusters developing power less than that indicated in [1.1.1] are to be built in accordance with sound marine practice and tested as required in [3.2] to the satisfaction of the Surveyor.

1.2 Definitions

1.2.1 Thruster

A thruster is a propeller installed in a revolving nozzle or in a special transverse tunnel in the ship, or a water-jet. A thruster may be intended for propulsion, manoeuvring and steering or any combination thereof. Propulsion propellers in fixed nozzles are not considered thrusters (see Ch 1, Sec 8, [1.1.1]).

1.2.2 Transverse thruster

A transverse thruster is an athwartship thruster developing a thrust in a transverse direction for manoeuvring purposes.

1.2.3 Azimuth thruster

An azimuth thruster is a thruster which has the capability to rotate through 360° in order to develop thrust in any direction.

1.2.4 Water-jet

A water-jet is equipment constituted by a tubular casing (or duct) enclosing an impeller. The shape of the casing is such as to enable the impeller to produce a water-jet of such intensity as to give a positive thrust. Water-jets may have means for deviating the jet of water in order to provide a steering function.

1.2.5 Continuous duty thruster

A continuous duty thruster is a thruster which is designed for continuous operation, such as a propulsion thruster.

1.2.6 Intermittent duty thruster

An intermittent duty thruster is a thruster designed for operation at full power for a period not exceeding 1 hour, followed by operation at reduced rating for a limited period of time not exceeding a certain percentage of the hours in a day and a certain (lesser) percentage of the hours in a year. In general, athwartship thrusters are intermittent duty thrusters.

1.3 Thrusters intended for propulsion

1.3.1 In general, at least two azimuth thrusters are to be fitted in ships where these are the sole means of propulsion. Single azimuth thruster installations will be specially considered by the Society on a case by case basis.

Single water-jet installations are permitted.

1.4 Documentation to be submitted

1.4.1 Plans to be submitted for athwartship thrusters and azimuth thrusters

For thrusters:

- intended for propulsion, steering and dynamic positioning
- intended for manoeuvring developing power equal to 500 kW or more,

the plans listed in Tab 1 are to be submitted. Plans as per item 6 of Tab 1 are also to be submitted for thrusters developing power less than 500 kW.

1.4.2 Plans to be submitted for water-jets

The plans listed in Tab 2 are to be submitted.

1.4.3 Additional data to be submitted

The data and documents listed in Tab 3 are to be submitted by the manufacturer together with the plans.

Table 1 : Plans to be submitted for athwartship thrusters and azimuth thrusters

No	A/I **(1)**	ITEM
GENERAL REQUIREMENTS FOR ALL THRUSTERS		
1	I	General arrangement of the thruster
2	A	Propeller, including the applicable details mentioned in Ch 1, Sec 8
3	A	Bearing details
4	A	Propeller and intermediate shafts
5	A	Gears, including the calculations according to Ch 1, Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears
SPECIFIC REQUIREMENTS FOR TRANSVERSE THRUSTERS		
6	A	Structure of the tunnel showing the materials and their thickness
7	A	Structural equipment or other connecting devices which transmit the thrust from the propeller to the tunnel
8	A	Sealing devices (propeller shaft gland and thruster-tunnel connection)
9	A	For the adjustable pitch propellers: pitch control device and corresponding monitoring system
SPECIFIC REQUIREMENTS FOR ROTATING AND AZIMUTH THRUSTERS		
10	A	Structural items (nozzle, bracing, etc.)
11	A	Structural connection to hull
12	A	Rotating mechanism of the thruster
13	A	Thruster control system
14	A	Piping systems connected to thruster
(1) A = to be submitted for approval I = to be submitted for information.		

Table 2 : Plans to be submitted for water-jets

No	A/I **(1)**	ITEM
1	I	General arrangement of the water-jet
2	A	Casing (duct) (location and shape) showing the materials and the thicknesses as well as the forces acting on the hull
3	A	Details of the shafts, flanges, keys
4	I	Sealing gland
5	A	Bearings
6	A	Impeller
7	A	Steering and reversing buckets and their control devices as well as the corresponding hydraulic diagrams
(1) A = to be submitted for approval I = to be submitted for information.		

Table 3 : Data and documents to be submitted for athwartship thrusters, azimuth thrusters and water-jets

No	A/I **(1)**	ITEM
1	I	Rated power and revolutions
2	I	Rated thrust
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties
4	A	Where parts of thrusters are of welded construction, all particulars on the design of welded joints, welding procedures, heat treatments and non-destructive examinations after welding
5	I	Where applicable, background information on previous operating experience in similar applications
(1) A = to be submitted for approval I = to be submitted for information.		

2 Design and construction

2.1 Materials

2.1.1 Propellers

For requirements relative to material intended for propellers, see Ch 1, Sec 8.

2.1.2 Other thruster components

For the requirements relative to materials intended for other parts of the thrusters, such as gears, shaft, couplings, etc., refer to the applicable Parts of the Rules.

2.2 Transverse thrusters and azimuth thrusters

2.2.1 Prime movers

a) Diesel engines intended for driving thrusters are to comply with the applicable requirements of Ch 1, Sec 2.

b) Electric motors intended for driving thrusters and their feeding systems are to comply with the requirements of Part C, Chapter 2. In particular:
   - Provisions are to be made to prevent starting of the motors whenever there are insufficient generators in operation.
   - Intermittent duty thrusters will be the subject of special consideration by the Society.

2.2.2 Propellers

a) For propellers of thrusters intended for propulsion, steering and dynamic positioning, the requirements of Ch 1, Sec 8 apply.

b) For propellers of thrusters intended for manoeuvring only, the requirements of Ch 1, Sec 8 also apply, although the increase in thickness of 10% required in Ch 1, Sec 8, [2.5] does not need to be applied.

2.2.3 Shafts

a) For propeller shafts of thrusters, the requirements of Ch 1, Sec 7 apply to the portion of propellershaft between the inner edge of the aftermost shaft bearing and the inner face of the propeller boss or the face of the integral propeller shaft flange for the connection to the propeller boss.

b) For other shafts of thrusters, the requirement of Ch 1, Sec 6, [4.4.2] apply.

2.2.4 Gears

a) Gears of thrusters intended for propulsion steering and dynamic positioning are to be in accordance with the applicable requirements of Ch 1, Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears, applying the safety factors for propulsion gears.

b) Gears of thrusters intended for manoeuvring only are to be in accordance with the applicable requirements of Ch 1, Sec 6, for cylindrical gears or Standards recognised by the Society for bevel gears, applying the safety factors for auxiliary gears.

2.2.5 Nozzles and connections to hull for azimuth thrusters

a) For the requirements relative to the nozzle structure, see Part B, Chapter 9.

b) The scantlings of the nozzle connection to the hull and the welding type and size will be specially considered by the Society, which reserves the right to require detailed stress analysis in the case of certain high power installations.

c) For steerable thrusters, the equivalent rudder stock diameter is to be calculated in accordance with the requirements of Part B, Chapter 9.

2.2.6 Transverse thruster tunnel

a) The thickness of the tunnel is not to be less than the adjacent part of the hull.

b) Special consideration will be given by the Society to tunnels connected to the hull by connecting devices other than welding.

2.2.7 Bearings

Bearing are to be identifiable and are to have a life adequate for the intended purpose. However, their life cannot be less than:

- 40 000 hours for continuous duty thrusters. For ships with restricted service, a lesser value may be considered by the Society.
- 5 000 hours for intermittent duty thrusters.

2.3 Water-jets

2.3.1 Shafts

The diameter of the shaft supporting the impeller is not to be less than the diameter d_2, in mm, obtained by the following formula:

$$d_2 = 100 \cdot f \cdot h \cdot \left(\frac{P}{N}\right)^{1/3} \cdot \left(\frac{1}{1-Q^4}\right)^{1/3}$$

where:

P : Power, in kW

N : Rotational speed, in rpm

f : Calculated as follows:

$$f = \left(\frac{560}{R_m + 160}\right)^{1/3}$$

where R_m is the ultimate tensile strength of the shaft material, in N/mm²

h : h = 1,0 when the shaft is only transmitting torque loads, and when the weight and thrust of the propeller are totally supported by devices located in the fixed part of the thruster

h = 1,2 where the impeller is fitted with key or shrink-fitted.

Q : Q = 0 in the case of solid shafts

Q = the ratio between the diameter of the hole and the external diameter of the shaft, in the case of hollow shafts. If $Q \leq 0,3$, Q may be assumed equal to 0.

The shafts are to be protected against corrosion by means of either a continuous liner or an oil-gland of an approved type, or by the nature of the material of the shaft.

2.3.2 Guide vanes, shaft support

a) a) Guide vanes and shaft supports, if any, are to be fitted in accordance with direction of flow. Trailing and leading edges are to be fitted with rounded profiles.

b) b) Fillet radius are generally not be less than the maximum local thickness of the concerned element. Fatigue strength calculation is to be submitted.

2.3.3 Stator and impellers

a) Design is to take into account the loads developed in free going conditions and also in peculiar manoeuvres like crash stop.

b) Tip clearance is to take into account vibratory behaviours, displacements and any other expansion mode in all operating conditions of the water jet.

c) Fillet radii are generally not to be less than the maximum local thickness of the concerned element.

d) There is to be no natural frequency of stator blades or rotor blades in the vicinity of the excitation frequencies due to hydrodynamic interaction between stator blades and rotor blades. Calculations are to be submitted for maximum speed and any currently used speed.

2.3.4 Nozzle and reversing devices

Design of nozzle and reversing devices are to take into account the loads developed in all operating conditions of the water jet, including transient loads.

2.3.5 Steering performance

Steering performance and emergency steering availability are to be at least equivalent to the requirements in Ch 1, Sec 12, [4.2] and Ch 1, Sec 12, [4.3].

2.4 Alarm, monitoring and control systems

2.4.1 Steering thruster controls

a) Controls for steering are to be provided from the navigating bridge and locally, and also from the machinery control station when the thruster is the normal steering system of the ship.

b) Means are to be provided to stop any running thruster at each of the control stations.

c) A thruster angle indicator is to be provided at each steering control station. The angle indicator is to be independent of the control system.

2.4.2 Alarm and monitoring equipment

Tab 4 summarises the minimum alarm and monitoring requirements for propulsion and steering thrusters. See also Ch 1, Sec 12, [4].

Table 4 : Azimuth thrusters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Steering oil pressure	L						
Oil tank level	L						

3 Testing and certification

3.1 Material tests

3.1.1 Propulsion and steering thrusters

All materials intended for parts transmitting torque and for propeller/impeller blades are to be tested in accordance with the applicable requirements of Ch 1, Sec 6, [6] or Ch 1, Sec 7, [4] or Ch 1, Sec 8, [4] in the presence of a Surveyor.

3.1.2 Transverse thrusters

Material testing for parts of athwartship thrusters does not need to be witnessed by a Surveyor, provided full test reports are made available to him.

3.2 Testing and inspection

3.2.1 Thrusters

Thrusters are to be inspected as per the applicable requirements given in the Rules for the specific components.

3.2.2 Prime movers

Prime movers are to be tested in accordance with the requirements applicable to the type of mover used.

3.3 Certification

3.3.1 Certification of thrusters

Thrusters are to be individually tested and certified by the Society.

3.3.2 Mass produced thrusters

Mass produced thrusters may be accepted within the framework of the type approval program of the Society.

Section 14 Refrigerating Installations

1 General

1.1 Application

1.1.1 Refrigerating installations on all ships

The minimum safety requirements addressed in this Section are to be complied with for any refrigerating plant installed on board a ship to be classed by the Society. These requirements do not cover any operation or availability aspect of the plants, which are not the subject of class requirements, unless an additional notation is requested.

1.1.2 Additional notations

Where the additional notation **REF-STORE** is requested, the requirements of Pt E, Ch 11, Sec 3 are to be complied with.

2 Minimum design requirements

2.1 Refrigerating installation components

2.1.1 General

In general, the specific requirements stated in Part C of the Rules for various machinery and equipment are also applicable to refrigerating installation components.

2.1.2 Pressure vessels and heat exchangers

a) Pressure vessels of refrigerating plants are to comply with the relevant requirements of Ch 1, Sec 3.

b) Vessels intended to contain toxic substances are to be considered as class 1 pressure vessels as indicated in Ch 1, Sec 3, [1.4].

c) The materials used for pressure vessels are to be appropriate to the fluid that they contain.

d) Notch toughness of steels used in low temperature plants is to be suitable for the thickness and the lowest design temperature. A check of the notch toughness properties may be required where the working temperature is below minus 40°C.

2.1.3 Piping systems

a) Refrigerant pipes are generally to be regarded as pressure pipes.

b) Refrigerant, brine and sea water pipes are to satisfy the requirements of Ch 1, Sec 10, as applicable.

c) Refrigerant pipes are to be considered as belonging to the following classes:
   - class I: where they are intended for toxic substances
   - class II: for other refrigerants
   - class III: for brine.

d) In general, the pipes conveying the cooling medium are not to come into direct contact with the ship's structure; they are to be carefully insulated on their run outside the refrigerated spaces, and more particularly when passing through bulkheads and decks.

e) The materials used for the pipes are to be appropriate to the fluids they convey.

f) Notch toughness of the steels used is to be suitable for the application concerned.

g) Where necessary, cooling medium pipes within refrigerated spaces or embedded in insulation are to be externally protected against corrosion; for steel pipes, this protection is to be ensured by galvanisation or equivalent. All useful precautions are to be taken to protect the joints of such pipes against corrosion.

h) The use of plastic pipes shall not be permitted.

2.2 Refrigerants

2.2.1 Prohibited refrigerants

In addition to the substances prohibited by the Montreal Protocol, the use of the following refrigerants is not allowed for shipboard installations:

- ethane
- ethylene
- ammonia
- other substances with lower explosion limit in air of less than 3,5%.

2.2.2 Statutory requirements

Particular attention is to be paid to any limitation on the use of refrigerants imposed by the Naval Authority.

2.2.3 Toxic or flammable refrigerants

The arrangement of refrigerating machinery spaces of plants using toxic or flammable refrigerants will be the subject of special consideration by the Society.

3 Instrumentation

3.1 Thermometers in refrigerated spaces

3.1.1 Number of thermometers

a) Each refrigerated space with a volume not exceeding 400 m^3 is to be fitted with at least 4 thermometers or temperature sensors. Where the volume exceeds 400 m^3, this number is to be increased by one for each additional 400 m^3.

b) Where the volume is not exceeding 60 m^3, this number may be reduced to 2 thermometers if the general shape of the refrigerating space is quite rectangular with no dead end.

c) Sensors for remote electric thermometers are to be connected to the instruments so that, in the event of failure of any one instrument, the temperature in any space can still be checked through half the number of sensors in this space.

3.1.2 Direct reading thermometers

The tubes intended to contain thermometers are to have a diameter not less than 50 mm and are to be carefully isolated from the ship's structure. If they pass through spaces other than those they serve, they are to be insulated when passing through those spaces. Joints and covers of such tubes are to be insulated from the plating to which they are attached and installed on open decks so that water will not collect and freeze in them when measuring temperatures. Local readings are to be provided in any adjacent corridor to refrigerating chambers.

3.1.3 Electric thermometer apparatus for remote reading

The apparatus is to provide the temperature indications, in any case in the damage control station and in manned stations, with the accuracy required in [3.1.5] in conditions of vibrations and inclinations expected on board and for all ambient temperatures, up to 45°C, to which indicating instruments and connection cables may be exposed.

3.1.4 Distant electric thermometer sensors

a) Sensing elements are to be placed in refrigerated spaces where they are not liable to be exposed to damage during goods' handling and well clear of heat sources such as, for instance, electric lamps, etc.

b) Sensing elements in air coolers are to be placed at a distance of at least 900 mm from coils or fan motors.

c) When arranged in ducts, they are to be placed at the centre of the air duct section, as far as possible.

d) Sensing elements are to be protected by a corrosion-resistant impervious covering. Conductors are to be permanently secured to sensing elements and to indicating instruments and connected accessories. Plug-and-socket connections are allowed only if they are of a type deemed suitable by the Society.

e) All sensing elements are to be easily accessible.

3.1.5 Accuracy

a) Direct reading thermometers are to permit reading with an accuracy of 0,1°C for temperatures between 0°C and 15°C. Temperatures given by remote reading are to have an accuracy of:
   - ± 0,3°C (at 0°C) for the carriage of fruit and vegetables, and
   - ± 0,5°C (at 0°C) for the carriage of frozen products.

b) The instrumental error, to be ascertained by means of calibration by comparison with a master-thermometer with officially certified calibration, is not to exceed the following values:
   - ± 0,15°C, in the range – 3°C to + 3°C
   - ± 0,25°C, in all other ranges of the scale.

c) In general, the scale range is to be within –30°C and +20°C; in any case it is to be ±5°C greater than the range of application of the instrument.

d) In the graduated scale, the space between each degree centigrade is not to be less than 5 mm.

3.1.6 Data-logger

a) When a data-logger is installed, at least one sensing element for each refrigerated space, both in the space itself and in its air circulating system, is to be connected to another independent indicating instrument, approved by the Society. The data-logger is to register to 0,1 of a degree. Indicating instruments are to be fed by two independent power sources. If they are fed by the network on board through a transformer and rectifier unit, a spare unit is also to be provided and is to be easily replaceable aboard. If they are fed by storage batteries, it will be sufficient to arrange easily changeable batteries.

b) A prototype apparatus is to be checked and tested by a Surveyor at an independent recognised laboratory, or at the Manufacturer’s facilities, to verify by means of suitable tests that the degree of accuracy corresponds to the above provisions.

c) The capacity of the apparatus to withstand stipulated vibrations, impacts and temperature variations and its non-liability to alterations due to the salt mist atmosphere, typical of conditions on board, are to be verified.

4 Installations related to preservation of ships’ victuals

4.1 Victuals chamber

4.1.1 The victuals chambers are to have the lining of stainless steel including surface joints.

4.1.2 The victuals chambers are not to be provided with scuppers for drainage. Drainage of victuals chambers is to be through their doors and the exterior antechamber door. A dripping-pan is to be located near such exterior door. The dripping-pan width is to be at least 200 mm greater than the exterior antichamber door. Pipes discharging from the dripping-pan are to be provided with liquid seal traps.

4.1.3 Only direct cooling systems are to be used.

4.1.4 No components of refrigerating installation are to be fitted inside the refrigerated chambers.

4.2 Instrumentation

4.2.1 In the adjacent corridor of the refrigerated chambers local reading of the temperatures both by a direct reading system and by a remote reading system (see [3.1.2] and [3.1.3]) is to be possible.

4.2.2 Data-logger (see [3.1.6]) is to be provided only for the frozen victuals at temperature minus 20°C.

Section 15 Turbochargers

1 General

1.1 Application

1.1.1 These Rules apply to turbochargers fitted on the diesel engines listed in Ch 1, Sec 2, [1.1.1] a), b) and c) having a power of 1000 kW and above.

1.1.2 Turbochargers not included in [1.1.1] are to be designed and constructed according to sound marine practice and delivered with the works' certificate (W) relevant to the bench running test as per [4.3.3] and the hydrostatic test as per [4.3.4].

1.1.3 In the case of special types of turbochargers, the Society reserves the right to modify the requirements of this Section, demand additional requirements in individual cases and require that additional plans and data be submitted.

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document
1	A	Longitudinal cross-sectional assembly with main dimensions
2	A	Rotating parts (shaft, wheels and blades)
3	A	Details of blade fixing
4	A	Technical specification of the turbocharger including the maximum operating conditions (maximum permissible rotational speed and maximum permissible temperature)
5	A	Material specifications for the main parts, including their physical, chemical and mechanical properties, values of tensile strength, average stress to produce creep, resistance to corrosion and heat treatments
6	I	Operation and service manual

(1) A = to be submitted for approval
I = to be submitted for information.

Note 1: Plans mentioned under items (2) and (3) are to be constructional plans with all main dimensions and are to contain any necessary information relevant to the type and quality of the materials employed. In the case of welded rotating parts, all relevant welding details are to be included in the above plans and the procedures adopted for welding or for any heat treatments will be subject to approval by the Society.

2 Design and construction

2.1 Materials

2.1.1 The requirements of Ch 1, Sec 5, [2.2.1] are to be complied with, as far as applicable, at the Society's discretion.

2.2 Design

2.2.1 The requirements of Ch 1, Sec 5, [2.4] are to be complied with, as far as applicable, at the Society's discretion.

2.3 Monitoring

2.3.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 2 apply.

2.3.2 Indicators

The local indicators for turbochargers fitted on diesel engines having a power of 2000 kW and above to be installed on ships without automation notations are given in Ch 1, Sec 2, Tab 2.

3 Arrangement and installation

3.1 General

3.1.1 The arrangement and installation are to be such as to avoid any unacceptable load on the turbocharger.

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests

4.1.1 Turbochargers as per [1.1.1] admitted to an alternative inspection scheme are to be type approved.

The type test is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. Normally, the type test is to consist of a hot gas running test of one hour's duration at the maximum permissible speed and maximum permissible temperature. After the test the turbocharger is to be opened up and examined.

For Manufacturers who have facilities for testing the turbocharger unit on an engine for which the turbocharger is to be type approved, replacement of the hot running test by a test run of one hour's duration at overload (110% of the rated output) may be considered.

4.2 Material tests

4.2.1 Material tests (mechanical properties and chemical composition) are required for shafts and rotors, including blades (see [4.4.2] as regards the certificate required).

4.3 Workshop inspections and testing

4.3.1 Overspeed test

All wheels (impellers and inducers), when machine-finished and complete with all fittings and blades, are to undergo an overspeed test for at least 3 minutes at one of the following test speeds:

a) 20% above the maximum speed at room temperature

b) 10% above the maximum speed at the maximum working temperature.

Note 1: If each forged wheel is individually controlled by an approved non-destructive examination method no overspeed test may be required except for wheels of the type test unit.

4.3.2 Balancing

Each shaft and bladed wheel, as well as the complete rotating assembly, is to be dynamically balanced by means of equipment which is sufficiently sensitive in relation to the size of the rotating part to be balanced.

4.3.3 Bench running test

Each turbocharger is to undergo a mechanical running test at the bench for 20 minutes at maximum rotational speed at room temperature.

Subject to the agreement of the Society, the duration of the running test may be reduced to 10 minutes, provided that the Manufacturer is able to verify the distribution of defects found during the running tests on the basis of a sufficient number of tested turbochargers.

For Manufacturers who have facilities in their works for testing turbochargers on an engine for which they are intended, the bench test may be replaced by a test run of 20 minutes at overload (110% of the maximum continuous output) on such engine.

Where turbochargers are admitted to an alternative inspection scheme and subject to the satisfactory findings of a historical audit, the Society may accept a bench test carried out on a sample basis.

4.3.4 Hydrostatic tests

The cooling spaces of turbochargers are to be hydrostatically tested at a test pressure of 0,4 MPa or 1,5 times the maximum working pressure, whichever is the greater.

4.4 Certification

4.4.1 Type Approval Certificate and its validity

Subject to the satisfactory outcome of the type tests specified in [4.1], the Society will issue to the turbocharger Manufacturer a Type Approval Certificate valid for all turbochargers of the same type.

4.4.2 Testing certification

a) Turbochargers admitted to an alternative inspection scheme.

A statement, issued by the Manufacturer, is required certifying that the turbocharger conforms to the one type tested. The reference number and date of the Type Approval Certificate are also to be indicated in the statement (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.2]).

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for material tests as per [4.2] and for works trials as per [4.3].

b) Turbochargers not admitted to an alternative inspection scheme.

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for the bench running test as per [4.3.3] and the overspeed test as per [4.3.1], as well as for material and hydrostatic tests as per [4.2] and [4.3.4].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) may be accepted for material tests, in place of the Society's certificates, for turbochargers fitted on diesel engines having a cylinder diameter of 300 mm or less.

Section 16 Tests on Board

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both at the moorings and during sea trials. Such tests are additional to the workshop tests required in the other Sections of this Chapter.

For computerized Machinery systems, requirements contained in Part C, Chapter 3 shall be refered to.

1.2 Purpose of shipboard tests

1.2.1 Shipboard tests are intended to demonstrate that the main and auxiliary machinery and associated systems are functioning properly, in particular in respect of the criteria imposed by the Rules. The tests are to be witnessed by a Surveyor.

1.3 Documentation to be submitted

1.3.1 A comprehensive list of the shipboard tests intended to be carried out by the shipyard is to be submitted to the Society.

For each test, the following information is to be provided:

- scope of the test
- parameters to be recorded.

2 General requirements for shipboard tests

2.1 Trials at the moorings

2.1.1 Trials at the moorings are to demonstrate the following:

a) satisfactory operation of the machinery in relation to the service for which it is intended

b) quick and easy response to operational commands

c) safety of the various installations, as regards:
   - the protection of mechanical parts
   - the safeguards for personnel.

d) accessibility for cleaning, inspection and maintenance.

Where the above features are not deemed satisfactory and require repairs or alterations, the Society reserves the right to require the repetition of the trials at the moorings, either wholly or in part, after such repairs or alterations have been carried out.

2.2 Sea trials

2.2.1 Scope of the tests

Sea trials are to be conducted after the trials at the moorings and are to include the following:

a) demonstration of the proper operation of the main and auxiliary machinery, including monitoring, alarm and safety systems, under realistic service conditions

b) check of the propulsion capability when one of the essential auxiliaries becomes inoperative

c) detection of dangerous vibrations by taking the necessary readings when required

d) checks either deemed necessary for ship classification or requested by the interested parties and which are possible only in the course of navigation in open sea.

2.2.2 Exemptions

Exemption from some of the sea trials may be considered by the Society in the case of ships having a sister ship for which the satisfactory behaviour in service is demonstrated.

Such exemption is, in any event, to be agreed upon by the interested parties and is subject to the satisfactory results of trials at the moorings to verify the safe and efficient operation of the propulsion system.

3 Shipboard tests for machinery

3.1 Conditions of sea trials

3.1.1 Displacement of the ship

Except in cases of practical impossibility, or in other cases to be considered individually, the sea trials are to be carried out at a displacement as close as possible to the full load displacement or to the half load displacement.

3.1.2 Power of the machinery

a) The power developed by the propulsion machinery in the course of the sea trials is to be as close as possible to the power for which classification has been requested. In general, this power is not to exceed the maximum continuous power at which the weakest component of the propulsion system can be operated. In cases of diesel engines and gas turbines, it is not to exceed the maximum continuous power for which the engine type concerned has been approved.

b) Where the rotational speed of the shafting is different from the design value, thereby increasing the stresses in excess of the maximum allowable limits, the power developed in the trials is to be suitably modified so as to confine the stresses within the design limits.

3.1.3 Determination of the power and rotational speed

a) The rotational speed of the shafting is to be recorded in the course of the sea trials, preferably by means of a continuous counter.

b) In general, the power is to be determined by means of torsiometric readings, to be effected with procedures and instruments deemed suitable by the Society.

   As an alternative, for reciprocating internal combustion engines and gas turbines, the power may be determined by measuring the fuel consumption and on the basis of the other operating characteristics, in comparison with the results of bench tests of the prototype engine.

   For electric propulsion, the power may be determined by recording electrical data.

   Other methods of determining the power may be considered by the Society on a case by case basis.

3.2 Navigation and manoeuvring tests

3.2.1 Speed trials

a) Where required by the Rules, the speed of the ship is to be determined using procedures deemed suitable by the Society.

b) The ship speed is to be determined as the average of the speeds taken in not less than two pairs of runs in opposite directions.

3.2.2 Astern trials

a) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest within reasonable distance from maximum ahead service speed, shall be demonstrated and recorded.

b) The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers or propulsion /steering systems to navigate and manoeuvre with one or more propellers or propulsion /steering systems inoperative, shall be available on board for the use of the Master or designated personnel.

c) Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means shall be demonstrated and recorded as referred to in paragraphs a) and b).

For electric propulsion systems, see [3.5].

3.2.3 Change of propulsion system configuration

a) Where several normal propulsion system configurations are possible, each of them are to be tested.

b) The normal transfers between these configurations are to be tested.

3.3 Tests of diesel engines

3.3.1 General

The scope of the trials of diesel engines may be expanded in consideration of the special operating conditions, such as towing, trawling, etc.

3.3.2 Main propulsion engines driving fixed propellers

Sea trials of main propulsion engines driving fixed propellers are to include the following tests:

a) operation at rated engine speed n_0 for at least 4 hours

b) operation at minimum load speed

c) starting and reversing manoeuvres

d) operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes

e) tests of the monitoring, alarm and safety systems.

Note 1: The test in d) may be performed during the dock or sea trials.

3.3.3 Main propulsion engines driving controllable pitch propellers or reversing gears

Sea trials of main propulsion engines driving controllable pitch propellers or reversing gear are to include the following tests:

a) operation at rated engine speed n_0 with nominal pitch of the propeller for at least 4 hours

b) test at various propeller pitches for engines driving controllable pitch propellers

c) operation in reverse thrust of propeller at the maximum torque or thrust allowed by the propulsion system for 10 minutes

d) tests of the monitoring, alarm and safety systems.

Note 1: The test in c) may be performed during the dock or sea trials.

3.3.4 Engines driving generators for electric propulsion

Sea trials of engines driving generators for electric propulsion are to include the following tests:

a) operation at 100% power (rated power) for at least 4 hours

b) operation at 110% power for 30 minutes

c) starting manoeuvres

d) tests of the monitoring, alarm and safety systems.

Note 1: The above tests a) to d) are to be performed at rated speed with a constant governor setting. The powers refer to the rated electrical powers of the driven generators.

3.3.5 Engines driving auxiliaries

a) Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for at least 2 hours.

b) It is to be demonstrated that the engine is capable of supplying 100% of its rated power and, in the case of shipboard generating sets, account is to be taken of the times needed to actuate the generator's overload protection system.

3.4 Tests of gas turbines

3.4.1 Main propulsion turbines

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- ship reversing manoeuvres.

During the various operations, the pressures, temperatures and relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.4.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.5 Tests of electric propulsion system

3.5.1 Dock trials

a) The dock trials are to include the test of the electrical production system, the power management system and the load limitation.

b) A test of the propulsion plant at a reduced power, in accordance with dock trial facilities, is to be carried out. During this test, the following are to be checked:
    - electric motor rotation speed variation
    - functional test, as far as practicable (power limitation is to be tested with a reduced value)
    - protection devices
    - monitoring and alarm transmission including interlocking system.

c) Prior to the sea trials, an insulation test of the electric propulsion plant is to be carried out.

3.5.2 Sea trials

Testing of the performance of the electric propulsion system is to be effected in accordance with an approved test program.

This test program is to include at least:

- speed rate of rise

- endurance test:
  - 4 hours at 100% rated output power
  - operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes

Note 1: The reverse test may be performed during the dock or sea trials.

- check of the crash astern operation in accordance with the sequence provided to reverse the speed from full ahead to full astern, in case of emergency. During this test, all necessary data concerning any effects of the reversing of power on the generators are to be recorded, including the power and speed variation
- test of functionality of electric propulsion, when manoeuvring and during the ship turning test
- test of power management performance: reduction of power due to loss of one or several generators to check, in each case, the power limitation and propulsion availability.

3.6 Tests of gears

3.6.1 Tests during sea trials

During the sea trials, the performance of reverse and/or reduction gearing is to be verified, both when running ahead and astern.

In addition, the following checks are to be carried out:

- check of the bearing and oil temperature
- detection of possible gear hammering, where required by Ch 1, Sec 9, [3.5.1]
- test of the monitoring, alarm and safety systems.

3.6.2 Check of the tooth contact

a) Prior to the sea trials, the tooth surfaces of the pinions and wheels are to be coated with a thin layer of suitable coloured compound.

Upon completion of the trials, the tooth contact is to be inspected. The contact marking is to appear uniformly distributed without hard bearing at the ends of the teeth and without preferential contact lines.

The tooth contact is to comply with Tab 1.

b) The verification of tooth contact at sea trials by methods other than that described above will be given special consideration by the Society.

Table 1 : Tooth contact for gears

Heat treatment and machining	Percentage of tooth contact	
	across the whole face width	of the tooth working depth
quenched and tempered, cut	70	40
• quenched and tempered, shaved or ground • surface-hardened	90	40

3.7 Tests of main propulsion shafting and propellers

3.7.1 Shafting alignment

Where alignment calculations are required to be submitted in pursuance of Ch 1, Sec 7, [3.3.1], the alignment conditions are to be checked on board as follows:

a) shafting installation and intermediate bearing position, before and during assembling of the shafts:
   - optical check of the relative position of bushes after fitting
   - check of the flanged coupling parameters (gap and sag)
   - check of the centring of the shaft sealing glands

b) engine (or gearbox) installation, with floating ship:
   - check of the engine (or gearbox) flanged coupling parameters (gap and sag)
   - check of the crankshaft deflections before and after the connection of the engine with the shaft line, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine

Note 1: The ship is to be in the loading conditions defined in the alignment calculations.

c) load on the bearings:
   - check of the intermediate bearing load by means of jack-up load measurements
   - check of the bearing contact area by means of coating with an appropriate compound.

3.7.2 Shafting vibrations

Torsional, bending and axial vibration measurements are to be carried out where required by Ch 1, Sec 9. The type of the measuring equipment and the location of the measurement points are to be specified.

3.7.3 Bearings

The temperature of the bearings is to be checked under the machinery power conditions specified in [3.1.2].

3.7.4 Stern tube sealing gland

The stern tube oil system is to be checked for possible oil leakage through the stern tube sealing gland.

3.7.5 Propellers

a) For controllable pitch propellers, the functioning of the system controlling the pitch from full ahead to full astern position is to be demonstrated. It is also to be checked that this system does not induce any overload of the engine.

b) The proper functioning of the devices for emergency operations is to be tested during the sea trials.

3.8 Tests of piping systems

3.8.1 Functional tests

During the sea trials, piping systems serving propulsion and auxiliary machinery, including the associated monitoring and control devices, are to be subjected to functional tests at the nominal power of the machinery. Operating parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

3.8.2 Performance tests

The Society reserves the right to require performance tests, such as flow rate measurements, should doubts arise from the functional tests.

3.9 Tests of steering gear

3.9.1 General

a) The steering gear is to be tested during the sea trials under the conditions stated in [3.1] in order to demonstrate, to the Surveyor's satisfaction, that the applicable requirements of Ch 1, Sec 12 are fulfilled.

b) For controllable pitch propellers, the propeller pitch is to be set at the maximum design pitch approved for the maximum continuous ahead rotational speed.

c) If the ship cannot be tested at the deepest draught, alternative trial conditions will be given special consideration by the Society on the basis of Naval Authority determinations. In such case, the ship speed corresponding to the maximum continuous number of revolutions of the propulsion machinery may apply.

3.9.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the main and auxiliary steering gear with demonstration of the performances required by Ch 1, Sec 12, [2.3]

b) test of the steering gear power units, including transfer between steering gear power units and between main and auxiliary

c) test of the isolation of one power actuating system, checking the time for regaining steering capability for both main and auxiliary steering gear operation

d) test of the hydraulic fluid refilling system

e) test of the alternative power supply required by Ch 1, Sec 12, [2.7.2], item e)

f) test of the steering gear controls, including transfer of controls and local control

g) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment and other position of emergency steering

h) test of the alarms and indicators

i) where the steering gear design is required to take into account the risk of hydraulic locking, a test is to be performed to demonstrate the efficiency of the devices intended to detect this.

Note 1: Tests d) to i) may be carried out either during the mooring trials or during the sea trials.

Note 2: Azimuth thrusters are to be subjected to the above tests, as far as applicable.

4 Inspection of machinery after sea trials

4.1 General

4.1.1

a) For all types of propulsion machinery, those parts which have not operated satisfactorily in the course of the sea trials, or which have caused doubts to be expressed as to their proper operation, are to be disassembled or opened for inspection.

   Machinery or parts which are opened up or disassembled for other reasons are to be similarly inspected.

b) Should the inspection reveal defects or damage of some importance, the Society may require other similar machinery or parts to be opened up for inspection.

c) An exhaustive inspection report is to be submitted to the Society for information.

4.2 Diesel engines

4.2.1

a) In general, for all diesel engines, the following items are to be verified:
   - the deflection of the crankshafts, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine
   - the cleanliness of the lubricating oil filters.

b) In the case of propulsion engines for which power tests have not been carried out in the workshop, some parts, agreed upon by the interested parties, are to be disassembled for inspection after the sea trials.

Appendix 1 Check of the Scantlings of Crankshafts for Diesel Engines

1 General

1.1 Application

1.1.1

a) The requirements for the check of scantlings of crankshafts given in this Appendix apply to diesel engines as per Ch 1, Sec 2, [1.1.1] a), b) and c), capable of continuous operation at their maximum continuous power P, (as defined in Ch 1, Sec 2, [1.3.2]), at the nominal maximum speed n.

Crankshafts which cannot satisfy these requirements will be subject to special consideration by the Society as far as detailed calculations or measurements can be submitted.

The following cases:

- surface treated fillets;
- when fatigue parameter influences are tested; and
- when working stresses are measured;

will be also specially considered by the Society.

b) The requirements of this Appendix apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between two adjacent main bearings.

1.2 Documentation to be submitted

1.2.1 Required data for the check of the scantlings are indicated in the specific Society form as per Ch 1, Sec 2, Tab 1, item 1.

1.3 Principles of calculation

1.3.1 The scantlings of crankshafts as per this Appendix are based on an evaluation of safety against fatigue failure in the highly stressed areas.

The calculation is also based on the assumption that the fillet transitions between the crankpin and web as well as between the journal and web are the areas exposed to the highest stresses.

The outlets of oil bores into crankpins and journals are to be formed in such a way that the safety margin against fatigue at the oil bores is not less than that acceptable in the fillets.

The engine manufacturer, where requested by the Society, is to submit documentation supporting his oil bore design.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion (von Mises' Criterion), result in an equivalent alternating stress (uni-axial stress). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

1.4 Symbols

1.4.1

B : Width of the web, in mm; see Fig 2

d_{BC} : Diameter of bore in crankpin, in mm; see Fig 2

d_{BJ} : Diameter of bore in journal, in mm; see Fig 2

d_C : Crankpin diameter, in mm; see Fig 2

d_J : Journal diameter, in mm; see Fig 2

D_E : The minimum value between:

- the outside diameter of web, in mm, or
- the value, in mm, equal to twice the minimum distance x between centre-line of journals and outer contour of web (see Fig 3)

d_S : Shrink-fit diameter, in mm; see Fig 3

E : Pin eccentricity, in mm; see Fig 2

E_W : Value of the modulus of elasticity of the web material, in N/mm²; see [7.2.2]

F : Area, in mm^2, related to cross-section of web, given by the following formula:

$$F = B \cdot W$$

K : Crankshaft manufacturing process factor; see [6.1.1] a)

K_E : Empirical factor for the modification of the alternating bending stress, which considers to some extent the influence of adjacent cranks and bearing restraint, whose value may be taken as follows:

- $K_E = 0,8$ for 2-stroke engines
- $K_E = 1,0$ for 4-stroke engines

L_S : Axial length of the shrink-fit, in mm; see Fig 3

M_B : Bending moment in the web centre, in N·m

$M_{B,MAX}$: Maximum value of the bending moment M_B, in N·m

$M_{B,MIN}$: Minimum value of the bending moment M_B, in N·m

M_{BN} : Nominal alternating bending moment, in Nm; for the determination of M_{BN} see [2.1.2] b)

$M_{T,MAX}$: Maximum value of the torque, in N·m, with consideration of the mean torque

$M_{T,MIN}$: Minimum value of the torque, in N·m, with consideration of the mean torque

M_{TN} : Nominal alternating torque, in N·m, given by the following formula:

$$M_{TN} = \pm 0,5 \cdot (M_{T,MAX} - M_{T,MIN})$$

Q_1 : Acceptability factor for the crankpin fillet; see [8.1.1]

Q_2 : Acceptability factor for the journal fillet; see [8.1.1]

Q_{MAX} : Maximum value of the alternating shearing force Q, in N

Q_{MIN} : Minimum value of the alternating shearing force Q, in N

Q_N : Nominal alternating shearing force, in N; for the determination of Q_N see [2.1.2] c)

r_C : Fillet radius of crankpin, in mm; see Fig 2

r_J : Fillet radius of journal, in mm; see Fig 2

R_m : Value of the minimum specified tensile strength of crankshaft material, in N/mm^2

$R_{S,MIN}$: Specified value, in N/mm^2, of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of the crank web material.

S : Pin overlap, in mm, (see Fig 2) whose value may be calculated by the following formula:

$$S = \frac{d_C + d_J}{2} - E$$

Where pins do not overlap, the negative value of S calculated by the above formula is to be considered.

T_C : Recess of crankpin, in mm; see Fig 2

T_J : Recess of journal, in mm; see Fig 2

W : Axial web thickness, in mm; see Fig 2

W_{EQ} : Equatorial moment of resistance, in mm^3, related to cross-sectional area of web, whose value may be calculated as follows:

$$W_{EQ} = \frac{B \cdot W^2}{6}$$

W_{PC} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of crankpin; for the determination of W_{PC} see [2.2.2]

W_{PJ} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of journal; for the determination of W_{PJ} see [2.2.2]

y : Distance, in mm, between the adjacent generating lines of journal and pin connected to the same web (see Fig 3).

In general y is not to be less than 0,05 d_s.

Where y is less than 0,1 d_S, special consideration will be given by the Society in each case, to the effect of the stress due to the shrink on the fatigue strength of the web at the crankpin fillet

β_{BC} : Stress concentration factor for bending in crankpin fillet; for the determination of β_{BC} see [3.1.2] a)

β_{BJ} : Stress concentration factor for bending in journal fillet; for the determination of β_{BJ} see [3.1.3] a)

β_{QJ} : Stress concentration factor for shearing in journal fillet; for the determination of β_{QJ} see [3.1.3] b)

β_{TC} : Stress concentration factor for torsion in crankpin fillet; for the calculation of β_{TC} see [3.1.2] b)

β_{TJ} : Stress concentration factor for torsion in journal fillet; for the calculation of β_{TJ} see [3.1.3] c)

$\sigma_{B,ADD}$: Additional bending stress, in N/mm^2, due to misalignment; see [4.1.1]

σ_{BN} : Nominal alternating bending stress, in N/mm^2; for the determination of σ_{BN} see [2.1.2] b)

σ_{BC} : Alternating bending stress in crankpin fillet, in N/mm^2; for the determination of σ_{BC} see [2.1.3] a)

σ_{BJ} : Alternating bending stress in journal fillet, in N/mm^2; for the determination of σ_{BJ} see [2.1.3] b)

σ'_E : Equivalent alternating stress in way of the crankpin fillet, in N/mm^2; for the determination of σ'_E see [5.2.1] a)

σ''_E	:	Equivalent alternating stress in way of the journal fillet, in N/mm²; for the determination of σ''_E see [5.2.1] b)
$\sigma'_{F,ALL}$	:	Allowable alternating bending fatigue strength in way of the crankpin fillet, in N/mm²; for the determination of $\sigma'_{F,ALL}$ see [6.1.1] a)
$\sigma''_{F,ALL}$	:	Allowable alternating bending fatigue strength in way of the journal fillet, in N/mm²; for the determination of $\sigma''_{F,ALL}$ see [6.1.1] b)
σ_{QN}	:	Nominal alternating shearing stress, in N/mm²; for the determination of σ_{QN} see [2.1.2] c)
τ_C	:	Alternating torsional stress in way of crankpin fillet, in N/mm²; for the determination of τ_C see [2.2.3] a)
τ_J	:	Alternating torsional stress in way of journal fillet, in N/mm²; for the determination of τ_J see [2.2.3] b)
τ_{NC}	:	Nominal alternating torsional stress referred to crankpin, in N/mm²; for the determination of τ_{NC} see [2.2.2]
τ_{NJ}	:	Nominal alternating torsional stress referred to journal, in N/mm²; for the determination of τ_{NJ} see [2.2.2].

2 Calculation of alternating stresses

2.1 Calculation of alternating stresses due to bending moments and shearing forces

2.1.1 Assumptions

The calculation of alternating stresses is based on the assumptions specified below.

a) The calculation is based on a statically determined system, so that only one single crank throw is considered with the journals supported in the centre of adjacent bearings and the throw subjected to gas and inertia forces. The bending length is taken as the length L_3 between the centre of two adjacent main bearings (see Fig 1(a) and (b)).

b) The nominal bending moment is taken as the bending moment in the crank web cross-section in the centre of the solid web (distance L_1 from the centre of the nearest main bearing) based on a triangular bending moment load due to the radial components of the connecting rod force. For crank throws with two connecting rods acting upon one crankpin, the nominal bending moment is taken as a bending moment obtained by superimposing the two triangular bending moment loads due to the radial components of the connecting rod forces, according to phase.

c) The nominal alternating stresses due to bending moments and shearing forces are to be related to the cross-sectional area of the crank web, at the centre of the overlap S in cases of overlap of the pins and at the centre of the distance y between the adjacent generating lines of the two pins in cases of pins which do not overlap (see Fig 2 and Fig 3).

   Nominal mean bending stresses are neglected.

2.1.2 Calculation of nominal alternating bending and shearing stresses

a) As a rule the calculation is carried out in such a way that the individual radial forces acting upon the crank pin owing to gas and inertia forces will be calculated for all crank positions within one working cycle. A simplified calculation of the radial forces may be used at the discretion of the Society.

b) The time curve of the bending moment M_B in the web centre is to be calculated by means of the radial forces variable in time within one working cycle, and taking into account the axial distance from the bearing center as defined in [2.1.1] a) to the acting position of the forces on the pin. The nominal alternating bending moment M_{BN}, in N·m, and, from this, the nominal alternating bending stress σ_{BN}, in N/mm², will then be calculated by the following formulae:

$$M_{BN} = \pm 0{,}5 \cdot (M_{B,MAX} - M_{B,MIN})$$

$$\sigma_{BN} = \pm \frac{M_{BN}}{W_{EQ}} \cdot K_E \cdot 10^3$$

   In the case of V-type engines, the bending moments, progressively calculated for the various crank angles and due to the gas and inertia forces of the two cylinders acting on one crank throw, are to be superimposed according to phase, the differing designs of the connecting rods (forked connecting rod, articulated-type connecting rod or adjacent connecting rods) being taken into account.

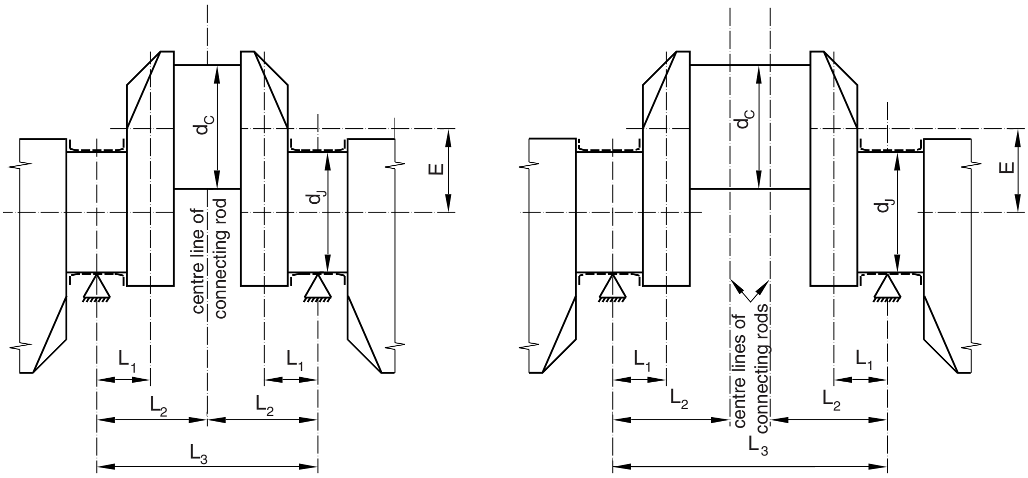
   Where there are cranks of different geometrical configuration (e.g., asymmetric cranks) in one crankshaft, the calculation is to cover all crank variants.

c) The nominal alternating shearing force Q_N, in N, and, from this, the nominal alternating shearing stress σ_{QN}, in N/mm², may be calculated by the following formulae:

$$Q_N = \pm 0{,}5 \cdot (Q_{MAX} - Q_{MIN})$$

$$\sigma_{QN} = \pm \frac{Q_N}{F} \cdot K_E$$

Figure 1 : Crank throw of solid crankshaft



(a) Crank throw for in-line engine

(b) Crank throw for engine with two adjacent connecting rods

Figure 2 : Crank dimensions necessary for the calculation of stress concentration factors

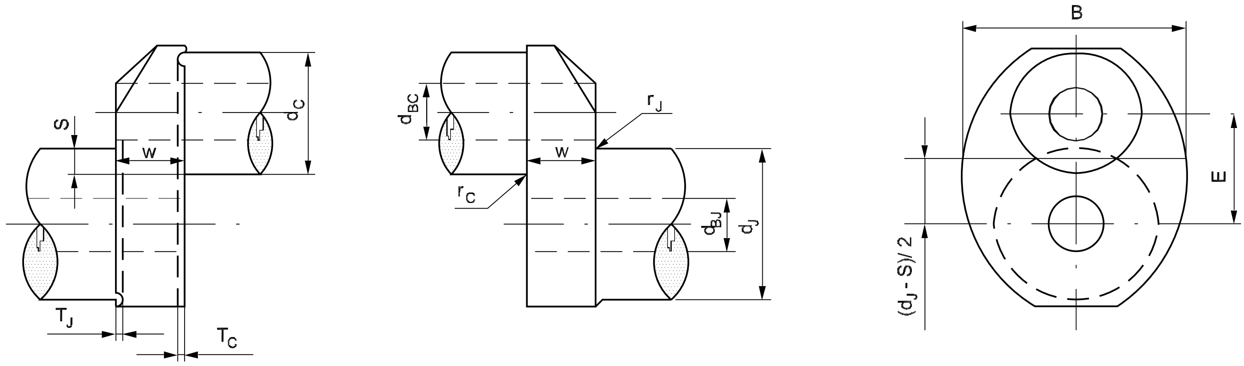
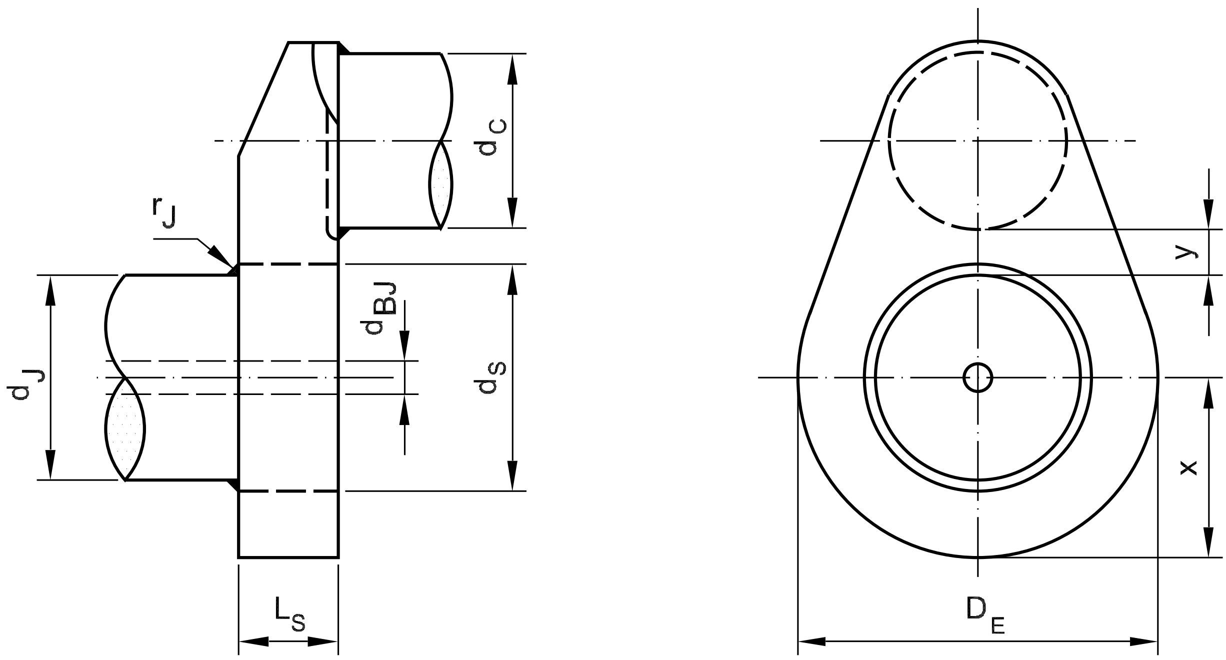


Figure 3 : Crank throw of semi-built crankshaft



2.1.3 Calculation of alternating bending stresses in way of crankpin and journal fillets

The calculation of the alternating bending stresses is to be carried out in way of crankpin and journal fillets, as specified below.

a) The alternating bending stress in crankpin fillet is to be taken equal to the value σ_{BC}, in N/mm², obtained by the following formula:

$$\sigma_{BC} = \pm(\beta_{BC} \cdot \sigma_{BN})$$

b) The alternating bending stress in journal fillet is to be taken equal to the value σ_{BJ}, in N/mm², obtained by the following formula:

$$\sigma_{BJ} = \pm(\beta_{BJ} \cdot \sigma_{BN} + \beta_{QJ} \cdot \sigma_{QN})$$

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in [2.2.2].

The maximum value obtained from such calculations will be used by the Society when determining the equivalent alternating stress according to the provisions of [5].

In the absence of such a maximum value, the Society reserves the right to incorporate a fixed value in the calculation for the crankshaft dimensions, to be established at its discretion in each case.

In the event of the Society being entrusted to carry out a forced vibration calculation on behalf of the engine manufacturer to determine the torsional vibration stresses expected in the engine and where relevant in the shafting, the following data are to be submitted in addition to those required in [1.2.1]:

a) equivalent dynamic system of the engine, comprising:
   1) mass moment of inertia of every mass point, in kg·m²
   2) inertialess torsional stiffnesses, in N·m/rad, of all crankshaft parts between two mass points
b) vibration dampers, specifying:
   1) type designation
   2) mass moments of inertia, in kg·m²
   3) inertialess torsional stiffnesses, in N·m/rad
   4) values of the damping coefficients, in N·m·s
c) flywheels, specifying:
   1) mass moment of inertia, in kg·m².

Where the whole propulsion system is to be considered, the following information is also to be submitted:

a) elastic couplings, specifying:
   1) dynamic characteristics and damping data, as well as the permissible value of alternating torque
b) gearing and shafting, specifying:
   1) shaft diameters of gear shafts, thrust shafts, intermediate shafts and propeller shafts, mass moments of inertia, in kg·m², of gearing or important mass points, gear ratios and, for gearboxes of complex type, the schematic gearing arrangement
c) propellers, specifying:
   1) propeller diameter
   2) number of blades
   3) pitch and developed area ratio
   4) mass moment of inertia of propeller in air and with entrained water, in kg·m², (for controllable pitch propellers both the values at full pitch and at zero pitch are to be specified)
   5) damping characteristics, if available and documented
d) natural frequencies with their relevant modes of vibration and the vector sums for the harmonics of the engine excitation
e) estimated torsional vibration stresses in all important elements of the system with particular reference to clearly defined resonance speeds of rotation and continuous operating ranges.

2.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum values of the alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the alternating stresses due to the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines, and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines.

In performing this calculation, allowance is to be made for the dampings that exist in the system and for unfavourable conditions (e.g., misfiring in one of the cylinders).

The speed stages is to be selected for the forced vibration calculations in such a way that the transient response can be recorded with sufficient accuracy at various speeds.

The values received from such calculation are to be submitted to the Society for consideration.

The nominal alternating torsional stresses, referred to crankpin and journal, in every mass point which is essential to the assessment, may be taken equal to the values τ_{NC} and τ_{NJ}, in N/mm², calculated by the following formulae:

$$\tau_{NC} = \pm \frac{M_{TN}}{W_{PC}} \cdot 10^3$$

$$\tau_{NJ} = \pm \frac{M_{TN}}{W_{PJ}} \cdot 10^3$$

where:

a) For unbored crankpins or journals:

$$W_{PC} = \frac{\pi \cdot d_C^3}{16}$$

$$W_{PJ} = \frac{\pi \cdot d_J^3}{16}$$

b) For bored crankpins or journals:

$$W_{PC} = \frac{\pi}{16} \cdot \frac{d_C^4 - d_{BC}^4}{d_C}$$

$$W_{PJ} = \frac{\pi}{16} \cdot \frac{d_J^4 - d_{BJ}^4}{d_J}$$

For the symbols d_C, d_J, d_{BC} and d_{BJ} see [3.1.1] and Fig 2.

For the calculation of the polar moments of resistance W_{PC} and W_{PJ}, bored crankpins and journals having bore diameter not exceeding 0,3 times the outer diameter of crankpins or journals may be considered as unbored.

Bored crankpins and journals whose bore longitudinal axis does not coincide with the axis of the said crankpins and journals, will be considered by the Society in each case.

The assessment of the proposed crankshaft dimensions is based on the alternating torsional stress which, in conjunction with the associated bending stress, results in the lowest acceptability factor F_A, as specified in [8.1].

Where barred speed ranges are necessary, the alternating torsional stresses within these ranges are to be neglected in the calculation of the above acceptability factor.

Barred speed ranges are to be so arranged that satisfactory operation is possible despite their existence.

There are to be no barred speed ranges for values of the speed ratio $\lambda \geq 0,8$, λ being the ratio between the rotational speed considered and the rotational speed corresponding to the maximum continuous power.

The approval of the proposed crankshaft dimensions will be based on the installation having the lowest value of the above-mentioned acceptability factor.

Thus, for each installation, it is to be ensured by suitable calculation that the nominal alternating torsional stress accepted for the purpose of checking the crankshaft scantlings is not exceeded.

This calculation is to be submitted for assessment to the Society (see Ch 1, Sec 9).

2.2.3 Calculation of alternating torsional stresses in crankpin and journal fillets

The calculation of alternating torsional stresses is to be carried out both in way of crankpin and journal fillets, as specified below:

a) The alternating torsional stress in way of crankpin fillet is to be taken equal to the value τ_C, in N/mm², given by the following formula:

$$\tau_C = \pm (\beta_{TC} \cdot \tau_{NC})$$

b) The alternating torsional stress in way of journal fillet is to be taken equal to the value τ_J, in N/mm², given by the following formula:

$$\tau_J = \pm (\beta_{TJ} \cdot \tau_{NJ})$$

3 Calculation of stress concentration factors

3.1 General

3.1.1 The stress concentration factors for bending (β_{BC} and β_{BJ}) are defined as the ratio of the maximum value of the bending stress occurring in the fillets under bending load acting in the central cross-section of a crank, to the value of the nominal alternating bending stress related to the web cross-section.

The value of the above nominal stress is to be determined under the bending moment in the middle of the solid web.

The stress concentration factors for torsion (β_{TC} and β_{TJ}) are defined as the ratio of the maximum value of the torsional stress occurring under torsional load in the fillets to the value of the nominal alternating torsional stress related to the crankpin or journal cross-section, taking account of the relevant bores, if any.

The stress concentration factor for shearing β_{QJ} is defined as the ratio of the maximum value of the shear stress occurring in the journal fillet under bending load to the value of the nominal shear stress related to the web cross-section.

Where the above stress concentration factors cannot be obtained by reliable measurements, their values may be evaluated by means of the formulae in [3.1.2] and [3.1.3], which are applicable to crankpin fillets and journal fillets for solid-forged crankshafts, and to the crankpin fillets only for semi-built crankshafts.

Fig 2 shows the dimensions necessary for the calculation of the above-mentioned stress concentration factors.

For the calculation of stress concentration factors for bending, torsion and shearing, the related dimensions shown in Tab 1 will be applied.

The values of the stress concentration factors, calculated as follows, are valid for the following ranges of related dimensions for which investigations have been carried out:

$-0{,}50 \leq s \leq 0{,}70$

$0{,}20 \leq w \leq 0{,}80$

$1{,}20 \leq b \leq 2{,}20$

$0{,}03 \leq r_1 \leq 0{,}13$

$0{,}03 \leq r_2 \leq 0{,}13$

$0 \leq d_1 \leq 0{,}80$

$0 \leq d_2 \leq 0{,}80$

The factor f(t,s), which accounts for the influence of a recess in the web in way of the crankpin and journal fillets, is valid if the related dimensions t_1 and t_2 meet the following conditions:

$t_1 \leq r_1 \quad t_2 \leq r_2$

and is to be applied for the values of the related dimension s within the range:

$-0{,}30 \leq s \leq 0{,}50$

Table 1 :

Crankpin fillets	Journal fillets
$r_1 = r_C / d_C$	$r_2 = r_J / d_C$
$s = S / d_C$	$s = S / d_C$
$w = W / d_C$	$w = W / d_C$
$b = B / d_C$	$b = B / d_C$
$d_1 = d_{BC} / d_C$	$d_2 = d_{BJ} / d_C$
$t_1 = T_C / d_C$	$t_2 = T_J / d_C$

3.1.2 Crankpin fillets

a) The value of the stress concentration factor for bending β_{BC} may be calculated by the following formula:

$$\beta_{BC} = 2{,}6914 \cdot f_1(s,w) \cdot f_1(w) \cdot f_1(b) \cdot f_1(r_1) \cdot f_1(d_1) \cdot f_1(d_2) \cdot f(t,s)$$

where:

$f_1(s,w)$: $-4{,}1883 + 29{,}2004 \cdot w - 77{,}5925 \cdot w^2 + 91{,}9454 \cdot w^3 - 40{,}0416 \cdot w^4 + (1-s) \cdot (9{,}5440 - 58{,}3480 \cdot w + 159{,}3415 \cdot w^2 - 192{,}5846 \cdot w^3 + 85{,}2916 \cdot w^4) + (1-s)^2 \cdot (-3{,}8399 + 25{,}0444 \cdot w - 70{,}5571 \cdot w^2 + 87{,}0328 \cdot w^3 - 39{,}1832 \cdot w^4)$

$f_1(w)$: $2{,}1790 \cdot w^{0{,}7171}$

$f_1(b)$: $0{,}6840 - 0{,}0077 \cdot b + 0{,}1473 \cdot b^2$

$f_1(r_1)$: $0{,}2081 \cdot r_1^{-0{,}5231}$

$f_1(d_1)$: $0{,}9978 + 0{,}3145 \cdot d_1 - 1{,}5241 \cdot d_1^2 + 2{,}4147 \cdot d_1^3$

$f_1(d_2)$: $0{,}9993 + 0{,}27 \cdot d_2 - 1{,}0211 \cdot d_2^2 + 0{,}5306 \cdot d_2^3$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1{,}8 + 3{,}2\ s)$

b) The value of the stress concentration factor for torsion β_{TC} may be calculated by the following formula:

$\beta_{TC} = 0,8 \cdot f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$

where:

$f_2(r_1,s)$: r_1^x with $x = -0,322 + 0,1015 \cdot (1 - s)$

$f_2(b)$: $7,8955 - 10,654 \cdot b + 5,3482 \cdot b^2 - 0,857 \cdot b^3$

$f_2(w)$: $w^{-0,145}$

3.1.3 Journal fillets

a) The value of the stress concentration factor for bending β_{BJ} may be calculated by the following formula:

$\beta_{BJ} = 2,7146 \cdot f_3(s,w) \cdot f_3(w) \cdot f_3(b) \cdot f_3(r_2) \cdot f_3(d_1) \cdot f_3(d_2) \cdot f(t,s)$

where:

$f_3(s,w)$: $-1,7625 + 2,9821 \cdot w - 1,5276 \cdot w^2$
$+ (1 - s) \cdot (5,1169 - 5,8089 \cdot w + 3,1391 \cdot w^2)$
$+ (1 - s)^2 \cdot (-2,1567 + 2,3297 \cdot w - 1,2952 \cdot w^2)$

$f_3(w)$: $2,2422 \cdot w^{0,7548}$

$f_3(b)$: $0,5616 + 0,1197 \cdot b + 0,1176 \cdot b^2$

$f_3(r_2)$: $0,1908 \cdot r_2^{-0,5568}$

$f_3(d_1)$: $1,0022 - 0,1903 \cdot d_1 + 0,0073 \cdot d_1^2$

$f_3(d_2)$: $1,0012 - 0,6441 \cdot d_2 + 1,2265 \cdot d_2^2$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1,8 + 3,2\ s)$

b) The value of the stress concentration factor for shearing β_{QJ} may be calculated by the following formula:

$\beta_{QJ} = 3,0128 \cdot f_4(s) \cdot f_4(w) \cdot f_4(b) \cdot f_4(r_2) \cdot f_4(d_1) \cdot f(t,s)$

where:

$f_4(s)$: $0,4368 + 2,1630 \cdot (1 - s) - 1,5212 \cdot (1 - s)^2$

$f_4(w)$: $\dfrac{w}{0,0637 + 0,9369 \cdot w}$

$f_4(b)$: $-0,5 + b$

$f_4(r_2)$: $0,5331 \cdot r_2^{-0,2038}$

$f_4(d_1)$: $0,9937 - 1,1949 \cdot d_1 + 1,7373 \cdot d_1^2$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1,8 + 3,2\ s)$

c) The value of the stress concentration factor for torsion β_{TJ} may be calculated by the following formulae:

- where $d_J = d_C$ and $r_J = r_C$:

  $\beta_{TJ} = \beta_{TC}$

- where $d_J \neq d_C$ and/or $r_J \neq r_C$:

  $\beta_{TJ} = 0,8 \cdot f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$

  and $f_2(r_1,s)$, $f_2(b)$ and $f_2(w)$ are to be determined in accordance with [3.1.2], but taking:

  $r_1 = r_J / d_J$

  instead of $r_1 = r_C / d_C$ for the calculation of $f_2(r_1,s)$.

4 Additional bending stresses

4.1

4.1.1 In addition to the alternating bending stresses in fillets (see [2.1.3]), further bending stresses due to misalignment, bedplate deformation and axial and bending vibrations are also to be considered.

The values of such additional bending stresses may be taken equal to the values $\sigma_{B,ADD}$, in N/mm², as shown in Tab 2.

Table 2 : Additional bending stresses

Type of engine	$\sigma_{B,ADD}$, in N/mm²
Crosshead engine	± 30
Trunk piston engine	± 10

5 Calculation of the equivalent alternating stress

5.1 General

5.1.1 The equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet.

For this calculation the theory of constant energy of distorsion (von Mises's Criterion) is to be used.

Here it is assumed that the maximum alternating bending stresses and maximum alternating torsional stresses within a crankshaft occur simultaneously and at the same point.

5.2 Equivalent alternating stress

5.2.1 The equivalent alternating stress is to be taken as the greater of the two values σ'_E and σ''_E, calculated according to the formulae of a) and b) below.

a) The equivalent alternating stress in way of the crankpin fillet is to be taken equal to the value σ'_E, in N/mm², calculated by the following formula:

$$\sigma'_E = \pm[(\sigma_{BC} + \sigma_{B,ADD})^2 + 3\tau_C^{\,2}]^{0,5}$$

b) The equivalent alternating stress in way of the journal fillet is to be taken equal to the value σ''_{ID}, in N/mm², calculated by the following formula:

$$\sigma''_E = \pm[(\sigma_{BJ} + \sigma_{B,ADD})^2 + 3\tau_J^{\,2}]^{0,5}$$

6 Calculation of the fatigue strength

6.1

6.1.1 The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets between webs and pins.

Where the fatigue strength for a crankshaft cannot be ascertained by reliable measurements, it may be taken equal to the lower of the values $\sigma'_{F,\,ALL}$ and $\sigma''_{F,\,ALL}$ evaluated by means of the formulae in a) and b) below.

a) The value of the allowable alternating bending fatigue strength in way of the crankpin fillet may be taken equal to the value $\sigma'_{F.ALL}$ in N/mm², calculated by the following formula:

$$\sigma'_{F,ALL} = \pm\, K . R'_m . (0{,}264 + 1{,}073 . d_C^{-0,2} + R''_m + R'''_m . r_C^{-0,5})$$

where:

- K : Factor for different types of forged and cast steel crankshafts without surface treatment of pins, whose value may be taken as follows:
  - 1,05 for continuous grain flow forged or drop-forged steel crankshafts
  - 1,00 for free form forged steel crankshafts
  - 0,93 for cast steel crankshafts
- R'_m : $0{,}42 \cdot R_m + 39{,}3$
- R''_m : $\dfrac{785 - R_m}{4900}$
- R'''_m : $196 / R_m$

b) The value of the allowable alternating bending fatigue strength in way of the journal fillet may be taken equal to the value $\sigma''_{F,.ALL}$, in N/mm², calculated by the following formula:

$$\sigma''_{F,ALL} = \pm\, K . R'_m . (0{,}264 + 1{,}073 . d_J^{-0,2} + R''_m + R'''_m . r_J^{-0,5})$$

For calculation of $\sigma'_{F,ALL}$ and $\sigma''_{F,ALL}$, the values of r_C and r_J are not to be taken less than 2 mm.

Where results of the fatigue tests conducted on full size crank throws or crankshafts whose pins have been subjected to surface treatment are not available, the factor K for crankshafts without surface treatment of pins is to be used.

In all cases the experimental values of fatigue strength carried out with full size crank throws or crankshafts is to be submitted to the Society for consideration.

The survival probability for fatigue strength values derived from testing is to be to the satisfaction of the Society and in principle not less than 80%.

7 Calculation of shrink-fit of semi-built crankshafts

7.1 General

7.1.1 Considering the radius of the transition r_J from the journal diameter d_J to the shrink diameter d_S, both the following equations are to be respected:

$r_J \geq 0{,}015 d_J$

$r_J \geq 0{,}5 \cdot (d_S - d_J)$

The actual oversize h of the shrink-fit must be within the limits h_{MIN} and h_{MAX} calculated in accordance with [7.2] and [7.3] or according to recognized standards.

7.2 Minimum required oversize of shrink-fit

7.2.1 The minimum oversize required for the shrink-fit is determined by the greater of the values calculated in accordance with [7.2.2] and [7.2.3].

7.2.2 The value of the minimum required oversize of the shrink-fit h_{MIN}, in mm, is to be not less than that calculated by the following formula for the crank throw with the absolute maximum torque $M_{T,MAX}$.

The above torque $M_{T,MAX}$, in N·m, corresponds to the maximum value of the torque for the various mass points of the crankshaft

$$h_{MIN} = \frac{4 \cdot 10^3}{\pi \cdot \mu} \cdot \frac{s_F \cdot M_{T,MAX}}{E_W \cdot d_S \cdot L_S} \cdot f(Z)$$

where:

s_F : safety factor against slipping; in no case is a value less than 2 to be taken

μ : coefficient for static friction between the journal and web surfaces, to be taken equal to 0,20, if $L_S / d_S \geq 0{,}40$

$f(Z)$: $\dfrac{1 - Z_A^2 \cdot Z_S^2}{(1 - Z_A^2) \cdot (1 - Z_S^2)}$

Z_A : d_S / D_E

Z_S : d_{BJ} / d_S

7.2.3 In addition to the provisions of [7.2.2], the minimum required oversize value h_{MIN}, in mm, is not to be less than that calculated according to the following formula:

$$h_{MIN} = \frac{R_{S,MIN} \cdot d_S}{E_W}$$

7.3 Maximum permissible oversize of shrink-fit

7.3.1 The value of the maximum permissible oversize of shrink-fit is not to be exceeded the value h_{MAX}, in mm, calculated in accordance with the following formula:

$$h_{MAX} = \frac{R_{S,MIN} \cdot d_S}{E_W} + \frac{0{,}8 d_S}{1000}$$

This condition concerning the maximum permissible oversize serves to restrict the shrinkage induced mean stress in the journal fillet.

8 Acceptability criteria

8.1

8.1.1 In order for the proposed crankshaft scantlings to be acceptable, the equivalent alternating stresses, calculated both at crankpin and journal fillets, are to be such as to satisfy the following conditions:

$$Q_1 = \frac{\sigma'_{F,ALL}}{\sigma'_E} \geq 1{,}15$$

$$Q_2 = \frac{\sigma''_{F,ALL}}{\sigma''_E} \geq 1{,}15$$

Appendix 2 Plastic Pipes

1 General

1.1 Application

1.1.1 These requirements are applicable to pipes / piping systems made of plastic or made predominantly of other material than metal. The installation of plastic pipes is to be avoided on naval ships if not agreed by the Society and the Naval Authority.

1.1.2 The use of mechanical joints approved for the use in metallic piping system only is not permitted.

1.1.3 Piping systems intended for non-essential services are only required to meet the requirements of recognized standards and [2.1.3], item b); [2.5.2]; [3.1.2]; [3.1.3]; [3.1.4]; [3.1.5]; [3.1.6]; [3.1.7] and Article [4].

1.2 Use of plastic pipes

1.2.1 Plastic may be used in piping systems in accordance with the provisions of Ch 1, Sec 10, [2.1.3], provided the requirements of this Appendix are complied with.

1.2.2 Plastic pipes are to be type approved by the Society.

1.3 Specifications

1.3.1 The specification of the plastic piping is to be submitted in accordance with the provisions of Ch 1, Sec 10, [1.2.2]. It is to comply with a recognised national or international standard approved by the Society. In addition, the requirements stated in this Appendix are to be complied with.

1.4 Terms and conditions

1.4.1 Plastic(s)

Plastic(s) includes both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastic (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties.

1.4.2 Pipes / piping systems

Pipes / piping systems means those made of plastic(s) and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria.

1.4.3 Joint

Joint means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints according to Ch 1, Sec 10, Fig 2.

1.4.4 Fitting

Fittings means bends, elbows, fabricated branch pieces etc. of plastic materials.

1.4.5 Nominal pressure

Nominal pressure means the maximum permissible working pressure which is to be determined in accordance with the requirements in [2.1.3].

1.4.6 Design pressure

Design pressure means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.4.7 Fire endurance

Fire endurance means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

1.4.8 Essential to the safety of ships

Essential to the safety of ships means all piping systems that in event of failure will pose a threat to personnel and the ship.

1.4.9 Essential services

Essential services are those services essential to propulsion and steering and safety of the ship as specified in Ch 2, Sec 1, [3.2].

Note: Examples for piping systems essential to the safety are provided by Tab 1.

2 General requirements

2.1 Strength

2.1.1 The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 100 kPa, relative humidity 30%, environmental and carried fluid temperature 298 kPa (25°C).

2.1.2 The strength of fittings and joints is to be not less than that of the pipes.

2.1.3 The nominal pressure P_N is to be determined from the following conditions:

a) Internal pressure

For an internal pressure $P_{N\ int}$, the following is to be taken whichever is smaller:

- $P_{N\ int} \leq P_{sth} / 4$
- $P_{N\ int} \leq P_{lth} / 2,5$

where:

P_{sth} : Short-term hydrostatic test pipe failure pressure

P_{lth} : Long-term hydrostatic test pipe failure pressure (>100 000 hours)

b) External pressure $P_{N\ ext}$, (for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS Chapter II-1, Regulation 8-1, as amended, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

$P_{N\ ext} \leq P_{col} / 3$

where P_{col} is the collapse pressure.

In no case is the pipe collapse pressure to be less than 0,3 MPa

The maximum working external pressure is the sum of the vacuum inside the pipe and the static pressure head outside the pipe.

2.1.4 Notwithstanding the requirements of items a) or b) as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of item a) above are to be met.

2.1.5 The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with Manufacturer's recommendations.

2.2 Axial strength

2.2.1 The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

2.2.2 In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see [2.1.3]).

2.3 Impact resistance

2.3.1 Plastic pipes and joints are to have a minimum resistance to impact in accordance with a recognised national or international standard.

After the test the specimen is to be subjected to hydrostatic pressure equal to 2,5 times the design pressure for at least 1 hour.

2.4 Temperature

2.4.1 The permissible working temperature depending on the working pressure is to be in accordance with Manufacturer's recommendations, but in each case it is to be at least 20ºC lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2:2013 method A, or equivalent e.g. ASTM D648-18.

The minimum heat distortion/deflection temperature is to be not less than 80ºC.

2.5 Requirements depending on service and/or location

2.5.1 Fire endurance

Pipes and their associated joints and fittings whose integrity is essential to the safety of ships are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO Resolution A.753(18), as amended.

Unless instructed otherwise by the Naval Authority, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings:

a) Pipes:
   - for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness
   - for sizes with outer diameter ≥ 200 mm one test specimen for each category of t/d, with:

     D= outer diameter,

     t = structural wall thickness.

   A scattering of ±10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

b) Joints:

   Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen

Note 1: A test specimen incorporating several components of a piping system may be tested in a single test.

Note 2: Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested.

If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1or 2 of the IMO Resolution A.753(18), as amended. During the test it is not permitted to replace media drained by fresh water or nitrogen.

Depending on the capability of a piping system to maintain its strength and integrity, there exist three different levels of fire endurance for piping systems:

a) Level 1. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1).

   Level 1W - Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).

b) Level 2. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2).

   Level 2W - Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).

c) Level 3. Piping having passed the fire endurance test specified in Appendix 2 of IMO Resolution A.753(18) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard (L3).

Permitted use of piping depending on fire endurance, location and piping system is given in Tab 1.

Table 1 : Fire endurance of piping systems

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A **(12)**	Other machinery spaces and pump rooms **(13)**	Cargo pump rooms **(14)**	Ro-Ro cargo holds **(15)**	Other dry cargo holds **(16)**	Cargo tanks **(17)**	Fuel oil tanks **(18)**	Ballast water tanks **(19)**	Cofferdams, void spaces, pipe tunnels and ducts **(20)**	Accommodation, service and control spaces **(21)**	Open decks **(22)**
CARGO (FLAMMABLE CARGOES WITH FLASH POINT ≤ 60°C)											
Cargo lines	NA	NA	L1	NA	NA	0	NA	0 **(9)**	0	NA	L1**(2)**
Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0 **(9)**	0	NA	L1**(2)**
Vent lines	NA	NA	NA	NA	NA	0	NA	0 **(9)**	0	NA	X
INERT GAS											
Water seal effluent line	NA	NA	0 **(1)**	NA	NA	0 **(1)**	0 **(1)**	0 **(1)**	0 **(1)**	NA	0
Scrubber effluent line	0 **(1)**	0 **(1)**	NA	NA	NA	NA	NA	0**(1)**	0 **(1)**	NA	0
Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1 **(6)**
Distribution line	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1 **(2)**
FLAMMABLE LIQUIDS (FLASH POINT > 60°C)											
Cargo lines	X	X	L1	X	X	NA**(3)**	0	0 **(9)**	0	NA	L1
Fuel oil	X	X	L1	X	X	NA**(3)**	0	0	0	L1	L1

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A **(12)**	Other machinery spaces and pump rooms **(13)**	Cargo pump rooms **(14)**	Ro-Ro cargo holds **(15)**	Other dry cargo holds **(16)**	Cargo tanks **(17)**	Fuel oil tanks **(18)**	Ballast water tanks **(19)**	Cofferdams, void spaces, pipe tunnels and ducts **(20)**	Accommodation, service and control spaces **(21)**	Open decks **(22)**
Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA WATER **(1)**											
Bilge main and branches	X	X	L1	X	X	NA	0	0	0	NA	L1
Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
Foam system	L1W	L1W	L1W	NA	NA	NA	NA	NA	0	L1W	L1W
Sprinkler system	L1W	L1W	L3	X	NA	NA	NA	0	0	L3	L3
Ballast	L3	L3	L3	L3	X	0 **(9)**	0	0	0	L2W	L2W
Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2W
Tank cleaning services, fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3 **(2)**
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER											
Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY, DRAINS, SCUPPERS											
Deck drains (internal)	L1W**(4)**	L1W**(4)**	NA	L1W**(4)**	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scuppers and discharges (over-board)	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0	0	0	0	0 **(1)(7)**	0
SOUNDING, AIR											
Water tanks, dry spaces	0	0	0	0	0	0**(9)**	0	0	0	0	0
Oil tanks (flash point > 60°C)	X	X	X	X	X	X**(3)**	0	0**(9)**	0	X	X
MISCELLANEOUS											
Control air	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1**(5)**	L1**(5)**	NA	0	0	0	L1 **(5)**	L1**(5)**
Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
Auxiliary low steam pressure (≤ 0,7 MPa)	L2W	L2W	0 **(8)**	0 **(8)**	0 **(8)**	0	0	0	0	0 **(8)**	0 **(8)**
Urea transfer / supply system (SCR installations)	L1**(11)**	L1**(11)**	NA	NA	NA	NA	NA	NA	0	L3 **(1)(10)** NA	0

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A (12)	Other machinery spaces and pump rooms (13)	Cargo pump rooms (14)	Ro-Ro cargo holds (15)	Other dry cargo holds (16)	Cargo tanks (17)	Fuel oil tanks (18)	Ballast water tanks (19)	Cofferdams, void spaces, pipe tunnels and ducts (20)	Accommodation, service and control spaces (21)	Open decks (22)

Note 1:

- L1 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 60 min
- L1W : Fire endurance test (see [2.5.1])
- L2 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 30 min
- L2W : Fire endurance test (see [2.5.1])
- L3 : Fire endurance test (appendix 2 of IMO Resolution A.753(18), as amended) in wet conditions, 30 min
- 0 : No fire endurance test required
- NA : Not applicable
- X : Metallic materials having a melting point greater than 925°C

(1) Where non-metallic piping is used, remote controlled valves to be provided at ship side (valve is to be controlled from outside space).
(2) Remote closing valves to be provided at the cargo tanks.
(3) When cargo tanks contain flammable liquids with flash point > 60 °C, “0” may replace “NA” or “X”.
(4) For drains serving only the space concerned, “0” may replace “L1W”.
(5) When controlling functions are not required by the Rules, “0” may replace “L1”.
(6) For pipes between machinery space and deck water seal, “0” may replace “L1”.
(7) Scuppers serving open decks in positions 1 and 2, as defined in Pt B, Ch 1, Sec 2, [9], are to be “X” throughout unless fitted at the upper end with a means of closing capable of being operated from a position above the damage control deck in order to prevent downflooding.
(8) For essential services, such as fuel oil tank heating and ship’s whistle, “X” is to replace “0”.
(9) For tankers, “NA” is to replace “0”.
(10) L3 in service spaces, NA in accommodation and control spaces.
(11) Type approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.
(12) Machinery spaces of category A are defined in Ch 4, Sec 1, [2.22].
(13) Spaces, other than category A machinery spaces and cargo pumps rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
(14) Spaces containing cargo pumps, and entrances and trunks to such spaces.
(15) Ro-ro and vehicle spaces are defined in Ch 4, Sec 1, [2]
(16) All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.
(17) All spaces used for liquid cargo and trunks to such spaces.
(18) All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.
(19) All spaces used for ballast water and trunks to such spaces.
(20) Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
(21) Accommodation spaces, service spaces and control stations are defined in Ch 4, Sec 1, [2].
(22) Open decks are defined in Ch 4, Sec 5, [1.2.3].

2.5.2 Flame spread

a) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels, and ducts if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead are to have low surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution A.753(18), as amended.

b) Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as also listed in Appendix 3 of IMO Resolution A.753(18), as amended.

c) Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635-18, or in other national equivalent standards. Under the procedure of ASTM D635-18 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

2.5.3 Fire protection coating

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

- The pipes are generally to be delivered from the manufacturer with the protective coating on.

- The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.
- In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations and elasticity are to be taken into account.
- The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

2.5.4 Electrical conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed $1 \cdot 10^5$ Ohm/m.

3 Material approval and quality control during manufacture

3.1 General

3.1.1 Except as required in [1.1.3], prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with the requirements of this Appendix.

3.1.2 For prototype testing representative samples of pipes and fittings are to be selected to the satisfaction of the Society.

3.1.3 The Manufacturer is to have quality system that meets ISO 9001:2015 standards or equivalent. The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

3.1.4 Each pipe and fitting is to be tested by the Manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognised national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

3.1.5 Piping and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

3.1.6 In case the Manufacturer does not have an approved quality system complying with ISO 9001:2015 or equivalent, pipes and fittings are to be tested in accordance with this Appendix to the satisfaction of the Surveyor for every batch of pipes.

3.1.7 Depending upon the intended application a Society may require the pressure testing of each pipe and/or fitting.

4 Arrangement and installation of plastic pipes

4.1 Supports

4.1.1 Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe Manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, length of the piping, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected.

Combination of loads is to be considered.

4.1.2 Each support is to evenly distribute the load of the pipe and its content over the full width of the support. Measures are to be taken to minimise wear of the pipes where they are in contact with the supports.

4.1.3 Heavy components in the piping system such as valves and expansion joints are to be independently supported.

4.2 Expansion

4.2.1 Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

- the high difference in the coefficients of thermal expansion
- deformations of the ship’s structure.

4.2.2 Calculations of the thermal expansions are to take into account the system working temperature and the temperature at which the assembly is performed.

4.3 External loads

4.3.1 When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowance is to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

4.3.2 Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with [2.1], may be increased taking into account the conditions encountered during service on board ships.

4.3.3 Pipes are to be protected from mechanical damage where necessary.

4.4 Strength of connections

4.4.1 General

a) The strength of connections is not to be less than that of the piping system in which they are installed.

b) Pipes and fittings may be assembled using adhesive-bonded, welded, flanged or other joints.

c) When used for joint assembly, adhesives are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

d) Tightening of joints, where required, is to be performed in accordance with the manufacturer's instructions.

4.5 Installation of conductive pipes

4.5.1 In piping systems for fluids with conductivity less than 1000 pico siemens per metre (pS/m) such as refined products and distillates use is to be made of conductive pipes.

Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1 x 10^6 Ohm. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.

After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection

4.6 Application of fire protection coatings

4.6.1 Where necessary for the required fire endurance as stated in [2.5.3], fire protection coatings are to be applied on the joints, after performing hydrostatic pressure tests of the piping system.

4.6.2 The fire protection coatings are to be applied in accordance with the manufacturer's recommendations, using a procedure approved in each case.

4.7 Penetration of fire divisions and watertight bulkheads or decks

4.7.1 Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that fire endurance is not impaired. These arrangements are to be tested in accordance with 'Recommendations for Fire Test Procedures for "A", "B" and "F" Bulkheads' 2010 FTP Code, annex 1, part 3, as amended.

4.7.2 When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in [2.1.3] item b), a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

4.7.3 If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

4.8 Control during installation

4.8.1 General

a) Installation is to be in accordance with the Manufacturer's guidelines.

b) Prior to commencing the work, joining techniques are to be approved by the Society.

c) The tests and explanations specified in the present Appendix are to be completed before shipboard piping installation commences.

d) The personnel performing this work are to be properly qualified and certified to the satisfaction of the Society.

e) The procedure for making bonds is to be submitted to the Society for qualification. It is to include the following:
   - materials used
   - tools and fixtures
   - joint preparation requirements
   - cure temperature
   - dimensional requirements and tolerances
   - acceptance criteria for the test of the completed assembly

f) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be requalified.

4.8.2 Bonding qualification test

a) A test assembly is to be fabricated in accordance with the procedure to be qualified. It is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.

b) When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor of 2,5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.

c) Selection of the pipes used for the test assembly is to be in accordance with the following:
   - when the largest size to be joined is 200 mm nominal outside diameter or smaller, the test assembly is to be the largest piping size to be joined.
   - when the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is the greater.

d) When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

4.9 Testing after installation on board

4.9.1 Piping systems for essential services are to be subjected to a test pressure not less than 1,5 times the design pressure or 4 bar whichever is greater. Notwithstanding the requirement above, the requirement in [4.9.2] may be applied to open ended pipes (drains, effluent, etc.).

4.9.2 Piping systems for non-essential services are to be checked for leakage under operational conditions.

4.9.3 For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

5 Test specification for plastic pipes

5.1 Scope

5.1.1 This Article contains requirements for the type approval of plastic pipes. It is applicable to piping systems, including pipe joints and fittings, made predominately of other material than metal.

5.2 Documentation

5.2.1 The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

a) General information
   - pipe and fitting dimensions
   - maximum internal and external working pressure
   - working temperature range
   - intended services and installation locations
   - the level of fire endurance
   - electrically conductive
   - intended fluids
   - limits on flow rates
   - serviceable life
   - installation instructions
   - details of marking.

b) Drawings and supporting documentation
- certificates and reports for relevant tests previously carried out
- details of relevant standards
- all relevant design drawings, catalogues, data sheets, calculations and functional descriptions
- fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

c) Materials (as applicable)
- the resin type
- catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed
- a statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed
- full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate
- cure/post-cure conditions. The cure and post-cure temperatures and times employ resin/reinforcement ratio
- winding angle and orientation
- Joint bonding procedures and qualification tests results, see [4.8.1], item e).

5.3 Testing

5.3.1 Testing is to demonstrate compliance of the pipes, fittings and joints for which type approval is sought with the present Appendix.

Pipes, joints and fittings are to be tested for compliance with the requirements of recognized standards acceptable to the Society. In that order, recommended standards are given in Tab 2 and Tab 3.

Table 2 : Typical requirements for all systems

No	Test	Typical standard	Notes
1	Internal pressure **(1)**	the present [2.1.3], item a) ASTM D 1599 ASTM D 2992 ISO 15493 or equivalent	Top, middle, bottom (of range) Tests are to be carried out on pipe spools made of different pipe sizes, fittings and pipe connections
2	External pressure **(1)**	the present [2.1.3], item b) ISO 15493 or equivalent	As above, for straight pipes only
3	Axial strength	the present [2.2]	As above
4	Load deformation	ASTM D 2412 or equivalent	Top, middle, bottom (of each pressure range)
5	Temperature limitations	ISO 75-2:2013 method A GRP piping system: HDT test on each type of resin according to ISO 75-2:2013 method A Thermoplastic piping systems: ISO 75:2-2013 method A ISO 306 - Thermoplastic materials - Determination of Vicat softening temperature (VST) VICAT test according to ISO 2507 Polyesters with an HDT below 80°C are not to be used	Each type of resin
6	Impact resistance	ISO 9854, ISO 9653, ISO 15493, ASTM D 2444, or equivalent	Representative samples of each type of construction
7	Ageing	Manufacturer's standard ISO 9142	Each type of construction
8	Fatigue	Manufacturer's standard or service experience	Each type of construction
9	Fluid absorption	ISO 8361	
10	Material compatibility **(2)**	ASTM C581 Manufacturer's standard	

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable.

Table 3 : Typical additional requirements depending on service and/or locations of piping

No	Test	Typical standard	Notes
1	Fire endurance**(1)(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 1, 2	Representative samples of each type of construction and type of pipe connection
2	Flame spread**(1)(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
3	Smoke generation**(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
4	Toxicity**(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
5	Electrical conductivity **(1)(2)(3)**	ASTM F1173-95 or ASTM D 257, NS 6126 § 11.2 or equivalent	Representative samples of each type of construction

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable
(3) Optional. However, if the test is not carried out, the range of approved applications for the pipes is to be limited accordingly.

Appendix 3 Independent Fuel Oil Tanks

1 General

1.1 Application

1.1.1

a) The provisions of this Appendix apply to fuel oil tanks and bunkers which are not part of the ship's structure.

b) Requirements for scantling apply only to steel tanks. Scantling of tanks not made of steel will be given special consideration.

1.2 Documents to be submitted

1.2.1 Constructional drawings of the tanks are to be submitted, showing the height of the overflow and air pipe above the top of the tank.

1.3 Symbols and units

1.3.1 Tanks

The meaning of the symbols used for tanks is given in Fig 1.

L : Greater length of the considered plating element, in m

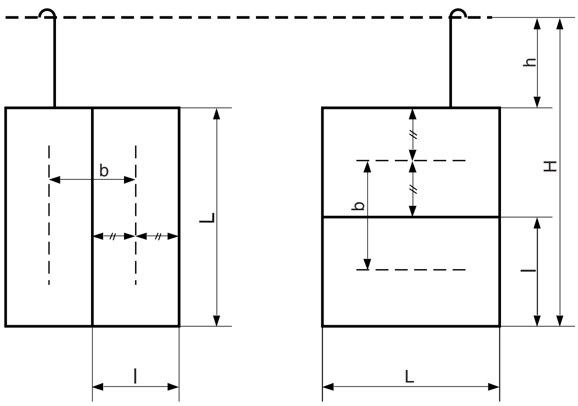
l : Smaller length of the considered plating element, in m

H : Height, in m, of the overflow or air pipe above the lower edge of the considered plating element

h : Height, in m, of overflow or air pipe above the top of the tank, subject to a minimum of:

- 3,60 m for fuel oil having a flash point below 60°C
- 2,40 m otherwise.

Figure 1 : Symbols used for tanks



1.3.2 Stiffeners

The following symbols and units are used for the stiffeners:

b : Width of the plating element supported by the stiffener, in m

w : Section modulus of the stiffeners, in cm^3.

2 Design and installation of tanks

2.1 Materials

2.1.1 General

Independent fuel oil tanks are to be made of steel except where permitted in [2.1.2].

2.1.2 Use of materials other than steel

a) On ships of less than 100 gross tonnage, independent fuel oil tanks may be made of:

- aluminium alloys or equivalent material, provided that the tanks are located outside the propulsion machinery spaces or, when located within such spaces, they are insulated to A-60 class standard

- glass reinforced plastics (GRP), provided:
  - the total volume of tanks located in the same space does not exceed 4,5 m^3, and
  - the properties of GRP including fire resistance comply with the relevant provisions of Ch 1, App 3.

b) On ships of 100 gross tonnage or more, the use of independent fuel oil tanks made of aluminium alloys or GRP will be given special consideration.

2.2 Scantling of steel tanks

2.2.1 General

a) The scantling of tanks whose dimensions are outside the range covered by the following provisions will be given special consideration.

b) The scantling of the tanks is to be calculated assuming a minimum height h of the overflow or air pipe above the top of the tank of:

- 3,60 m for fuel oil having a flash point below 60°C,
- 2,40 m otherwise.

c) All tanks having plating elements of a length exceeding 2,5 m are to be fitted with stiffeners.

2.2.2 Thickness of plating

The thickness of the plates is not to be less than the value given in Tab 1 for the various values of l, L/l and H. However, for tanks having a volume of more than 1 m^3, the thickness of the plates is not to be less than 5 mm.

2.2.3 Scantlings of stiffeners

a) This requirement applies only to stiffeners which are all vertical or all horizontal and attached according to the types shown in Fig 2. Other cases will be given special consideration.

b) The minimum values of the ratio w/b required for stiffeners are given in:

- Tab 2 for vertical stiffeners
- Tab 3 for horizontal stiffeners

for the different types of attachments shown in Fig 2.

Table 1 : Thickness of plating (mm)

l (m)	L / l	H (m)													
		2,4 - 2,7	2,7 - 3,0	3,0 - 3,3	3,3 - 3,6	3,6 - 4,0	4,0 - 4,4	4,4 - 4,8	4,8 - 5,2	5,2 - 5,8	5,8 - 6,4	6,4 - 7,0	7,0 - 8,0	8,0 - 9,0	9,0 - 10,0
0,40	< 2	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5
	≥ 2	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5
0,45	< 2	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0
	≥ 2	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	6,0	6,0
0,50	< 2	3,0	3,0	3,5	3,5	3,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
	≥ 2	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
0,55	< 2	3,5	3,5	3,5	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0
	≥ 2	4,0	4,5	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0	7,5
0,60	< 2	3,5	4,0	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5
	≥ 2	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0
0,65	< 2	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0
	≥ 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,5	8,5
0,70	< 2	4,0	4,0	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,5
	≥ 2	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	–
0,75	< 2	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0
	≥ 2	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	–	–
0,80	< 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,0	6,5	7,0	7,0	7,5	8,0	8,5
	≥ 2	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	–	–	–
0,85	< 2	5,0	5,0	5,5	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0
	≥ 2	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,0	8,5	9,0	–	–	–	–
0,90	< 2	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	–
	≥ 2	6,5	6,5	7,0	7,0	7,5	8,0	8,5	8,5	9,0	–	–	–	–	–
0,95	< 2	5,5	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	–	–
	≥ 2	6,5	7,0	7,0	7,5	8,0	8,5	9,0	9,0	–	–	–	–	–	–
1,00	< 2	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	–	–	–
	≥ 2	7,0	7,5	7,5	8,0	8,5	8,5	9,0	–	–	–	–	–	–	–

Figure 2 : Type of stiffener end attachments

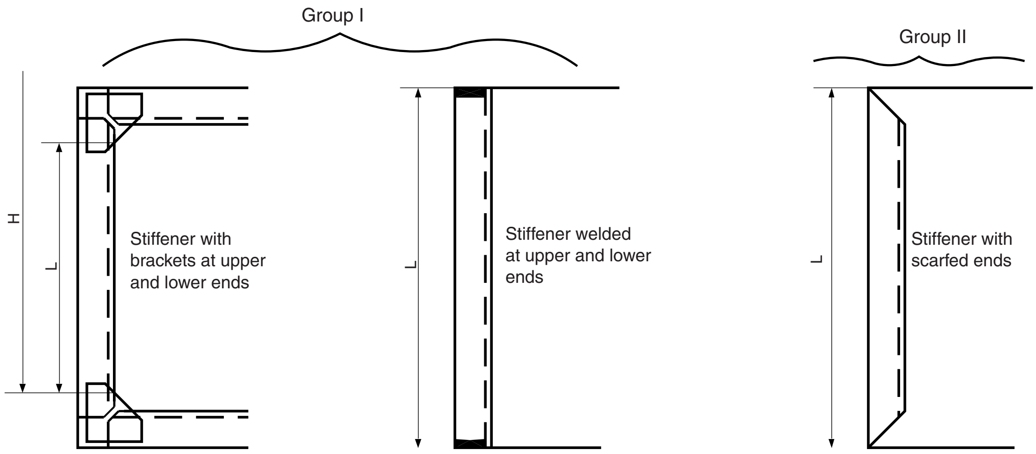


Table 2 : Values of w/b ratio for vertical stiffeners (cm³/m)

L (m)	end attachment	H, in m **(1)**												
		3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I	5,0	5,5	6,0	6,5	7,5	8,0	9,0	9,5	10,5	11,5	14,0	16,0	18,0
	II	8,0	9,0	10,0	11,0	12,0	12,5	13,0	15,0	16,0	19,0	22,0	25,0	28,0
0,8	I	8,5	9,5	10,5	11,5	13,0	14,0	15,0	16,5	18,0	22,0	25,0	28,0	31,5
	II	13,0	15,0	16,0	18,0	20,0	21,5	24,0	25,5	28,5	34,0	38,0	43,0	48,0
1,0	I		14,5	16,0	17,5	19,5	21,0	23,0	26,0	28,5	34,0	38,0	43,0	49,0
	II		22,0	24,0	27,0	30,0	32,5	36,0	39,0	43,0	51,0	58,0	67,0	75,0
1,2	I			22,5	24,5	28,0	30,0	33,0	37,0	40,5	48,0	55,0	63,0	71,0
	II			34,0	30,7	42,5	46,0	50,0	55,0	61,0	73,0	84,0	96,0	107
1,4	I			30,0	32,5	37,0	40,0	44,0	49,0	55,0	65,0	75,0	85,0	96,0
	II			45,0	49,0	56,0	61,0	67,0	74,0	82,0	98,0	113,0	129,0	144,0
1,6	I				47,0	53,0	57,0	64,0	71,0	79,0	94,0	110,0	125,0	140,0
	II				71,0	80,0	87,0	96,0	107,0	118,0	141,0	165,0	187,0	
1,8	I				58,0	65,0	71,0	79,0	88,0	98,0	117,0	136,0	156,0	175,0
	II				87,0	98,0	107,0	118,0	132,0	147,0	176,0	204,0		
2,0	I					78,0	85,0	95,0	107,0	119,0	142,0	166,0	190,0	
	II					118,0	129,0	142,0	160,0	178,0				
2,2	I						100,0	112,0	126,0	140,0	170,0	198,0		
	II						151,0	168,0	190,0					
2,5	I						124,0	139,0	158,0					
	II						187,0							

(1) H is to be taken equal to the height of the tank top above the lower end of the stiffener, plus h.

2.3 Installation

2.3.1 Securing

Independent tanks are to be securely fixed to hull structures and are to be so arranged as to permit inspection of adjacent structures.

2.3.2 Protection against spillage

Where permitted, independent fuel oil tanks are to be placed in an oil-tight spill tray of ample size with a suitable drain pipe leading to a suitably sized spill oil tank.

Table 3 : Values of w/b ratio for horizontal and top and bottom stiffeners (cm³/m)

L (m)	end attach-ment	H, in m **(1)**															
		2,4	2,6	2,8	3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,5	9,0	10,0	11,0	12,0	13,5	15,0	17,0	19,0
	II	7,0	8,0	8,5	9,0	10,0	11,0	11,5	12,5	13,5	15,0	16,0	17,5	21,0	24,0	27,0	30,0
0,8	I	8,0	9,0	9,5	10,0	11,0	12,0	13,0	14,5	15,5	17,0	18,5	20,0	23,5	27,0	30,0	33,5
	II	13,0	15,0	15,5	16,5	18,0	19,5	21,5	23,5	25,0	27,0	30,0	34,0	38,0	44,0	49,0	55,0
1,0	I	13,0	15,0	15,5	16,5	18,0	19,5	21,5	23,5	25,0	27,0	30,0	34,0	38,0	44,0	49,0	55,0
	II	20,0	22,0	23,5	25,0	28,0	30,0	33,0	36,0	39,0	42,0	46,0	50,0	59,0	67,0	75,0	84,0
1,2	I	18,0	20,0	21,0	22,5	25,0	26,5	29,5	32,5	34,5	37,5	41,5	45,0	52,5	60,0	67,5	75,0
	II	28,0	31,0	33,0	35,0	39,0	42,0	46,0	51,0	54,0	59,0	65,0	70,0	82,0	93,0	105	117
1,4	I	26,0	28,0	30,5	32,5	36,0	39,0	42,5	46,5	50,0	54,5	59,5	65,0	76,0	87,0	97,0	108
	II	39,0	43,0	45,5	49,0	54,0	58,5	63,5	70,0	75,0	81,0	89,0	97,0	113	130	146	162
1,6	I	36,0	39,0	42,0	45,0	50,0	54,0	59,0	65,0	69,0	75,0	82,0	90,0	105	120	135	150
	II	56,0	61,0	66,0	70,0	77,0	84,0	91,0	100	107	117	128	140	163	186		
1,8	I	46,0	50,0	54,0	58,0	63,0	69,0	75,0	82,0	88,0	95,0	105	115	134	153	172	191
	II	70,0	76,0	82,0	88,0	96,0	105	113	125	134	146	160	175	204			
2,0	I	57,0	62,0	67,0	72,0	78,0	85,0	92,0	102	109	118	130	142	166	190		
	II	87,0	95,0	102	109	120	130	141	155	166	181	198					
2,2	I	70,0	76,0	82,0	88,0	96,0	105	113	125	134	145	160	175	204			
	II	107	116	125	134	147	160	174	192	205							
2,5	I	92,0	100	108	115	127	138	150	165	176	191						
	II	140	152	163	175	192											

(1) For horizontal stiffeners, H is to be measured from the horizontal stiffener immediately below the stiffener considered. For top stiffeners, H = h.

Appendix 4 Special Approval of Alloy Steel used for Intermediate Shaft Material

1 General

1.1 Application

1.1.1 This Appendix is applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm², but less than 950 N/mm² intended for use as intermediate shaft material.

1.2 Torsional fatigue test

1.2.1 A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formula of τ_1 in Ch 1, Sec 9, [3.4.2], item b).

The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

Note 1: The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{t(hole)} + 0,8\frac{(l-e)/d}{\sqrt{\left(1-\frac{d_i}{d}\right)\frac{e}{d}}}$$

This formula applies to:

- slots at 120 or 180 or 360 degrees apart
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

where:

l	:	Slot length
e	:	Slot width
d	:	Shaft outside diameter
d_i	:	Shaft inside diameter
$\alpha_{t(hole)}$	:	Stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$\alpha_{t(hole)} = 2,3 - 3\frac{e}{d} + 15\left(\frac{e}{d}\right)^2 + 10\left(\frac{e}{d}\right)^2\left(\frac{d_i}{d}\right)^2$$

or simplified to $\alpha_{t(hole)} = 2,3$

For unnotched specimen, scf = 1

1.2.2 Test conditions

Test conditions are to be in accordance with Tab 1. Mean surface roughness, in µm, is to be less than 0,2 Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011.

Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table 1 : Test condition

Loading type	Torsion
Stress ratio	R = −1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10^7 cycles

1.2.3 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{C2} are to be equal to or greater than the values given by the following formulae:

$$\tau_{C1} \geq \tau_{C,\lambda=0} = \frac{\sigma_B + 160}{6} C_K C_D$$

$$\tau_{C2} \geq 1{,}7 \frac{1}{\sqrt{C_K}} \tau_{C1}$$

where:

C_K : Factor for the particular shaft design features, see Ch 1, Sec 9, Tab 1

C_D : Size factor, see Ch 1, Sec 9, [3.3.2]

σ_B : Specified minimum tensile strength in N/mm² of the shaft material.

1.3 Cleanliness requirements

1.3.1 The steels are to have a degree of cleanliness as shown in Tab 2 when tested according to ISO 4967:2013 method A. Representative samples are to be obtained from each heat of forged or rolled products.

The steels are generally to comply with the minimum requirements of NR216, Ch 5, Sec 2, Tab 1, with particular attention given to minimising the concentrations of sulphur, phosphorus and oxygen in order to achieve the cleanliness requirements. The specific steel composition is required to be approved by the Society.

1.4 Inspection

1.4.1 The ultrasonic testing required by NR216, Ch 5, Sec 1, [10.3.1] is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.

Table 2 : Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
Type A	Fine	1,0
	Thick	1,0
Type B	Fine	1,5
	Thick	1,0
Type C	Fine	1,0
	Thick	1,0
Type D	Fine	1,0
	Thick	1,0
Type DS	–	1,0

Part C
Machinery, Systems and Fire Protection

CHAPTER 2
ELECTRICAL INSTALLATIONS

Section 1	General
Section 2	General Design Requirements
Section 3	System Design
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Section 15	Testing

Section 1 General

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to electrical installations on ships. In particular, they apply to the components of electrical installations for essential services.

The other parts of the installation are to be so designed as not to introduce any malfunction to the ship and hazard to personnel.

1.2 References to other regulations and standards

1.2.1 The Society may refer to other regulations and standards when deemed necessary. These include the IEC publications, notably the IEC 60092 series.

It is to be noted however that, where the prescriptive requirements in the present Rules and such standards are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2.2 When referred to by the Society, publications by the International Electrotechnical Commission (IEC) or other internationally recognized standards, are those currently in force at the date of agreement for ship classification.

2 Documentation to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No	I/A **(1)**	Document
1	A	Single line diagram of main power and lighting systems
2	A	Electrical power balance
3	A	Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kVA (kW)
4	A	List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices
5	A	Single line diagram and detailed diagram of the main switchboard
6	A	Single line diagram and detailed diagram of the emergency switchboards
7	A	Diagram of the most important section boards and motor control centres (above 100 kW)
8	A	Diagram of the supply, monitoring and control systems of propulsion motors and generator prime movers
9	A	Diagram of the supply, monitoring and control systems of the rudder propellers
10	A	Diagram of the supply, monitoring and control systems of controllable pitch propellers
11	A	Diagram of the general emergency alarm system and of the intercommunication systems requested in Ch 4, Sec 8, [1.1.2]
12	A	Detailed diagram of the navigation-light switchboard
13	A	Diagram of the remote stop system (ventilation, fuel pump, fuel valves, etc.)
14	A **(2)**	Selectivity and coordination of the electrical protection
15	A	Single line diagram of electrical propulsion system
16	A	Principles of control system and power supply of electrical propulsion system
17	A	Alarm and monitoring system including, for electrical propulsion system: • list of alarms and monitoring points • power supply diagram.

(1) A = to be submitted for approval ; I = to be submitted for information.
(2) For high voltage installations.
(3) For electric propulsion installations.

No	I/A **(1)**	Document
18	A	Safety system including, for electrical propulsion system: • list of monitored parameters for safety system • power supply diagram.
19	I **(3)**	Arrangements and details of the propulsion control consoles and panels
20	I **(3)**	Arrangements and details of electrical coupling
21	I **(3)**	Arrangements and details of the frequency converters together with the justification of their characteristics
22	I **(3)**	Arrangements of the cooling system provided for the frequency converters and motor enclosure
23	I **(3)**	Measurements of voltage signal form for converters directly connected to high voltage (HV) network
24	I **(3)**	Computation of permanent and transitory voltage drops of LV and HV networks
25	A **(3)**	Test program for converters and rotating machines having rated power > 1 MW, dock and sea trials
(1) A = to be submitted for approval ; I = to be submitted for information. **(2)** For high voltage installations. **(3)** For electric propulsion installations.		

3 Definitions

3.1 General

3.1.1 Unless otherwise stated, the terms used in this Chapter have the definitions laid down by the IEC standards.

The definitions given in the following requirements also apply.

3.2 Essential services

3.2.1 Essential services are defined in Pt A, Ch 1, Sec 1, [1.2.1]. They are subdivided in primary and secondary essential services defined in [3.3] [3.4].

3.3 Primary essential services

3.3.1 Primary essential services are those which need to be maintained in continuous operation.

Primary essential services are services such as:

- steering gear
- actuating systems of controllable pitch propellers
- scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for the propulsion
- forced draught fans, feed water pumps, water circulating pumps, condensate pumps, oil burning installations, for steam plants or steam turbines ship, and also for auxiliary boilers on ship where steam is used for equipment supplying primary essential services
- azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps
- electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
- electric generators and associated power sources supplying the above equipment
- hydraulic pumps supplying the above equipment
- viscosity control equipment for heavy fuel oil
- control, monitoring and safety devices/systems for equipment for primary essential services
- speed regulators dependent on electrical energy for main or auxiliary engines necessary for propulsion
- starting equipment of diesel engines and gas turbines
- at least one fire pump, when required to be permanently in operation.

The main lighting system for those parts of the ship normally accessible to and used by personnel is also considered as a primary essential service.

3.4 Secondary essential services

3.4.1 Secondary essential services are those services which need not necessarily be in continuous operation.

Secondary essential services are services such as:

- windlasses
- fuel oil transfer pumps and fuel oil treatment equipment
- lubrication oil transfer pumps and lubrication oil treatment equipment

- preheaters for heavy fuel oil
- sea water pumps
- starting air and control air compressors
- bilge, ballast and heeling pumps
- fire pumps and other fire-extinguishing medium pumps
- ventilation fans for engine and boiler rooms
- services considered necessary to maintain dangerous cargo in a safe condition
- navigation lights, aids and signals
- internal safety communication equipment
- fire detection and alarm systems
- electrical equipment for watertight closing appliances
- electric generators and associated power supplying the above equipment
- hydraulic pumps supplying the above equipment
- control, monitoring and safety for cargo containment systems
- control, monitoring and safety devices/systems for equipment for secondary essential services
- ammunition elevators
- cooling system of environmentally controlled spaces, see Ch 2, Sec 12, [1.4].

3.5 Services for habitability

3.5.1 Services for habitability are those intended for minimum comfort conditions for people on board, and specially in engine control room, safety room and operation control room.

Examples of equipment for maintaining conditions of habitability:

- cooking
- heating
- domestic refrigeration
- mechanical ventilation
- sanitary and fresh water
- electric generators and associated power sources supplying the above equipment.

3.6 Safety voltage

3.6.1 A voltage which does not exceed 50 V a.c. r.m.s. between conductors, or between any conductor and earth, in a circuit isolated from the supply by means such as a safety isolating transformer.

3.6.2 A voltage which does not exceed 50 V d.c. between conductors or between any conductor and earth in a circuit isolated from higher voltage circuits.

3.7 Low-voltage systems

3.7.1 Alternating current systems with rated voltages greater than 50 V r.m.s. up to 1000 V r.m.s. inclusive and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 50 V up to 1500 V inclusive.

3.8 High-voltage systems

3.8.1 Alternating current systems with rated voltages greater than 1000 V r.m.s. and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 1500 V.

3.9 Basic insulation

3.9.1 Insulation applied to live parts to provide basic protection against electric shock.

Note 1: Basic insulation does not necessarily include insulation used exclusively for functional purposes.

3.10 Supplementary insulation

3.10.1 Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

3.11 Double insulation

3.11.1 Insulation comprising both basic insulation and supplementary insulation.

3.12 Reinforced insulation

3.12.1 A single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation.

Note 1: The term "single insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

3.13 Earthing

3.13.1 The earth connection to the general mass of the hull of the ship in such a manner as will ensure at all times an immediate discharge of electrical energy without danger.

3.14 Normal operational and habitable condition

3.14.1 A condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, pay load, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally.

3.15 Emergency condition

3.15.1 A condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.

3.16 Main source of electrical power

3.16.1 A source intended to supply electrical power to a main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

3.17 Dead ship condition

3.17.1 The condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.

Note 1: Dead ship condition is a condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply are not available.

3.18 Main generating station

3.18.1 The space in which a main source of electrical power is situated.

3.19 Main switchboard

3.19.1 A switchboard which is directly supplied by a main source of electrical power and is intended to distribute electrical energy to the ship's services.

3.20 Emergency switchboard

3.20.1 A switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency electrical power and is intended to distribute electrical energy to the emergency services.

3.21 Emergency source of electrical power

3.21.1 A source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main electrical power supply system.

3.22 Section boards

3.22.1 A switchgear and controlgear assembly which is supplied by another assembly and arranged for the distribution of electrical energy to other section boards or distribution boards.

3.23 Distribution board

3.23.1 A switchgear and controlgear assembly arranged for the distribution of electrical energy to final sub-circuits.

3.24 Final sub-circuit

3.24.1 That portion of a wiring system extending beyond the final required overcurrent protective device of a board.

3.25 Hazardous areas

3.25.1 Areas in which an explosive atmosphere is present, or may be expected to be present due to the presence of vapours, gases, flammable dusts or explosives in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

3.25.2 Hazardous areas are classified in zones based upon the frequency and the duration of the occurrence of explosive atmosphere.

3.25.3 Hazardous areas for explosive gas atmosphere are classified in the following zones:
- zone 0: an area in which an explosive gas atmosphere is present continuously or is present for long periods
- zone 1: an area in which an explosive gas atmosphere is likely to occur in normal operation
- zone 2: an area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur, is likely to do only infrequently and will exist for a short period only.

3.26 High fire risk areas

3.26.1 The high fire risk areas are defined as follows:

a) machinery spaces as defined in Ch 4, Sec 1, [2.21], except spaces having little or no fire risk as defined by category (10) of Ch 4, Sec 5, [1.2.3], item b) 2)

b) spaces containing fuel treatment equipment and other highly flammable substances

c) galleys and pantries containing cooking appliances

d) laundry with drying equipment

e) spaces as defined in Ch 4, Sec 5, [1.2.3], item b) 2), as:
   - (8) accommodation spaces of greater fire risk
   - (12) machinery spaces and main galleys
   - (14) special purpose spaces
   - (15) ammunition spaces or other equivalent spaces

f) enclosed or semi-enclosed hazardous spaces, in which certified safe type electric equipment is required.

3.27 Certified safe-type equipment

3.27.1 Certified safe-type equipment is electrical equipment of a type for which a national or other appropriate authority has carried out the type verifications and tests necessary to certify the safety of the equipment with regard to explosion hazard when used in an explosive gas atmosphere.

3.28 Environmental categories

3.28.1 Electrical equipment is classified into environmental categories according to the temperature range, vibration levels, and resistance to chemically active substances and to humidity.

The designation of the environmental categories is indicated by the EC Code i Tab 2.

The first characteristic numeral indicates the temperature range in which the electrical equipment operates satisfactorily, as specified in Tab 3.

The second characteristic numeral indicates the vibration level in which the electrical equipment operates satisfactorily, as specified in Tab 4.

3.28.2 The tests for verifying the additional and supplementary letters and the characteristic numeral of the environmental categories are defined in Ch 3, Sec 6.

Table 2 : EC Code

Code letter	First characteristic numeral	Second characteristic numeral	Additional letter	Supplementary letter
EC	(numerals 1 to 4)	(numerals 1 to 3)	(letter S) **(1)**	(letter C) **(2)**

(1) The additional letter S indicates the resistance to salt mist (exposed decks, masts) of the electrical equipment.
(2) The supplementary letter C indicates the relative humidity up to 80% (air conditioned areas) in which the electrical equipment operates satisfactorily.

Table 3 : First characteristic numeral

First characteristic numeral	Brief description of location	Temperature range °C	
1	Air conditioned areas	+ 5	+ 40
2	Enclosed spaces	+ 5	+ 45
3	Inside consoles or close to combustion engines and similar	+ 5	+ 55
4	Exposed decks, masts	– 25	+ 45

Table 4 : Second characteristic numeral

Second characteristic numeral	Brief description of location	Frequency r ange Hz	Displacement amplitude (mm)	Acceleration amplitude g
1	Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 –	– 0,7
2	Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 –	– 2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 –	– 4,0

Section 2 General Design Requirements

1 Environmental conditions

1.1 General

1.1.1 The electrical components of installations are to be designed and constructed to operate satisfactorily under the environmental conditions on board.

In particular, the conditions shown in the tables in this Article are to be taken into account.

Note 1: The environmental conditions are characterised by:

- one set of variables including climatic conditions (e.g. ambient air temperature and humidity), biological conditions, conditions dependent upon chemically active substances (e.g. salt mist) or mechanically active substances (e.g. dust or oil), mechanical conditions (e.g. vibrations or inclinations) and conditions dependent upon electromagnetic noise and interference, and
- another set of variables dependent mainly upon location on vessels, operational patterns and transient conditions.

1.2 Ambient air temperatures

1.2.1 For ships classed for unrestricted navigation, the ambient air temperature ranges shown in Tab 1 are applicable in relation to the various locations of installation.

Table 1 : Ambient air temperature

Location	Temperature range (°C)	
Enclosed spaces	+ 5	+ 45
Inside consoles or fitted on combustion engines and similar	+ 5	+ 55
Air conditioned areas	+ 5	+ 40
Exposed decks	– 25	+ 45

1.2.2 For ships classed for service in specific zones, the Society may accept different ranges for the ambient air temperature (e.g. for ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40°C instead of + 45°C).

1.3 Humidity

1.3.1 For ships classed for unrestricted service, the humidity ranges shown in Tab 2 are applicable in relation to the various locations of installation.

Table 2 : Humidity

Location	Humidity
General	95% at 55°C
Air conditioned areas	Different values may be considered on a case by case basis

1.4 Cooling water temperatures

1.4.1 The temperatures shown in Tab 3 are applicable to ships classed for unrestricted service.

Table 3 : Water temperature

Coolant	Temperature range (°C)	
Sea water	0	+ 32

1.4.2 For ships classed for service in specific zones, the Society may accept different values for the cooling water temperature (e.g. for ships operating outside the tropical belt, the maximum cooling water temperature may be assumed as equal to + 25°C instead of + 32°C).

1.5 Salt mist

1.5.1 The applicable salt mist content in the air is to be 1 mg/m^3.

1.6 Inclinations

1.6.1 The inclinations applicable are those shown in Tab 4.

The Society may consider deviations from these angles of inclination taking into consideration the type, size and service conditions of the ships.

1.7 Vibrations

1.7.1 In relation to the location of the electrical components, the vibration levels given in Tab 5 are to be assumed. The necessary damping elements on machinery supports will be fitted to reach this level.

1.7.2 The natural frequencies of the equipment, their suspensions and their supports are to be outside the frequency ranges specified.

Where this is not possible using a suitable constructional technique, the equipment vibrations are to be dumped so as to avoid unacceptable amplifications.

1.8 Shock

1.8.1 When required by the Naval Authority and in general for front line ships, shock levels are to be evaluated.

1.8.2 Electrical components are to be so designed, manufactured and installed that they are capable of operating satisfactorily under shock conditions.

1.8.3 This capability may be achieved through their own characteristics or through particular installation arrangements.

Table 4 : Inclination of ship

Type of machinery, equipment or component	Angles of inclination, in degrees **(1)**			
	Athwartship		Fore-and-aft	
	static	dynamic **(3)**	static	dynamic **(4)**
Machinery and equipment relative to main electrical power installation	15,0	22,5	5,0	7,5
Machinery and equipment relative to the emergency power installation, safety systems of the ship (e.g. emergency source of power, emergency fire pumps, etc.)	22,5	22,5	10,0	10,0
Switchgear and associated electrical and electronic components and remote control systems **(2)**	22,5	22,5	10,0	10,0

(1) Athwartship and fore-and-aft angles may occur simultaneously in their most unfavourable combination.
(2) No undesired switching operations or functional changes may occur up to an angle of inclination of 45°.
(3) The period of dynamic inclination may be assumed equal to 10 s.
(4) The period of dynamic inclination may be assumed equal to 5 s.

Table 5 : Vibration levels

Location	Frequency range (Hz)	Displacement amplitude (mm)	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks	from 2,0 to 13,2 from 13,2 to 100	0,25 –	– 0,2
On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 –	– 4,0
Masts	from 2,0 to 13,2 from 13,2 to 50	1,0 –	– 0,7

Table 6 : Voltage and frequency variations of power supply in a.c.

Parameter	Variations	
	Continuous	Transient
Voltage	+ 6% – 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Note 1: For alternating current components supplied by emergency generating sets, different variations may be considered.

2 Quality of power supply

2.1 General

2.1.1 All electrical components are to be so designed and manufactured that they are capable of operating satisfactorily under the variations of voltage, frequency and harmonic distortion of the power supply specified from [2.2] to [2.4].

2.2 A.c. distribution systems

2.2.1 For alternating current components the voltage and frequency variations of power supply shown in Tab 6 are to be assumed.

2.3 D.c. distribution systems

2.3.1 For direct current components voltage variations of power supply shown in Tab 7 are to be assumed.

Table 7 : Voltage variations of power supply in d.c.

Parameters	Variations
Voltage tolerance (continuous)	± 10%
Voltage cyclic variation	5%
Voltage ripple (a.c. r.m.s. over steady d.c. voltage)	10%

2.3.2 For direct current components supplied by electrical battery the following voltage variations are to be assumed:

- + 30% to – 25% for components connected to the battery during charging (see Note 1)
- + 20% to – 25% for components not connected to the battery during charging.

Note 1: Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.

2.4 Harmonic distortions

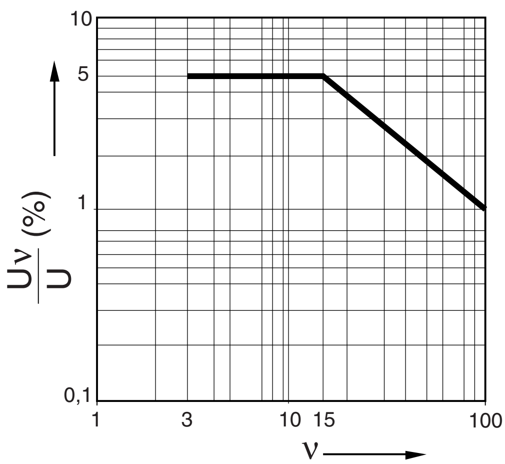
2.4.1 For components intended for systems without substantially static converter loads and supplied by synchronous generators, it is assumed that the total voltage harmonic distortion does not exceed 5%, and the single harmonic does not exceed 3% of the nominal voltage.

2.4.2 For components intended for systems fed by static converters, and/or systems in which the static converter load predominates, it is assumed that:

- the single harmonics do not exceed 5% of the nominal voltage up to the 15th harmonic of the nominal frequency, decreasing to 1% at the 100th harmonic (see Fig 1), and that
- the total harmonic distortion does not exceed 8%.

2.4.3 Higher values for the harmonic content (e.g. in electric propulsion plant systems) may be accepted on the basis of correct operation of all electrical devices.

Figure 1 :



3 Electromagnetic susceptibility

3.1

3.1.1 For electronic type components such as sensors, alarm panels, automatic and remote control equipment, protective devices and speed regulators, the conducted and radiated disturbance levels to be assumed are those given in Part C, Chapter 3.

Note 1: See also IEC Publication 60533 - “Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units”.

4 Materials

4.1 General

4.1.1 In general, and unless it is adequately protected, all electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant materials which are not subject to deterioration in the atmosphere and at the temperatures to which they are likely to be exposed. Particular consideration is to be given to sea air and oil vapour contamination.

Note 1: The flame-retardant and moisture-resistant characteristics may be verified by means of the tests cited in IEC Publication 60092-101 or in other recognised standards.

4.1.2 Where the use of incombustible materials or lining with such materials is required, the incombustibility characteristics may be verified by means of the test cited in IEC Publication 60092-101 or in other recognized standards.

4.2 Insulating materials for windings

4.2.1 Insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect insulants against such agents.

4.2.2 The insulation classes given in Tab 8 may be used in accordance with IEC Publication 60085.

Table 8 : Insulation Classes

Class	Maximum continuous operating temperature (°C)
A	105
E	120
B	130
F	155
H	180

4.3 Insulating materials for cables

4.3.1 See Ch 2, Sec 9, [1.3].

5 Construction

5.1 General

5.1.1 All electrical apparatus is to be so constructed as not to cause injury when handled or touched in the normal manner.

5.1.2 The design of electrical equipment is to allow accessibility to each part that needs inspection or adjustment, also taking into account its arrangement on board.

5.1.3 Enclosures are to be of adequate mechanical strength and rigidity.

5.1.4 Enclosures for electrical equipment are generally to be of metal; other materials may be accepted for accessories such as connection boxes, socket-outlets, switches and luminaires. Other exemptions for enclosures or parts of enclosures not made of metal will be specially considered by the Society.

5.1.5 Cable entrance are not to impair the degree of protection of the relevant enclosure (see Ch 2, Sec 3, Tab 3).

5.1.6 All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

5.1.7 All equipment is generally to be provided with suitable, fixed terminal connectors in an accessible position for convenient connection of the external cables.

5.2 Degree of protection of enclosures

5.2.1 Electrical equipment is to be protected against the ingress of foreign bodies and water.

The minimum required degree of protection, in relation to the place of installation, is generally that specified in Ch 2, Sec 3, Tab 3.

5.2.2 The degrees of protection are to be in accordance with:

- IEC Publication No. 60529 for equipment in general
- IEC Publication No. 60034-5 for rotating machines.

5.2.3 For cable entries see [5.1.5].

6 Protection against explosion hazard

6.1 Protection against explosive gas or vapour atmosphere hazard

6.1.1 Electrical equipment intended for use in areas where explosive gas or vapour atmospheres may occur, is to be of a "safe type" suitable for the relevant flammable atmosphere and for shipboard use.

6.1.2 The following “certified safe type” equipment is considered:

- intrinsically-safe: Ex(ia) - Ex(ib)
- flameproof: Ex(d)
- increased safety: Ex(e)
- pressurised enclosure: Ex(p)
- encapsulated: Ex(m)
- sand filled: Ex(q)
- special protection: Ex(s)
- oil-immersed apparatus (see Note 1): Ex(o)

Note 1: Only when required by the application.

6.1.3 Other equipment complying with types of protection other than those in [6.1.2] may be considered by the Society, such as:

- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules
- electrical apparatus specifically designed and certified by the appropriate authority for use in Zone 0 or specially tested for Zone 2 (e.g. type “n” protection)
- equipment the type of which ensures the absence of sparks and arcs and of “hot spots” during its normal operation
- pressurised equipment
- equipment having an enclosure filled with a liquid dielectric, or encapsulated.

6.2 Protection against combustible dust hazard

6.2.1 Electrical appliances intended for use in areas where a combustible dust hazard may be present are to be arranged with enclosures having a degree of protection and maximum surface temperature suitable for the dust to which they may be exposed.

Note 1: Where the characteristics of the dust are unknown, the appliances are to have a degree of protection IP6X. For most dusts a maximum surface temperature of 135°C is considered adequate.

Section 3 System Design

1 Supply systems and characteristics of the supply

1.1 Supply systems

1.1.1 The following distribution systems may be used:

a) on d.c. installations:
- two-wire insulated
- two-wire with one pole earthed

b) on a.c. installations:
- three-phase three-wire with neutral insulated
- three-phase three-wire neutral directly earthed or through impedance
- three-phase four-wire neutral directly earthed or through impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed.

1.1.2 The hull return system of distribution is not to be used.

1.1.3 The requirement of [1.1.2] does not preclude under conditions approved by the Society the use of:

a) impressed current cathodic protective systems

b) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

1.1.4 For the supply systems in HV installations, see Ch 2, Sec 13.

1.1.5 When required by the Naval Authority, for the supply of weapon system and shore supply, the STANAG standard 1008 NAV is to be applied. Mainly, the distribution systems to be of the three phase three wires with neutral insulated.

1.2 Maximum voltages

1.2.1 The maximum voltages for both alternating current and direct current low-voltage systems of supply for the ship's services are given in Tab 1.

Table 1 : Maximum voltages for various ship services

Use		Maximum voltage V
For permanently installed and connected to fixed wiring	Power equipment Cooking equipment Lighting Space heaters in accommodation spaces Control **(1)**, communication (including signal lamps) and instrumentation equipment	1000 500 250 250 250
For permanently installed and connected by flexible cable	Power and heating equipment, where such connection is necessary because of the application (e.g. for moveable cranes or other hoisting gear)	1000
For socket-outlets supplying	Portable appliances which are not hand-held during operation (e.g. refrigerated containers) by flexible cables Portable appliances and other consumers by flexible cables Equipment requiring extra precaution against electric shock where an isolating transformer is used to supply one appliance **(2)(3)** Equipment requiring extra precaution against electric shock with or without a safety transformer **(2)(3)**	1000 250 250 50

(1) For control equipment which is part of a power and heating installation (e.g. pressure or temperature switches for starting/stopping motors), the same maximum voltage as allowed for the power and heating equipment may be used provided that all components are constructed for such voltage. However, the control voltage to external equipment is not to exceed 500 V.
(2) Both conductors in such systems are to be insulated from earth.
(3) Equipment located in narrow and wet spaces such as machinery spaces provided with bilge spaces.

1.2.2 Voltages exceeding those shown will be specially considered in the case of specific systems.

1.2.3 For high voltage systems see Ch 2, Sec 13.

2 Sources of electrical power

2.1 General

2.1.1 Electrical installations are to be such that:

a) All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be assured without recourse to the emergency source of electrical power

b) Electrical services essential for safety will be assured under various emergency conditions

c) When a.c. generators are involved, attention is to be given to the starting of squirrel-cage motors connected to the system, or other pay load consumers having pulse loads, particularly with regard to the effect of the magnitude and duration of the transient voltage change produced due to the maximum starting or pulse currents and the power factor. The voltage drop due to such currents is not to cause any motor already operating to stall or have any adverse effect on other equipment in use.

2.2 Main source of electrical power

2.2.1 A main source of electrical power is to be provided, of sufficient capability to supply all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions without recourse to the emergency source of electrical power.

2.2.2 For vessels propelled by electrical power and having two or more constant voltage propulsion generating sets which constitute the source of electrical energy for the ship’s auxiliary services, see Ch 2, Sec 14.

2.2.3 When only one main source of electrical power is provided, it is to consist of at least two generating sets.

The capacity of the main generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions.

Such capacity is, in addition, to be sufficient to start the largest motor and to supply pay-load consumers having pulse loads without causing any other motor to stop or having any adverse effect on other equipment in operation.

2.2.4 For the purpose of calculating the necessary capacity, it is essential to consider which consumers can be expected to be in use simultaneously, in the various operational conditions of the ship.

For a duplicated service, one being supplied electrically and the other non-electrically (see Note 1) (e.g. driven by the main engine), the electrical capacity is not included in the above calculation.

Note 1: It is assumed that the consumers not electrically driven are capable to operate satisfactorily in all conditions.

2.2.5 The services in [2.2.4] do not include:

- thrusters not forming part of the main propulsion or dynamic positioning system
- refrigerators for air conditioning other than air refrigerator systems for satisfactory operation of essential services.

2.2.6 Further to the provisions above, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a "dead ship" condition.

2.2.7 The arrangement of the ship's main sources of electrical power shall be such that essential services can be maintained regardless of the speed and direction of rotation of the main propulsion machinery or shafting.

2.2.8 Generators driven by the propulsion plant (shaft generators) which are intended to operate at constant speed (e.g. a system where vessel speed and direction are controlled by varying propeller speed) may be accepted as forming part of the main source of electrical power if, in all sailing and manoeuvring conditions, and including the propeller being stopped, the capacity of these generators is sufficient to provide the electrical power to comply with [2.2.3] and all further requirements, especially those of [2.2.6]. They are to be not less effective and reliable than the independent generating sets.

2.2.9 Shaft generator installations which do not comply with the provisions of [2.2.8] may be used as additional sources of electrical power with respect to the power balance provided that:

a) in the event of a loss of power from the shaft generator(s), e.g. due to a sudden stopping of the propulsion plant, a standby generating set is started automatically

b) the capacity of the standby set is sufficient for the loads necessary for propulsion and safety of the vessel

c) the time required to restore these services is not longer than 45 s.

2.2.10 Where transformers, converters or similar appliances constitute an essential part of the electrical supply system, the system is to be so arranged as to ensure the same continuity of supply as stated in this sub-article.

This may be achieved by arranging at least two three-phase or three single-phase transformers so that with any one transformer not in operation, the remaining transformer(s) is (are) sufficient to ensure the supply to the services stated in [2.2.3].

Each transformer required is to be located as a separate unit with separate enclosure or equivalent.

Where single phase transformers are used, only one spare element is required for each different type of transformer if special precautions are taken to rapidly replace the faulty one.

2.2.11 For ships having qualified automation systems, see Part E, Chapter 4.

2.2.12 For starting arrangements for main generating sets, see Ch 1, Sec 2, [3.1].

2.2.13 Generators and generator systems, having the ship propulsion machinery as their prime mover but not forming part of the ship main source of electrical power, may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that:

a) there are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by [2.2.1]

b) arrangements are fitted to automatically start one or more of the generators, constituting the main source of electrical power required by [2.2.1], upon the frequency variations exceeding 10% of the limits specified below

c) within the declared operating range of the generators and/or generator systems the specified limits for the voltage variations and the frequency variations in Ch 2, Sec 2 can be met

d) the short circuit current of the generator and/or generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system

e) where considered appropriate, load shedding arrangements are to be fitted

f) on ships having remote control of the ship's propulsion machinery from the navigating bridge, means are provided, or procedures be in place, so as to ensure that supplies to essential services are maintained during manoeuvring conditions in order to avoid a blackout situation.

2.3 Emergency source of electrical power

2.3.1 A self-contained emergency source of electrical power shall be provided, except where:

a) The main sources of electrical power are located in two or more compartments that are not contiguous with each other and separated in such a way to ensure the supply to the emergency services also in case of flooding of the maximum number of contiguous compartments according to stability regulation (see Part B), and

b) Each source has its own independent self contained systems, including power distribution and control systems such that a fire in any one of the compartments or other casualty including the flooding of the maximum number of contiguous compartments according to stability regulation as above, will not affect the power distribution from the other main sources, or to the services required by [3.5.3], and

c) There is at least one generating set complying with the requirements from [2.3.4] to [2.3.14] and of sufficient capacity to meet the requirements of [3.5.3] in at least two non-contiguous (as prescribed above) compartments, and

d) The generator sets referred to in item c) and their self contained systems are installed such that one of them remains operable after damage or flooding in any one compartment.

2.3.2 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

Exceptionally is understood to mean conditions, while the vessel is at sea, such as:

a) blackout situation

b) dead ship situation

c) routine use for testing

d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless otherwise instructed by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of [2.4] are complied with.

2.3.3 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

2.3.4 The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in [3.5.3] for the period specified, if they depend upon an electrical source for their operation.

2.3.5 The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services for the time stated in [3.5.6], if they depend upon an electrical source for their operation.

2.3.6 An indicator shall be mounted in a suitable place, in a continuously manned control position (e.g. platform control room), to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

2.3.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor convertors, means are to be provided for supplying such services also in the event of failure of the convertors (e.g. providing a bypass feeder or a duplication of convertors).

2.3.8 Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator or the other means stored starting energy is not to be directly used for starting the propulsion plant.

For steam ships, the 30 minute time limit given can be interpreted as time from blackout/dead ship condition defined above to light-off the first boiler.

2.3.9 Provision shall be made for the periodic testing of the complete emergency system and shall include the testing of automatic starting arrangements, where provided.

2.3.10 For starting arrangements for emergency generating sets, see Ch 1, Sec 2, [3.1].

2.3.11 The emergency source of electrical power may be either a generator or an accumulator battery which shall comply with the requirements of [2.3.12] or [2.3.13], respectively.

2.3.12 Where the emergency source of electrical power is a generator, it shall be:

a) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C

b) started automatically upon failure of the electrical supply to the emergency switchboard from the main source of electrical power and shall be automatically connected to the emergency switchboard; those services referred to in [3.5.6] shall then be transferred automatically to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s, and

c) provided with a transitional source of emergency electrical power according to [2.3.14].

2.3.13 Where here the emergency source of electrical power is an accumulator battery, it shall be capable of:

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage

b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power, and

c) immediately supplying at least those services specified in [3.5.6].

2.3.14 The transitional source of emergency electrical power required by [2.3.12] c) shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the services in [3.5.6] if they depend upon an electrical source for their operation.

2.4 Use of emergency generator in port

2.4.1 To prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation.

2.4.2 The prime mover is to be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as requested for the prime mover for main power generation and for unattended operation.

2.4.3 The fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in [3.5].

2.4.4 The prime mover is to be designed and built for continuous operation and should be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.

2.4.5 Fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed.

2.4.6 Means are to be provided to readily change over to emergency operation.

2.4.7 Control, monitoring and supply circuits for the purpose of the use of the emergency generator in port are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services.

When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits.

2.4.8 Instructions are to be provided on board to ensure that, even when the vessel is underway, all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard.

These instructions are also to contain information on the required fuel oil tank level, position of harbour/sea mode switch, if fitted, ventilation openings, etc.

3 Distribution

3.1 Earthed distribution systems

3.1.1 System earthing is to be effected by means independent of any earthing arrangements of the non-current-carrying parts.

3.1.2 Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance or insulation resistance measurements.

3.1.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage wave form of each generator does not exceed 5%.

3.1.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

3.1.5 Where for final sub-circuits it is necessary to locally connect a pole (or phase) of the sub-circuits to earth after the protective devices (e.g. in automation systems or to avoid electromagnetic disturbances), provision (e.g. d.c./d.c. convertors or transformers) is to be made such that current unbalances do not occur in the individual poles or phases.

3.1.6 For high voltage systems see Ch 2, Sec 13.

3.2 Insulated distribution systems

3.2.1 Every insulated distribution system, whether primary or secondary (see Note 1), for power, heating or lighting, shall be provided with a device capable of continuously monitoring the insulation level to earth (i.e. the values of electrical insulation to earth) and of giving an audible and visual indication of abnormally low insulation values (see Ch 2, Sec 15).

Note 1: A primary system is one supplied directly by generators. Secondary systems are those supplied by transformers or convertors.

3.2.2 For high voltage systems see Ch 2, Sec 13.

3.3 General requirements for distribution systems

3.3.1 The distribution system is to be such that the failure of any single circuit will not endanger or impair essential services.

3.3.2 No common switchgear (e.g. contactors for emergency stop) is to be used between the switchboard's bus-bars and two duplicated essential services.

3.3.3 The system shall be so arranged that the electrical supply will be maintained or immediately restored in the case of loss of any one of the generators in service. Automatic restart of equipment necessary for propulsion and steering and to ensure safety of the ship is also to be provided.

3.3.4 Arrangements are to be provided to prevent overloading of the generating set(s) supplying the electrical power that is/are required to maintain the ship in a normal operational and habitable condition.

On loss of electrical power, arrangements are to be made for a standby generator set to be automatically started, automatically connected to the switchboard within 30 seconds after loss of power, and essential services restarted in as short a time as is practicable.

These load restart functions may be achieved by the actions of suitably trained personnel but in ships with **AUT-QAS**, **AUT-IAS** notations the arrangements are to be automatic.

Where prime movers with longer starting time are used, this starting and connection time may be exceeded upon approval from the Society.

3.3.5 Automatic load shedding or other equivalent arrangements are to be provided to protect the generators against sustained over-load.

3.3.6 The non-essential services, service for habitable conditions may be shed to ensure the connected generator set or generator sets are not overloaded.

3.4 Main distribution of electrical power

3.4.1 Where more than one main generator is connected to a main switchboard, the main bus-bar is to be divided into at least two parts which are normally to be connected by circuit breakers or other approved means such as circuit breakers without tripping mechanisms or disconnecting switches by means of which bus-bars can be split safely and easily.

The connection of generating sets, associated auxiliaries and other duplicated equipment is to be equally divided between the parts as far as practicable, so that in the event of damage to one section of the switchboard the remaining parts are still supplied.

The same applies in case of main switchboards supplied by one generating set and connected to another main switchboard, being this connection considered as a connection of a second generator.

3.4.2 Two or more units serving the same consumer (e.g. main and standby lubricating oil pumps) are to be supplied by individual separate circuits without the use of common feeders, protective devices or control circuits. This requirement is satisfied when such units are supplied by separate cables from the a main switchboard or from two independent section boards.

3.4.3 A main electric lighting system, which is to provide illumination throughout those parts of the ship normally accessible to and used by personnel, is to be supplied from the main sources of electrical power.

3.5 Emergency distribution of electrical power

3.5.1 The emergency switchboard shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.5.2 In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.

3.5.3 The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 3 hours, emergency lighting at every muster and embarkation station and over the sides;

b) for a period of 18 hours, emergency lighting unless, when an electrical distribution by zones is adopted, alternative arrangements are provided by movable lamps having their own dedicated accumulator batteries for at least 3 hours operation that in normal condition are continuously charged:

   1) in all service and accommodation alleyways, stair-ways and exits, personnel lift cars and personnel lift trunks

   2) in the machinery spaces and main generating stations including their control positions

   3) in all control stations including platform control room and combat system control rooms, machinery control rooms, and at each main and emergency switchboard

   4) at all stowage positions for firemen’s outfits

   5) at the steering gear, and

   6) at the fire pump referred to in e) below, at the sprinkler pump, if any, at the emergency bilge pump, if any, and at the starting positions of their motors

c) for a period of 18 hours:

   1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force and/or by the Naval Authority

   2) the radio installation and external communication systems required by SOLAS and or by the Naval Authority

d) for a period of 18 hours:

   1) all internal communication equipment as required in an emergency [3.5.4]

   2) the shipborne navigational equipment as required by SOLAS and or by the Naval Authority, including those for flight assistance

   3) the fire detection and fire alarm systems, and

   4) intermittent operation of the daylight signalling lamp, the ship’s whistle, the manually operated call points and all internal signals (see [3.5.5]) that are required in an emergency, unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency

e) for a period of 18 hours:
   1) One or more of the fire pumps listed in Ch 4, Sec 6, [1.3] allowing to face a fire in any machinery space
   2) the automatic sprinkler pump, if any, and
   3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves
f) for the period of time required in Ch 1, Sec 12, the steering gear where it is required to be so supplied
g) for a period of half an hour, any watertight doors required to be power operated together with their indicators and warning signals
h) equipment necessary for ship's self defence or a selection of apparatus of the pay load to be defined case by case by the Naval Authority.

3.5.4 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment
b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled
c) the means of communication for fire fighting and damage control
d) the means of communication for combat system operation
e) the public address system.

3.5.5 Internal signals required in an emergency generally include:

a) general alarm
b) watertight door alarm and indication system.

3.5.6 The transitional source of emergency electrical power shall supply for half an hour at least the following services if they depend upon an electrical source for their operation:

a) the lighting required by [3.5.3], items a), b) and c)1), for this transitional phase, the required emergency electric lighting, in respect of the machinery space and the accommodation and service spaces may be provided by individual, automatically charged, relay operated accumulator lamps, and
b) all services required by [3.5.3], items d) 1), d) 3) and d) 4) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

It is also to supply power to close the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided and powers the control, indication and alarm circuits, for half an hour.

3.6 Shore/Ship supply

3.6.1 Arrangements are to be made for supplying the electrical installation from a source on shore or elsewhere. At least a suitable connection box is to be installed on the ship in a convenient location to receive the flexible cable from outside.

3.6.2 Permanently fixed cables of adequate rating are to be provided for connecting the box to the main distribution system.

3.6.3 Where necessary for systems with earthed neutrals, the box is to be provided with an earthed terminal for connection between the shore's/ship's and ship's neutrals or for connection of a protective conductor.

3.6.4 The connection box is to contain a circuit-breaker or a switch-disconnector and fuses.

The shore connection is to be protected against short-circuit and overload; however, the overload protection may be omitted in the connection box if provided on the main switchboard.

3.6.5 Means are to be provided for checking the phase sequence of the incoming supply in relation to the ship's system.

3.6.6 The cable connection to the box is to be provided with at least one switch-disconnector on the main switch-board.

3.6.7 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

3.6.8 At the connection box a notice is to be provided giving full information on the nominal voltage and frequency of the installation.

3.6.9 The switch-disconnector on the main switchboard is to be interlocked with the main generator circuit-breakers in order to prevent its closure when any generator is supplying the main switchboard.

3.6.10 Adequate means are to be provided to equalize the potential between the hull and the shore when the electrical installation of the ship is supplied from shore.

3.7 Supply of motors

3.7.1 A separate final sub-circuit is to be provided for every motor required for an essential service (and for every motor rated at 1 kW or more).

3.7.2 Each motor is to be provided with controlgear ensuring its satisfactory starting.

Depending on the capacity of the generating plant or the cable network, it may be necessary to limit the starting current to an acceptable value.

Direct on line starters are accepted if the voltage drop does not exceed 15% of the network voltage.

3.7.3 Efficient means are to be provided for the isolation of the motor and its associated control gear from all live poles of the supply.

Where the control gear is mounted on or adjacent to a switchboard, a disconnecting switch in the switchboard may be used for this purpose.

Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.

3.7.4 Where the starter or any other apparatus for disconnecting the motor is remote from the motor itself, one of the following is to be arranged:

a) provision for locking the circuit disconnecting switch in the OFF position

b) an additional disconnecting switch fitted near the motor

c) provision such that the fuses in each live pole or phase can be readily removed and retained by persons authorized to have access to the motor.

3.8 Specific requirements for special power services

3.8.1 For the supply and characteristics of the distribution of the following services see the requirements listed:

- steering gear: Ch 1, Sec 12
- fire-extinguishing and detecting systems: Ch 4, Sec 13
- permanently installed submerged bilge pump: [9.7]
- ventilation fans: Ch 4, Sec 2, [2.1.2]
- fuel pumps: Ch 1, Sec 10
- pumps discharging overboard above the lightest waterline and in way of the area of lifeboat and liferaft launching: Ch 1, Sec 10, [5.2.4].

3.8.2 All power circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch out-side the space for disconnecting such circuits.

3.9 Power supply to heaters

3.9.1 Each heater rated more than 16 A is to be connected to a separate final circuit.

3.10 Power supply to lighting installations

3.10.1 Final sub-circuits for lighting supplying more than one lighting point and socket outlets are to be fitted with protective devices having a current rating not exceeding 16 A.

3.10.2 Final sub-circuits for socket-outlets are to be fitted with protective devices having a current rating not exceeding 10 A.

3.11 Special lighting services

3.11.1 In spaces such as:

- main and large machinery spaces
- large galleys
- passageways
- stairways leading to boat-decks
- public spaces
- operation control room.

there is to be more than one final sub-circuit for lighting such that failure of any one circuit does not reduce the lighting to an insufficient level.

3.11.2 Where the emergency installation is required, one of the circuits in [3.11.1] may be supplied from the emergency source of power.

3.11.3 All lighting circuits terminating in a bunker or dry holds are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.11.4 A vessel is to be designed so as, at night, without fog or rain, when observed 500 meters away from a vessel:
- no light is to be seen with bare eye
- direct or indirect lighted surface is not to be more visible than the non lighted hull surface.

In addition, when observed 500 meters away from a aircraft, in the same condition as above:
- no light is to be seen with bare eye
- all lighted surface is not to be more visible than the lighted deck
- no part of the sea surface in the vicinity of the hull is to be more lighted than the hull.

3.11.5 A red lighting is to be provided in the following locations:
- all alleyways leading to outside spaces, and used for personnel on duty
- all rooms and acces leading directly to the outside spaces without airlock
- all airlocks for external access.

The red lighting is to be maximum 2 Lux on the floor in passageway and 5 lux where reading is necessary.

3.12 Navigation and signalling lights

3.12.1 Navigation and signalling lights are to be connected separately to a distribution board specially reserved for this purpose.

3.12.2 The distribution board in [3.12.1] is to be supplied from two alternative circuits, one from the main source of power and one from the emergency source of power; see also [3.5].

The transfer of supply is to be practicable from the bridge, for example by means of a switch.

3.12.3 Each navigation light is to be controlled and protected in each insulated pole by a double-pole switch and a fuse or, alternatively, by a double-pole circuit-breaker, fitted on the distribution board referred to in [3.12.1].

3.12.4 Where there are double navigation lights, i.e. lights with two lamps or where for every navigation light a spare is also fitted, the connections to such lights may run in a single cable provided that means are foreseen in the distribution board to ensure that only one lamp or light may be supplied at any one time.

3.12.5 Each navigation light is to be provided with an automatic indicator giving audible and/or visual warning in the event of failure of the light. If an audible device alone is fitted, it is to be connected to a separate source of supply from that of the navigation lights, for example an accumulator (storage) battery.

If a visual signal is used connected in series with the navigation light, means are to be provided to prevent the extinction of the navigation light due to the failure of the visual signal.

A minimum level of visibility is to be assured in the case of use of dimmer devices on the signalling panel. On request of the Naval Authority, dimmering of navigation and signalling lights may be accepted.

3.13 General emergency alarm system

3.13.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal, is to comply with the requirements of this sub-article. General emergency alarm systems installed on ships having the service notation **aircraft carrier** are also to comply with the requirements of Pt D, Ch 2, Sec 4, [4.1].

3.13.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.14] or other suitable means of communication.

3.13.3 Entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.13.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.13.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.3] and [3.5].

3.13.6 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle, also from other strategic points

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a platform control room should normally be regarded as strategic points.

3.13.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.13.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces during normal operational condition.

3.13.9 For cables used for the general emergency alarm system, see [9.6].

3.14 Public address system

3.14.1 The public address system is to be a loudspeaker installation enabling the broadcast of messages into all spaces where people on board are normally present.

If not feasible, adequate additional visual indication is to be provided to indicate that a message is being broadcasted.

3.14.2 Where the public address system is used to supplement the general emergency alarm system as per [3.13.2], it is to be continuously powered from the emergency source of electrical power required by [2.3] and [3.5].

3.14.3 The system is to allow for the broadcast of messages from the navigation bridge and from other strategic points as above.

3.14.4 The system is not to require any action from the addressee.

3.14.5 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

3.15 Combined general emergency alarm - public address system

3.15.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.13] and [3.14], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required
- the system is arranged to prevent feedback or other interference
- the system is arranged to minimize the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the case of failure of any one circuit or component, by means of the use of:
  - multiple amplifiers
  - segregated cable routes to public rooms, alleyways, stairways and control stations
  - more than one device for generating electronic sound signal
  - electrical protection for individual loudspeakers against short-circuits.

3.16 Control and indication circuits

3.16.1 For the supply of automation systems, including control, alarm and safety system, see the requirements of Part C, Chapter 3.

3.16.2 Control and indicating circuits relative to essential services are to be branched off from the main circuit in which the relevant equipment is installed. Equivalent arrangements may be accepted by the Society.

3.16.3 Control and indicating circuits relative to non-essential services may be supplied by distribution systems reserved for the purpose to the satisfaction of the Society.

3.17 Power supply to the speed control systems of main propulsion engines

3.17.1 Electrically operated speed control systems of main engines are to be fed from the main source of electrical power.

3.17.2 Where more than one main propulsion engine is foreseen, each speed control system is to be provided with an individual supply by means of separate wiring from the main switchboard or from two independent section boards.

Being the main busbars divided into two sections, the governors are, as far as practicable, to be supplied equally from the two sections.

3.17.3 In the case of propulsion engines which do not depend for their operation on electrical power, i.e. pumps driven from the main engine, the speed control systems are to be fed both from the main source of electrical power and from an accumulator battery for at least 15 minutes or from a similar supply source.

Such battery may also be used for other services such as automation systems, where foreseen.

3.18 Power supply to the speed control systems of generator sets

3.18.1 Each electrically operated control and/or speed control system of generator sets is to be provided with a separate supply from a main source of electric power and from an accumulator battery for at least 15 minutes or from a similar supply source.

3.18.2 The wiring supplying a main source of electrical power is to be from the main switchboard or from independent section boards.

Being the main busbars divided into two sections, the governors are, as far as practicable, to be supplied from the sections to which the relevant generators are connected.

3.19 Harmonic distortion for ship electrical distribution system including harmonics filters

3.19.1 Where harmonic filters are installed on main busbars of electrical distribution system, other than those installed for single application frequency drives such as pump motors, the ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar. The crew is to be alerted when the level of harmonic distortion exceed the acceptable limits.

3.19.2 Where the electrical distribution system on board a ship includes harmonic filters the system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced.

3.19.3 The system integrator of the distribution system is to provide the Society, for information, with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters.

3.19.4 Arrangements are to be provided to alert the crew in the event of activation of the protection of a harmonic filter circuit.

3.19.5 A harmonic filter is to be arranged as a three phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter.

3.19.6 A current unbalance detection system, independent of the overcurrent protection, is to be provided in order to alert the crew in case of current unbalance.

3.19.7 Additional protection for the individual capacitor element as e.g. relief valve or overpressure disconnector in order to protect against damage from rupturing may be considered, depending on the type of capacitors used.

4 Degrees of protection of the enclosures

4.1 General

4.1.1 The minimum required degree of protection for electrical equipment, in relation to the place of installation, is generally that specified in Tab 2.

The degree of protection of control panels intended for specific equipment and of consoles is to be at least IP 20 and evaluated case by case by the Society with the agreement of the Naval Authority.

4.1.2 In addition to the requirements of this paragraph, equipment installed in spaces with an explosion hazard is also subject to the provisions of Ch 2, Sec 2, [6].

4.1.3 The enclosures of electrical equipment for the monitoring and control of watertight doors which are situated below the bulkhead deck are to provide suitable protection against the ingress of water.

In particular, the minimum required degree of protection is to be:

- IPX7 for electric motors, associated circuits and control components
- IPX8 for door position indicators and associated circuit components
- IPX6 for door movement warning signals.

Note 1: The water pressure testing of the enclosures protected to IPX8 is to be based on the pressure that may occur at the location of the component during flooding for a period of 18 hours.

4.1.4 Equipment supplied at nominal voltages in excess of 500 V and accessible to non-authorized personnel (e.g. equipment not located in machinery spaces or in locked compartments under the responsibility of the ship's officers) is to have a degree of protection against touching live parts of at least IP 4X.

Table 2 : Minimum required degrees of protection

Condition in location	Example of location	Switchboard, control gear, motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outlets	Accessories (e.g. switches, connection boxes)
Danger of touching live parts only	Dry accommodation spaces, dry control rooms	IP 20	X**(1)**	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20
Danger of dripping liquid and/or moderate mechanical damage	Control rooms, wheel-house, radio room	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22
	Engine and boiler rooms above floor	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Steering gear rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Emergency machinery rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	General storerooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 22	IP 44
	Pantries	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Provision rooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Ventilation ducts	X	X	IP 22	X	X	X	X	X	X
Increased danger of liquid and/or mechanical damage	Bathrooms and/or showers	X	X	X	X	IP 34	IP 44	X	IP 55	IP 55
	Engine and boiler rooms below floor	X	X	IP 44	X	IP 34	IP 44	X	X	IP 55
	Closed fuel oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
	Closed lubricating oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
Increased danger of liquid and mechanical damage	Ballast pump rooms	IP 44	X	IP 44 **(2)**	IP 44**(2)**	IP 34	IP 44	X	IP 55	IP 55
	Refrigerated rooms	X	X	IP 44	X	IP 34	IP 44	X	IP 55	IP 55
	Galleys and laundries	IP 44	X	IP 44	IP 44	IP 34	IP 44	IP 44	IP 44	IP 44
	Public bathrooms and shower	X	X	IP 44	IP 44	IP 34	IP 44	X	IP 44	IP 44
Danger of liquid spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	Shaft or pipe tunnels in double bottom	IP 55	X	IP 55	IP 55	IP 55	IP 55	X	IP 56	IP 56
	Holds for general cargo	X	X	IP 55	X	IP 55	IP 55	X	IP 56	IP 56
	Ventilation trunks	X	X	IP 55	X	X	X	X	X	X
Danger of liquid in massive quantities	Open decks	IP 56	X	IP 56	X	IP 55	IP 56	X	IP 56	IP 56

(1) The symbol “X” denotes equipment which it is not advised to install.
(2) Electric motors and starting transformers for lateral thrust propellers located in spaces similar to ballast pump rooms may have degree of protection IP 22.

4.2 Installation of electrical and electronic equipment in engine rooms protected by fixed water-based local application fire-fighting systems (FWBLAFFS)

4.2.1 Unless it is essential for safety or operational purposes, electrical and electronic equipment is not to be located within areas protected by FWBLAFFS and in adjacent areas where water may extend.

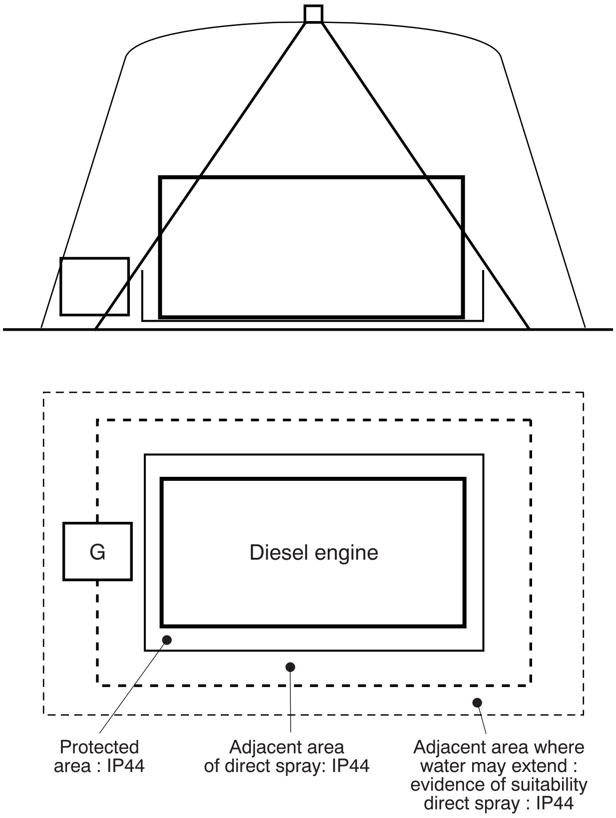
The electrical and electronic equipment located within areas protected by FWBLAFFS and those within adjacent exposed to direct spray are to have a degree of protection not less than IP44.

Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, filters, baffles, etc. to prevent or restrict the ingress mist/spray into the equipment. The cooling airflow for the equipment is to be assured.

Note 1: Definitions (see Fig 1):

- protected space: machinery space where a FWBLAFFS is installed
- protected areas: areas within a protected space which is required to be protected by FWBLAFFS
- adjacent areas:
  - areas other those protected areas, exposed
  - areas other those defined above, where water may extend.

Figure 1 : Definitions of areas



Note 2: Additional precautions may be required to be taken in respect of:

- tracking as the result of water entering the equipment
- potential damage as the result of residual salts from sea water systems
- high voltage installations
- personnel protection against electric shock.

Equipment may require maintenance after being subjected to water mist/spray.

5 Diversity (demand) factors

5.1 General

5.1.1 The cables and protective devices of final sub-circuits are to be rated in accordance with their connected load.

5.1.2 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justifiable, to the application of a diversity (demand) factor.

5.1.3 A diversity (demand) factor may be applied provided that the known or anticipated operating conditions in a particular part of an installation are suitable for the application of diversity.

6 Environmental categories of the equipment

6.1 Environmental categories

6.1.1 The environmental categories of the electrical equipment, in relation to the place of installation, are generally to be those specified in Tab 3.

Table 3 : Required environmental categories

Main areas on board	Location within main area: General	Inside cubicles, desks, etc.	On machinery such as internal combustion engines, compressors	Masts
Machinery spaces	EC21	EC31	EC23	X **(1)**
Steering gear	EC23	EC33	X	X
Control room, Accommodation, bridge	EC21 EC11C	EC31	X	X
Pump room, holds, rooms with no heating	EC41	X	X	X
Exposed Decks	EC41S	X	X	EC42S
(1) The symbol “X” denotes locations which are generally not applicable.				

7 Electrical protection

7.1 General requirements for overcurrent protection

7.1.1 Electrical installations are to be protected against accidental overcurrents including short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure as far as possible:

- continuity of service in the event of a fault, through coordinated and discriminative action of the protective devices, up to the second level of the main switchboard
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

7.1.2 Devices provided for overcurrent protection are to be chosen according to the requirements, especially with regard to overload and shortcircuit.

Note 1: Overload is an operating condition in an electrically undamaged circuit which causes an overcurrent.

7.1.3 Systems are to be such as to withstand the thermal and electrodynamic stresses caused by the possible overcurrent, including short-circuit, for the admissible duration.

7.2 Short-circuit currents

7.2.1 In calculating the maximum prospective short-circuit current, the source of current is to include the maximum number of generators which can be simultaneously connected (as far as permitted by any interlocking arrangements), and the maximum number of motors which are normally simultaneously connected in the system.

The maximum number of generators or transformers is to be evaluated without taking into consideration short-term parallel operation (e.g. for load transfer) provided that suitable interlock is foreseen.

7.2.2 Short-circuit current calculations are to be performed in accordance with a method recognized by the Society, such as that given in IEC Publication 60363.

7.2.3 In the absence of precise data concerning the characteristics of generators, accumulator batteries and motors, the maximum short-circuit currents on the main bus-bars may be calculated as follows:

- for alternating current systems:

  $I_{ac} = 10\ I_{TG} + 3{,}5\ I_{TM}$

  $I_{pk} = 2{,}4\ I_{ac}$

- for direct current systems supplied by batteries:

  $I_p = K\ C_{10} + 6\ I_{TM}$

where:

I_p : Maximum short-circuit current

I_{ac} : r.m.s. value of the symmetrical component (at the instant T/2)

I_{pk} : Maximum peak value

I_{TG} : Rated current of all generators which can be connected simultaneously

C_{10} : Battery capacity in Ah for a discharge duration of 10 hours

K : Ratio of the short-circuit current of the batteries to C_{10} (see Note 1)

I_{TM} : Rated current of all motors which are normally simultaneously connected in the system.

Note 1: For stationary batteries the following values may be assumed for guidance:

- vented lead-acid batteries: K = 8
- vented alkaline type batteries intended for discharge at low rates corresponding to a battery duration exceeding three hours: K = 15
- sealed lead-acid batteries having a capacity of 100 Ah or more or alkaline type batteries intended for discharge at high rates corresponding to a battery duration not exceeding three hours: K = 30.

7.3 Selection of equipment

7.3.1 Circuit-breakers of withdrawable type are required where they are not suitable for isolation and on main and emergency switchboards.

7.3.2 Equipment is to be chosen on the basis of its rated current and its making/breaking capacity.

7.3.3 In the selection of circuit-breakers with intentional short-time delay for short-circuit release, those of utilization category B are to be used and they are to be selected also taking into account their rated short-time withstand current capacity (I_{cw}).

For circuit-breakers without intentional short-time delay for short-circuit release, circuit breakers of utilization category A may be used and they are to be selected according to their rated service short-circuit breaking capacity (I_{cs}).

Note 1: For the purpose of these Rules, utilization categories A and B are defined as follows:

- Utilization category A: circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions
- Utilization category B: circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable) provided for selectivity under short-circuit conditions.

7.3.4 For non-essential services and duplicated essential services, circuit-breakers may be selected according to their ultimate short-circuit breaking capacity (I_{cu}).

7.3.5 For switches, the making/breaking capacity is to be in accordance with utilization category AC-22 A or DC-22 A (in compliance with IEC Publication 60947-3).

7.3.6 For fuse-switch disconnectors or switch-disconnector fuse units, the making/breaking capacity is to be in accordance with utilization categories AC-23 A or DC-23 A (in compliance with IEC Publication 60947-3).

7.4 Protection against short-circuit

7.4.1 Protection against short-circuit currents is to be provided by circuit- breakers or fuses.

7.4.2 The rated short-circuit breaking capacity of every protective device is to be not less than the maximum prospective value of the short-circuit current at the point of installation at the instant of contact separation.

7.4.3 The rated short-circuit making capacity of every mechanical switching device intended to be capable of being closed on short-circuit is to be not less than the maximum value of the short-circuit current at the point of installation.

On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

7.4.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current liable to occur at the point of installation having regard to the time required for the short-circuit to be removed.

7.4.5 The use of a protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point where it is installed is not permitted in general.

Nevertheless, this solution may be accepted upon agreement of the Naval Authority, and provided that the following are complied with:

- the protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point is backed up on the generator side by a fuse or by a circuit-breaker having at least the necessary short-circuit rating and not being the generator circuit-breaker
- the same fuse or circuit-breaker is not to back up more than one circuit-breaker, except for circuits relevant to non essential services
- the short-circuit performance of the back-up arrangement is to be equal to the requirements of IEC Publication 60947-2 for a single circuit-breaker having the same short-circuit performance category as the backed-up circuit-breaker and rated for the maximum prospective short-circuit level at the supply terminals of the arrangement.

7.4.6 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuses and the circuit-breakers are of coordinated design, in order to ensure that the operation of the fuses takes place in due time so as to prevent arcing between poles or against metal parts of the circuit-breakers when they are submitted to overcurrents involving the operation of the fuse.

7.4.7 When determining the performance requirements for the above-mentioned back-up protection arrangement, it is permissible to take into account the impedance of the various circuit elements of the arrangement, such as the impedance of a cable connection when the backed-up circuit-breaker is located away from the back-up breaker or fuse.

7.5 Continuity of supply and continuity of service

7.5.1 Selectivity is to be ensured as far as practicable.

7.5.2 The protection is to be so arranged that the circuit under failure is the only one isolated from the network and a fault in one service does not cause the loss of any other essential services.

7.5.3 Selectivity is not strictly required for groups of consumers when the failure of one of them jeopardizes the operation of the whole system to which it belongs.

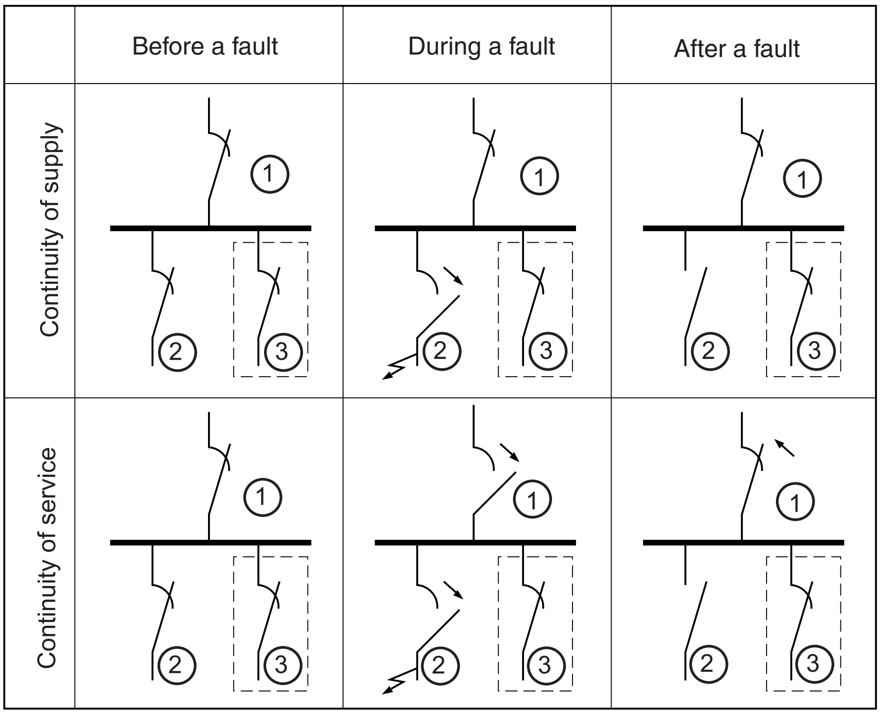
7.5.4 The protection of the emergency circuit is to be such that a failure in one circuit does not cause a loss of other emergency services.

7.6 Protection against overload

7.6.1 Devices provided for overload protection are to have a tripping characteristic (overcurrent-trip time) adequate for the overload ability of the elements of the system to be protected and for any discrimination requirements.

7.6.2 The use of fuses up to 320 A for overload protection is permitted.

Figure 2 :



7.7 Localization of over-current protection

7.7.1 Short-circuit protection is to be provided for every non-earthed conductor.

7.7.2 Overload protection is to be provided for every non-earthed conductor; nevertheless, in insulated single-phase circuits or insulated three-phase circuits having substantially balanced loads, the overload protection may be omitted on one conductor.

7.7.3 Short-circuit and overload protective devices are not to interrupt earthed conductors, except in the case of multiple disconnection devices which simultaneously interrupt all the conductors, whether earthed or not.

7.7.4 Electrical protection is to be located as close as possible to the origin of the protected circuit.

7.8 Protection of generators

7.8.1 Generators are to be protected against short-circuits and overloads by multipole circuit-breakers.

7.8.2 Where a circuit-breaker is used:

a) the overload protection is to trip the generator circuit-breaker at an overload between 10% and 50%; for an overload of 50% of the rated current of the generator the time delay is not to exceed 2 minutes; however, the figure of 50% or the time delay of 2 minutes may be exceeded if the construction of the generator permits this

b) the setting of the short-circuit protection is to instantaneously trip the generator circuit-breaker at an overcurrent less than the steady short-circuit current of the generator. Short time delays (e.g. from 0,5 s to 1 s) may be introduced for discrimination requirements in "instantaneous" tripping devices.

7.8.3 For emergency generators the overload protection may, instead of disconnecting the generator automatically, give a visual and audible alarm in a permanently attended space.

7.8.4 After disconnection of a generator due to overload, the circuit-breaker is to be ready for immediate reclosure.

7.8.5 Generator circuit-breakers are to be provided with a reclosing inhibitor which prevents their automatic reclosure after tripping due to a short-circuit.

7.8.6 Generators having a capacity of 1500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit-breaker, will de-excite the generator and open the circuit-breaker (e.g. by means of differential protection).

7.8.7 Where the main source of electrical power is necessary for the propulsion of the ship, load shedding or other equivalent arrangements are to be provided to protect the generators against sustained overload.

7.8.8 Arrangements are to be made to disconnect or reduce automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed and/or voltage (see Ch 3, Sec 2, Tab 6). The operation of such device is to activate a visual and audible alarm. A time delay of 5-20 s is considered acceptable.

7.8.9 When an overload is detected the load shedding system is to disconnect automatically, after an appropriate time delay, the circuits supplying the non-essential services and, if necessary, services for maintaining normal habitable conditions.

7.8.10 Alternating current generators arranged to operate in parallel are to be provided with reverse-power protection.

The protection is to be selected in accordance with the characteristics of the prime mover.

The following values are recommended:

- 2-6% of the rated power for turbogenerators
- 8-15% of the rated power for diesel generators.

The reverse-power protection may be replaced by other devices ensuring adequate protection of the prime movers.

7.8.11 Generators are to be provided with an undervoltage protection which trips the breaker if the voltage falls to 70% - 35% of the rated voltage.

For generators arranged for parallel operation, measures are to be taken to prevent the generator breaker from closing if the generator is not generating and to prevent the generator remaining connected to the busbars if voltage collapses.

The operation of the undervoltage release is to be instantaneous when preventing closure of the breaker, but it is to be delayed for selectivity purposes when tripping the breaker.

7.9 Protection of circuits

7.9.1 Each separate circuit shall be protected against short-circuit and against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.

7.9.2 Each circuit is to be protected by a multipole circuit-breaker or switch and fuses against overloads and short-circuits.

7.9.3 Circuits for lighting are to be disconnected on both non-earthed conductors; single-pole disconnection of final sub-circuits with both poles insulated is permitted only in accommodation spaces.

7.9.4 The protective devices of the circuits supplying motors are to allow excess current to pass during transient starting of motors.

7.9.5 Final sub-circuits which supply one consumer with its own overload protection (for example motors), may be provided with short-circuit protection only.

7.9.6 Steering gear control circuits are to be provided with short-circuit protection only (see Ch 1, Sec 12).

7.10 Protection of motors

7.10.1 Motors of rating exceeding 1 kW and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection may be provided by the same protective device for the motor and its supply cable (see [7.9.5]).

7.10.2 For motors intended for essential services, the overload protection may be replaced by an overload alarm (for steering gear motors see Ch 1, Sec 12).

7.10.3 The protective devices are to be designed so as to allow excess current to pass during the normal accelerating period of motors according to the conditions corresponding to normal use.

If the current/time characteristic of the overload protection device does not correspond to the starting conditions of a motor (e.g. for motors with extra-long starting period), provision may be made to suppress operation of the device during the acceleration period on condition that the short-circuit protection remains operational and the suppression of overload protection is only temporary.

7.10.4 For continuous duty motors the protective gear is to have a time delay characteristic which ensures reliable thermal protection against overload.

7.10.5 The protective devices are to be adjusted so as to limit the maximum continuous current to a value within the range 105% - 120% of the motor's rated full load current.

7.10.6 For intermittent duty motors the current setting and the delay (as a function of time) of the protective devices are to be chosen in relation to the actual service conditions of the motor.

7.10.7 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

7.10.8 Motors rated above 1 kW are to be provided with:

- undervoltage protection, activated by the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted or
- undervoltage release, activated by the reduction or failure of voltage, so arranged that the motor restarts automatically when power is restored after a power failure.

7.10.9 The automatic restart of a motor is not to produce a starting current such as to cause excessive voltage drop.

In the case of several motors required to restart automatically, the total starting current is not to cause an excessive voltage drop or sudden surge current; to this end, it may be necessary to achieve a sequence start.

7.10.10 The undervoltage protective devices are to allow the motor to be started when the voltage exceeds 85% of the rated voltage and are to intervene without fail when the voltage drops to less than approximately 20% of the rated voltage, at the rated frequency and with a time delay as necessary.

7.11 Protection of storage batteries

7.11.1 Batteries are to be protected against overload and short-circuit by means of fuses or multipole circuit-breakers at a position adjacent to the battery compartment.

Overcurrent protection may be omitted for the circuit to the starter motors when the current drawn is so large that is impracticable to obtain short-circuit protection.

7.11.2 Emergency batteries supplying essential services are to have short-circuit protection only.

7.12 Protection of shore power connection

7.12.1 Permanently fixed cables connecting the shore connection box to the main switchboard are to be protected by fuses or circuit-breakers (see [3.6]).

7.13 Protection of measuring instruments, pilot lamps and control circuits

7.13.1 Measuring circuits and devices (voltage transformers, voltmeters, voltage coils of measuring instruments, insulation monitoring devices etc.) and pilot lamps are to be protected against short-circuit by means of multipole circuit-breakers or fuses.

The protective devices are to be placed as near as possible to the tapping from the supply.

The secondary side of current transformers is not to be protected.

7.13.2 Control circuits and control transformers are to be protected against overload and short-circuit by means of multipole circuit-breakers or fuses on each pole not connected to earth.

Overload protection may be omitted for transformers with a rated current of less than 2 A on the secondary side.

The short-circuit protection on the secondary side may be omitted if the transformer is designed to sustain permanent short-circuit current.

7.13.3 Where a fault in a pilot lamp would impair the operation of essential services, such lamps are to be protected separately from other circuits such as control circuits.

Note 1: Pilot lamps connected via short-circuit-proof transformers may be protected in common with control circuits.

7.13.4 Circuits whose failure could endanger operation, such as steering gear control feeder circuits, are to be protected only against short-circuit.

7.13.5 The protection is to be adequate for the minimum cross-section of the protected circuits.

7.14 Protection of transformers

7.14.1 The primary winding side of power transformers is to be protected against short-circuit and overload by means of multipole circuit -breakers or switches and fuses.

7.14.2 The protection against short-circuit is to be such as to ensure the selectivity between the circuits supplied by the secondary side of the transformer and the feeder circuit of the transformer.

7.14.3 When transformers are arranged to operate in parallel, means are to be provided so as to trip the switch on the secondary winding side when the corresponding switch on the primary side is open.

8 System components

8.1 General

8.1.1 The components of the electrical system are to be dimensioned such as to withstand the currents that can pass through them during normal service without their rating being exceeded.

8.1.2 The components of the electrical system are to be designed and constructed so as to withstand for the admissible duration the thermal and electro-dynamic stresses caused by possible overcurrents, including short-circuit.

9 Electrical cables

9.1 General

9.1.1 All electrical cables and wiring external to equipment shall be at least of a flame-retardant type, in accordance with IEC Publication 60332-1 and they have to comply with Ch 2, Sec 9.

9.1.2 In addition to the provisions of [9.1.1], when cables are laid in bundles, cable types are to be chosen in compliance with IEC Publication 60332-3 Category A, or other means (See Ch 3, Sec 12) are to be provided such as not to impair their original flame-retarding properties.

9.1.3 Where necessary for specific applications such as radio frequency or digital communication systems, which require the use of particular types of cables, the Society, with the agreement of the Naval Authority; may permit the use of cables which do not comply with the provisions in [9.1.1] and [9.1.2].

9.1.4 Cables which are required to have fire-resisting characteristics are to comply with the requirements stipulated in IEC Publication 60331.

9.1.5 Cables used onboard are to be of the halogen free type and tested according to IEC 60754-1, IEC 60754-2, 61034-1 and 61034-2.

Halogen cables may be accepted if they do not exceed 10% of the total cables passing in the room.

Table 4 : Maximum rated conductor temperature

Type of insulating compound	Abbreviated designation	Maximum rated conductor temperature, in °C	
		Normal operation	Short-circuit
a) Thermoplastic: - based upon polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate	PVC/A	60	150
b) Elastomeric or thermosetting:			
- based upon ethylene-propylene rubber or similar (EPM or EPDM)	EPR	85	250
- based upon high modulus or hardgrade ethylene propylene rubber	HEPR	85	250
- based upon cross-linked polyethylene	XLPE	85	250
- based upon rubber silicon	S 95	95	350
- based upon ethylene-propylene rubber or similar (EPM or EPDM) halogen free	HF EPR	85	250
- based upon high modulus or hardgrade halogen free ethylene propylene rubber	HF HEPR	85	250
- based upon cross-linked polyethylene halogen free	HF XLPE	85	250
- based upon rubber silicon halogen free	HF S 95	95	350
- based upon cross-linked polyolefin material for halogen free cable **(1)**	HF 85	85	250
(1) Used on sheathed cable only			

9.2 Choice of insulation

9.2.1 The maximum rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to occur or to be produced in the space where the cable is installed.

9.2.2 The maximum rated conductor temperature for normal and short-circuit operation, for the type of insulating compounds normally used for shipboard cables, is not to exceed the values stated in Tab 4. Special consideration will be given to other insulating materials.

9.2.3 PVC insulated cables are not to be used either in refrigerated spaces, or on decks exposed to the weather of ships classed for unrestricted service.

9.3 Choice of protective covering

9.3.1 The conductor insulating materials are to be enclosed in an impervious sheath of material appropriate to the expected ambient conditions where cables are installed in the following locations:

- on decks exposed to the weather
- in damp or wet spaces (e.g. in bathrooms)
- in refrigerated spaces
- in machinery spaces and, in general
- where condensation water or harmful vapour may be present.

9.3.2 Where cables are provided with armour or metallic braid (e.g. for cables installed in hazardous areas), an overall impervious sheath or other means to protect the metallic elements against corrosion is to be provided.

9.3.3 An impervious sheath is not required for single-core cables installed in tubes or ducts inside accommodation spaces, in circuits with maximum system voltage 250V.

9.3.4 In choosing different types of protective coverings, due consideration is to be given to the mechanical action to which each cable may be subjected during installation and in service.

If the mechanical strength of the protective covering is considered insufficient, the cables are to be mechanically protected (e.g. by an armour or by installation inside pipes or conduits).

9.3.5 Single-core cables for a.c. circuits with rated current exceeding 20 A are to be either non-armoured or armoured with non-magnetic material.

9.4 Cables in refrigerated spaces

9.4.1 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armour is applied on the sheath, the armour is to be protected against corrosion by a further moisture-resisting covering.

9.5 Cables in areas with a risk of explosion

9.5.1 For cables in areas with a risk of explosion, see Article [10].

9.6 Cables in circuits required to be operable under fire condition

9.6.1 Electrical services required to be operable under fire conditions are as follows:

- control and power systems to power-operated fire doors and status indication for all fire doors
- control and power systems to power-operated watertight doors and their status indication
- emergency fire pump
- emergency lighting
- fire and general alarms
- fire detection systems
- fire-extinguishing systems and fire-extinguishing media release alarms
- low location lighting
- public address systems
- remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion.

9.6.2 Where cables for services specified in [9.6.1] including their power supplies pass through high fire risk areas, and through main vertical zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

a) Cables of a fire resistant type complying with Ch 2, Sec 9, [1.1.7] are installed and run continuous to keep the fire integrity within the high fire risk area (see Fig 3)

Note 1: The application of this requirement for public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 or more will be considered on the case-by-case basis.

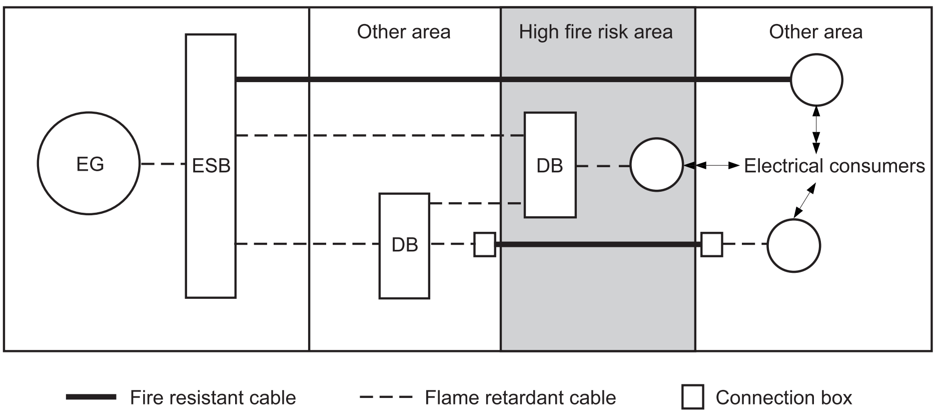
b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

9.6.3 Cables for services required to be operable under fire conditions, including their power supplies, are to be run as directly as is practicable.

9.6.4 Cables connecting fire pumps to the emergency switchboard shall be of a fire-resistant type where they pass through high fire risk areas.

Figure 3 : Routing of cables in high fire risk area



9.7 Cables for submerged bilge pumps

9.7.1 Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cable is to be impervious-sheathed and armoured, is to be installed in continuous lengths from above the bulkhead to the motor terminals and is to enter the air bell from the bottom.

9.8 Internal wiring of switchboards and other enclosures for equipment

9.8.1 For installation in switchboards and other enclosures for equipment, single-core cables may be used without further protection (sheath).

Other types of flame-retardant switchboard wiring may be accepted at the discretion of the Society.

9.9 Current carrying capacity of cables

9.9.1 The current carrying capacity for continuous service of cables given in Tab 5 to Tab 9 is based on the maximum permissible service temperature of the conductor also indicated therein and on an ambient temperature of 45°C.

9.9.2 The current carrying capacity cited in [9.9.1] is applicable, with rough approximation, to all types of protective covering (e.g. both armoured and non-armoured cables).

9.9.3 Values other than those shown in Tab 5 to Tab 9 may be accepted provided they are determined on the basis of calculation methods or experimental values approved by the Society.

9.9.4 When the actual ambient temperature obviously differs from 45°C, the correction factors shown in Tab 10 may be applied to the current carrying capacity in Tab 5 to Tab 9.

9.9.5 Where more than six cables are bunched together in such a way that there is an absence of free air circulating around them, and the cables can be expected to be under full load simultaneously, a correction factor of 0,85 is to be applied.

9.9.6 Where a cable is intended to supply a short-time load for 1/2-hour or 1-hour service (e.g. mooring winches or bow thruster propellers), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the corresponding correction factors given in Tab 11.

In no case a period shorter than 1/2-hour is to be used, whatever the effective period of operation.

9.9.7 For supply cables to single services for intermittent loads (e.g. cargo winches or machinery space cranes), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the correction factors given in Tab 12.

The correction factors are calculated with rough approximation for periods of 10 minutes, of which 4 minutes with a constant load and 6 minutes without load.

9.9.8 The current carrying capacity of cables connected in parallel is the sum of the current ratings of all parallel conductors but the cables must have equal impedance, equal cross-section, equal maximum permissible conductor temperatures and follow substantially identical routing or be installed in close proximity. Connections in parallel are only permitted for cross-sections of 10 mm² or above. When equal impedance can not be assumed, a correction factor of 0,9 is to be applied to the current carrying capacity.

Table 5 : Current carrying capacity, in A in continuous service for cables based on maximum conductor operating temperature of 60°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	10	9	7
2,5	17	14	12
4	23	20	16
6	29	25	20
10	40	34	28
16	54	46	38
25	71	60	50
35	88	75	62
50	110	94	77
70	135	115	95
95	164	139	115
120	189	161	132
150	218	185	153
185	248	211	174
240	292	248	204
300	336	286	235
400	dc: 390 ac: 380	dc: 332 ac: 323	dc: 273 ac: 266
500	dc: 450 ac: 430	dc: 383 ac: 366	dc: 315 ac: 301
630	dc: 520 ac: 470	dc: 442 ac: 400	dc: 364 ac: 329

Table 6 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 85°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	21	18	15
2,5	28	24	20
4	38	32	27
6	49	42	34
10	67	57	47
16	91	77	64
25	120	102	84
35	148	126	104
50	184	156	129
70	228	194	160
95	276	235	193
120	319	271	223
150	367	312	257
185	418	355	293
240	492	418	344
300	565	480	396
400	dc: 650 ac: 630	dc: 553 ac: 536	dc: 455 ac: 441
500	dc: 740 ac: 680	dc: 629 ac: 578	dc: 518 ac: 476
630	dc: 840 ac: 740	dc: 714 ac: 629	dc: 588 ac: 518

Table 7 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 70°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	15	13	11
2,5	21	18	15
4	29	25	20
6	37	31	26
10	51	43	36
16	68	58	48
25	90	77	63
35	111	94	78
50	138	117	97
70	171	145	120
95	207	176	145
120	239	203	167
150	275	234	193
185	313	266	219
240	369	314	258
300	424	360	297
400	dc: 500 ac: 490	dc: 425 ac: 417	dc: 350 ac: 343
500	dc: 580 ac: 550	dc: 493 ac: 468	dc: 406 ac: 385
630	dc: 670 ac: 610	dc: 570 ac: 519	dc: 469 ac: 427

Table 8 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 90°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	23	20	16
2,5	30	26	21
4	40	34	28
6	52	44	36
10	72	61	50
16	96	82	67
25	127	108	89
35	157	133	110
50	196	167	137
70	242	206	169
95	293	249	205
120	339	288	237
150	389	331	272
185	444	377	311
240	522	444	365
300	601	511	421
400	dc: 690 ac: 670	dc: 587 ac: 570	dc: 483 ac: 469
500	dc: 780 ac: 720	dc: 663 ac: 612	dc: 546 ac: 504
630	dc: 890 ac: 780	dc: 757 ac: 663	dc: 623 ac: 546

Table 9 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 95°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	26	22	18
2,5	32	27	22
4	43	37	30
6	55	47	39
10	76	65	53
16	102	87	71
25	135	115	95
35	166	141	116
50	208	177	146
70	256	218	179
95	310	264	217
120	359	305	251
150	412	350	288
185	470	400	329
240	553	470	387
300	636	541	445
400	dc: 760 ac: 725	dc: 646 ac: 616	dc: 532 ac: 508
500	dc: 875 ac: 810	dc: 744 ac: 689	dc: 612 ac: 567
630	dc: 1010 ac: 900	dc: 859 ac: 765	dc: 707 ac: 630

Table 10 : Correction factors for various ambient air temperatures

Maximum conductor temperature, in °C	Correction factors for ambient air temperature of:										
	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C
60	1,29	1,15	1,00	0,82	–	–	–	–	–	–	–
65	1,22	1,12	1,00	0,87	0,71	–	–	–	–	–	–
70	1,18	1,10	1,00	0,89	0,77	0,63	–	–	–	–	–
75	1,15	1,08	1,00	0,91	0,82	0,71	0,58	–	–	–	–
80	1,13	1,07	1,00	0,93	0,85	0,76	0,65	0,53	–	–	–
85	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	–	–
90	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	–
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 11 : Correction factors for short-time loads

½-hour service		1-hour service		Correction factor
Sum of nominal cross-sectional areas of all conductors in the cable, in mm²		Sum of nominal cross-sectional areas of all conductors in the cable, in mm²		
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
up to 20	up to 75	up to 80	up to 230	1,06
21-41	76-125	81-170	231-400	1,10
41-65	126-180	171-250	401-600	1,15
66-95	181-250	251-430	601-800	1,20
96-135	251-320	431-600	–	1,25
136-180	321-400	601-800	–	1,30
181-235	401-500	–	–	1,35
236-285	501-600	–	–	1,40
286-350	–	–	–	1,45

Table 12 : Correction factors for intermittent service

Sum of nominal cross sectional areas of all conductors in the cable, in mm²		Correction factor
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
	$S \leq 5$	1,10
	$5 < S \leq 8$	1,15
	$8 < S \leq 16$	1,20
$S \leq 4$	$16 < S \leq 825$	1,25
$4 < S \leq 7$	$25 < S \leq 42$	1,30
$7 < S \leq 17$	$42 < S \leq 72$	1,35
$17 < S \leq 42$	$72 < S \leq 140$	1,40
$42 < S \leq 110$	$140 < S$	1,45
$110 < S$	–	1,50

Table 13 : Minimum nominal cross-sectional areas

Service	Nominal cross-sectional area	
	external wiring, in mm²	internal wiring, in mm²
Power, heating and lighting systems	1,0	1,0
Control circuits for power plant	1,0	1,0
Control circuits other than those for power plant	0,75	0,5
Control circuits for telecommunications, measurement, alarms	0,5	0,2
Telephone and bell equipment, not required for the safety of the ship or crew calls	0,2	0,1
Bus and data cables	0,2	0,1

9.10 Minimum nominal cross-sectional area of conductors

9.10.1 In general the minimum allowable conductor cross-sectional areas are those given in Tab 13.

9.10.2 The nominal cross-sectional area of the neutral conductor in three-phase distribution systems is to be equal to at least 50% of the cross-sectional area of the phases, unless the latter is less than or equal to 16 mm². In such case the cross-sectional area of the neutral conductor is to be equal to that of the phase.

9.10.3 For the nominal cross-sectional area of:

- earthing conductors, see Ch 2, Sec 12, [2.3]
- earthing connections for distribution systems, see Ch 2, Sec 12, [2.5]
- neutral connections for three-phase systems, see Ch 2, Sec 12, [2.4].

9.11 Choice of cables

9.11.1 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

9.11.2 The nominal cross-sectional area of each cable is to be sufficient to satisfy the following conditions with reference to the maximum anticipated ambient temperature:

- the current carrying capacity is to be not less than the highest continuous load carried by the cable
- the voltage drop in the circuit, by full load on this circuit, is not to exceed the specified limits
- the cross-sectional area calculated on the basis of the above is to be such that the temperature increases which may be caused by overcurrents or starting transients do not damage the insulation.

9.11.3 The highest continuous load carried by a cable is to be calculated on the basis of the power requirements and of the diversity factor of the loads and machines supplied through that cable.

9.11.4 When the conductors are carrying the maximum nominal service current, the voltage drop from the main or emergency switchboard busbars to any point in the installation is not to exceed 6% of the nominal voltage.

For battery circuits with supply voltage less than 55 V, this value may be increased to 10%.

For the circuits of navigation lights, the voltage drop is not to exceed 5% of the rated voltage under normal conditions.

10 Electrical installations in hazardous areas

10.1 Electrical equipment

10.1.1 No electrical equipment is to be installed in hazardous areas unless the Society is satisfied that such equipment is:

- essential for operational purposes
- of a type which will not ignite the mixture concerned
- appropriate to the space concerned, and
- appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

10.1.2 Where electrical equipment of a safe type is permitted in hazardous areas it is to be selected with due consideration to the following:

a) risk of explosive dust concentration; see Ch 2, Sec 2, [6.2]:
   - degree of protection of the enclosure
   - maximum surface temperature

b) risk of explosive gas atmosphere; see Ch 2, Sec 2, [6.1]:
   - explosion group
   - temperature class.

10.1.3 Where electrical equipment is permitted in hazardous areas, all switches and protective devices are to interrupt all poles or phases and, where practicable, to be located in a non-hazardous area unless specifically permitted otherwise.

Such switches and equipment located in hazardous areas are to be suitably labelled for identification purposes.

10.1.4 For electrical equipment installed in Zone 0 hazardous areas, only the following types are permitted:

- certified intrinsically-safe apparatus Ex(ia)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ia” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules
- equipment specifically designed and certified by the appropriate authority for use in Zone 0.

10.1.5 For electrical equipment installed in Zone 1 hazardous areas, only the following types are permitted:

- any type that may be considered for Zone 0
- certified intrinsically-safe apparatus Ex(ib)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ib” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules)
- certified flameproof Ex(d)
- certified pressurized Ex(p)
- certified increased safety Ex(e)
- certified encapsulated Ex(m)
- certified sand filled Ex(q)
- certified specially Ex(s)
- through runs of cable.

10.1.6 For electrical equipment installed in Zone 2 hazardous areas, only the following types are permitted:

- any type that may be considered for Zone 1
- tested specially for Zone 2 (e.g. type “n” protection)
- pressurized, and accepted by the Society in agreement with the Naval Authority
- encapsulated, and accepted by the Society in agreement with the Naval Authority
- the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation (minimum class of protection IP55).

10.1.7 When apparatus incorporates a number of types of protection, it is to be ensured that all are suitable for use in the zone in which it is located.

10.2 Electrical cables

10.2.1 Electrical cables are not to be installed in hazardous areas except as specifically permitted or when associated with intrinsically safe circuits.

10.2.2 All cables installed in Zone 0, Zone 1 or weather exposed areas are to be sheathed with at least one of the following:

a) a non-metallic impervious sheath in combination with braiding or other metallic covering

b) a copper or stainless steel sheath (for mineral insulated cables only).

10.2.3 All cables installed in non-weather exposed Zone 2 areas are to be provided with at least a non-metallic external impervious sheath.

10.2.4 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

10.2.5 The circuits of a category “ib” intrinsically safe system are not to be contained in a cable associated with a category “ia” intrinsically safe system required for a hazardous area in which only category “ia” systems are permitted.

10.3 Electrical installations in battery rooms

10.3.1 Only intrinsically safe equipment and lighting fittings may be installed in compartments assigned solely to large vented storage batteries; see Ch 2, Sec 11, [6.2].

The associated switches are to be installed outside such spaces.

Electric ventilator motors are to be outside ventilation ducts and, if within 3 m of the exhaust end of the duct, they are to be of an explosion-proof safe type. The impeller of the fan is to be of the non-sparking type.

Overcurrent protective devices are to be installed as close as possible to, but outside of, battery rooms.

Electrical cables other than those pertaining to the equipment arranged in battery rooms are not permitted.

10.3.2 Electrical equipment for use in battery rooms is to have minimum explosion group IIC and temperature class T1.

10.3.3 Standard marine electrical equipment may be installed in compartments assigned solely to valve-regulated sealed storage batteries.

10.4 Electrical installations in paint stores

10.4.1 General

Electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services.

Certified safe type equipment of the following type is acceptable:

- certified intrinsically-safe apparatus Ex(i)
- certified flameproof Ex(d)
- certified pressurised Ex(p)
- certified increased safety Ex(e)
- certified specially Ex(s).

In general, cables (through runs or termination cables) of armoured type or installed in metallic conduits are to be used. However, through runs of cables complying with [10.2] are allowed in paint stores.

10.4.2 In the areas on open deck within 1 m of inlet and exhaust ventilation openings of paint stores or within 3 m of exhaust mechanical ventilation outlets of such spaces, the following electrical equipment may be installed:

- electrical equipment with the type of protection as permitted in paint stores
- equipment of protection class Ex(n)
- appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature
- appliances with simplified pressurised enclosures or vapour-proof enclosures (minimum class of protection IP55) whose surface does not reach unacceptably high temperature or
- cables as specified in [10.4.1].

10.4.3 Minimum requirements

The minimum requirements for the certified safe type equipment are as follows:

- explosion group II B
- temperature class T3.

10.4.4 Switches, protective devices and motor control gear of electrical equipment installed in a paint store are to interrupt all poles or phases and are preferably to be located in a non-hazardous space.

10.4.5 Hazardous area classification

a) The paint stores and supply and exhaust ventilation ducts serving such spaces are to be classified as Zone 1, as defined in Ch 2, Sec 1, [3.25].

b) Areas on open deck within 1 m of inlet and exhaust ventilation openings of paint stores or within 3 m of exhaust mechanical ventilation outlets of such spaces are to be classified as Zone 2, as defined in Ch 2, Sec 1, [3.25].

c) Enclosed spaces giving access to paint stores may be considered as non-hazardous, provided that:
   - the door to the paint store is a gastight door with self-closing devices without holding back arrangements. A watertight door may be considered as being gastight.
   - the paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area, and
   - warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids.

10.5 Electrical installations in stores for welding gas (acetylene) bottles

10.5.1 The following equipment may be installed in stores for welding gas bottles provided that it is of a safe type appropriate for Zone 1 area installation:

- lighting fittings
- ventilator motors where provided.

10.5.2 Electrical cables other than those pertaining to the equipment arranged in stores for welding gas bottles are not permitted.

10.5.3 Electrical equipment for use in stores for welding gas bottles is to have minimum explosion group IIC and temperature class T2.

10.6 Ammunition spaces

10.6.1 The following spaces may be considered as hazardous areas according to the specification of the Naval Authority:

- ammunition storage spaces
- ammunition transit/preparation room
- ammunition elevators.

In such a case, the electrical equipment in these spaces are to be certified of a safety type accordingly.

Section 4 Rotating Machines

1 Constructional requirements for generators and motors

1.1 Mechanical construction

1.1.1 Insulating materials, insulated windings and construction of electrical machines are to conform to the relevant requirements of Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.1.2 Shafts are to be made of material complying with the provisions of NR216 Materials and Welding, Chapter 5, Sec 3 or, where rolled products are allowed in place of forgings, with those of NR216 Materials and Welding, Chapter 3, Sec 8.

1.1.3 Where welded parts are foreseen on shafts and rotors, the provisions of NR216 Materials and Welding, Chapter 12 are to apply.

1.1.4 Sleeve bearings are to be efficiently and automatically lubricated at all running speeds.

Provision is to be made for preventing the lubricant from gaining access to windings or other insulated or bare current carrying parts.

1.1.5 Means are to be provided to prevent bearings from being damaged by the flow of currents circulating between them and the shaft. According to the Manufacturer’s requirements, electrical insulation of at least one bearing is to be considered.

1.1.6 For surface-cooled machines with an external fan installed on the open deck, adequate protection of the fan against icing is to be provided.

1.1.7 When liquid cooling is used, the coolers are to be so arranged as to avoid entry of water into the machine, whether by leakage or condensation in the heat exchanger, and provision is to be made for the detection of leakage.

1.1.8 Rotating machines whose ventilation or lubrication system efficiency depends on the direction of rotation are to be provided with a warning plate.

1.1.9 Generator and their excitation system which may be required to sustain overloads (for limited and specified periods of time) are to be designed so as to maintain network electrical characteristics within the prescribed limits.

1.2 Sliprings, commutators and brushes

1.2.1 Sliprings and commutators with their brushgear are to be so constructed that undue arcing is avoided under all normal load conditions.

1.2.2 The working position of brushgear is to be clearly and permanently marked.

1.2.3 Sliprings, commutators and brushgear are to be readily accessible for inspection, repairs and maintenance.

1.3 Terminal connectors

1.3.1 Suitable, fixed terminal connectors are to be provided in an accessible position for connection of the external cables.

1.3.2 All terminal connectors are to be clearly identified with reference to a diagram.

1.4 Electrical insulation

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2, [4.2] and Ch 2, Sec 2, [4.3].

2 Special requirements for generators

2.1 Prime movers, speed governors and overspeed protection

2.1.1 Prime movers for generators are to comply with the relevant requirements of Ch 1, Sec 2, [2.10].

2.1.2 When a.c. generators are to operate in parallel, the characteristics of speed governors are to comply with the provisions of [2.2].

2.2 A.c. generators

2.2.1 Alternators are to be so constructed that, when started up, they take up the voltage without the aid of an external electrical power source.

Where these provisions are not complied with, the external electrical power source is to be constituted by a battery installation in accordance with the requirements for electrical starting systems of auxiliary machinery (see Ch 1, Sec 2).

2.2.2 The voltage wave form is to be approximately sinusoidal, with a maximum deviation from the sinusoidal fundamental curve of 5% of the peak value.

2.2.3 Each alternator is to be provided with automatic means of voltage regulation.

2.2.4 For a.c. generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

2.2.5 For a.c. generating sets intended to operate in parallel, means are to be provided to regulate the governor so as to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.2.6 When a.c. generators are operated in parallel, the reactive loads of the individual generating sets are not to differ from their proportionate share of the total reactive load by more than 10% of the rated reactive power of the largest machine, or 25% of that of the smallest machine, whichever is the lesser.

2.3 Approval of generating gensets

2.3.1 A generating set is considered as a whole system including:

- a prime mover engine and its auxiliaries (for fuel oil, turbo compressor, lubricating oil, cooling circuits...)
- an alternator, and its auxiliaries, if any (lubricating and cooling system...)
- engine control system, speed governor and associated sensors
- an automatic voltage regulator
- a coupling system
- cabling.

2.3.2 Components are to be type approved. Case-by-case approvals may be admitted at the discretion of the Society.

2.3.3 Documentation for system assembly is to be provided:

- list of components
- general electrical diagram
- coupling system
- Torsional Vibration Calculation, when required in Ch 1, Sec 9, [1.1].

3 Testing of rotating machines

3.1 General

3.1.1 All machines are to be tested by the Manufacturer

3.1.2 Manufacturer's test records are to be provided for machines for essential services, for other machines they are to be available upon request.

3.1.3 All tests are to be carried out according to IEC Publication 60092-301.

3.1.4 All machines of 50 kW and over, intended for essential services are to be surveyed by the Society during testing and, if appropriate, during manufacturing.

3.2 Shaft material

3.2.1 Shaft material for electric propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by the Society.

3.2.2 Shaft material for other machines is to be in accordance with recognized international or national standards (see [1.1.2]).

3.3 Tests

3.3.1 Type tests are to be carried out on a prototype machine or on the first of a batch of machines, and routine tests carried out on subsequent machines in accordance with Tab 1.

Table 1 : Tests to be carried out on electrical rotating machines

No.	Tests	a.c. generators		Motors	
		Type test**(1)**	Routine test**(2)**	Type test**(1)**	Routine test**(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection	X	X	X	X
2	Insulation resistance measurement	X	X	X	X
3	Winding resistance measurement	X	X	X	X
4	Verification of the voltage regulation system	X	X**(3)**		
5	Rated load test and temperature rise measurement	X		X	
6	Overload/overcurrent test	X	X	X	X**(4)**
7	Verification of steady short-circuit conditions**(5)**	X			
8	Overspeed test	X	X	X**(6)**	X**(6)**
9	Dielectric strength test	X	X	X	X
10	No load test	X	X	X	X
11	Verification of degree of protection	X		X	
12	Verification of bearings	X	X	X	X

(1) Type tests on prototype machine or tests on at least the first of a batch of machines.
(2) The report on routinely tested machines is to contain the Manufacturer's serial number of the machine which has been type tested and the test result.
(3) Only functional test of voltage regulator system.
(4) Only applicable for machine of essential services rated above 50 kW/kVA.
(5) Verification of steady short circuit condition applies to synchronous generators only.
(6) Not applicable for squirrel cage motors.

4 Description of the test

4.1 Examination of the technical documentation, as appropriate, and visual inspection

4.1.1 Examination of the technical documentation

Technical documentation of machines rated at 50 kW (kVA) and over is to be available for examination by the Surveyor.

4.1.2 Visual inspection

A visual examination of the machine is to be made to ensure, as far as is practicable, that it complies with the technical documentation.

4.2 Insulation resistance measurement

4.2.1 Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester between:

a) all current carrying parts connected together and earth,

b) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Tab 2. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

4.3 Winding resistance measurement

4.3.1 The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

Table 2 : Minimum insulation resistance

Rated voltage U_n, in V	Minimum test voltage, in V	Minimum insulation resistance, in MΩ
$U_n = 250$	$2\ U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$U_n / 1000 + 1$
$7200 < U_n \leq 15000$	5000	$U_n / 1000 + 1$

4.4 Verification of the voltage regulation system

4.4.1 The alternating current generator, together with its voltage regulation system, is to be verified in such a way that, at all loads from no load running to full load, the rated voltage at the rated power factor is maintained under steady conditions within ± 2.5%. These limits may be increased to ± 3.5% for emergency sets.

4.4.2 When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is not to fall below 85% nor exceed 120% of the rated voltage

4.4.3 The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage for the main generator sets in not more than 1.5 s. For emergency sets, these values may be increased to plus or minus 4% in not more than 5 s.

4.4.4 In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60% of the rated current with a power factor of between 0.4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady - state conditions have been reached.

4.5 Rated load test and temperature rise measurements

4.5.1 The temperature rises are to be measured at the rated output, voltage and frequency and for the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests.

The limits of temperature rise are those specified in Table 6 of IEC Publication 60034-1 adjusted as necessary for the ambient reference temperatures specified in Ch 2, Sec 2.

4.6 Overload/overcurrent tests

4.6.1 Overload test is to be carried out as a type test for generators as proof of overload capability of generators and the excitation system, for motors as proof of momentary excess torque as required in IEC Publication 60034-1. The overload test can be replaced at a routine test by an overcurrent test. The overcurrent test is to be proof of the current capability of the windings, wires, connections etc. of each machine. The overcurrent test can be performed at reduced speed (motors) or at short-circuit (generators).

4.6.2 In the case of machines for special uses (e.g. for windlasses), overload values other than the above may be considered.

4.7 Verification of steady short-circuit conditions

4.7.1 It is to be verified that under steady state short-circuit conditions, the generator with its voltage regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of at least 2 s or, where precise data is available, for a duration of any time delay which may be fitted in a tripping device for discrimination purposes.

4.8 Overspeed test

4.8.1 Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

4.9 Dielectric strength test

4.9.1 New and completed rotating machines are to withstand a dielectric test as specified in IEC Publication 60034-1.

4.9.2 For high voltage machines an impulse test is to be carried out on the coils according to Ch 2, Sec 13.

4.9.3 When it is necessary to perform an additional high voltage test, this is to be carried out after any further drying, with a test voltage of 80% of that specified in IEC Publication 60034-1.

4.9.4 Completely rewound windings of used machines are to be tested with the full test voltage applied in the case of new machines.

4.9.5 Partially rewound windings are to be tested at 75% of the test voltage required for new machines. Prior to the test, the old part of the winding is to be carefully cleaned and dried.

4.9.6 Following cleaning and drying, overhauled machines are to be subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 500 V if the rated voltage is less than 100 V, and with a minimum of 1000 V if the rated voltage is equal to or greater than 100 V.

4.9.7 A repetition of the high voltage test for groups of machines and apparatus is to be avoided if possible, but if a test on an assembled group of several pieces of new apparatus, each of which has previously passed its high voltage test, is performed, the test voltage to be applied to such assembled group is 80% of the lowest test voltage appropriate for any part of the group.

Note 1: For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

4.10 No load test

4.10.1 Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor while generators are to be driven by a suitable means and excited to give rated terminal voltage.

During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

4.11 Verification of degree of protection

4.11.1 As specified in IEC Publication 60034-5.

4.12 Verification of bearings

4.12.1 Upon completion of the above tests, machines which have sleeve bearings are to be opened upon request for examination by the Surveyor, to establish that the shaft is correctly seated in the bearing shells.

Section 5 Transformers

1 Constructional requirements

1.1 Construction

1.1.1 Transformers, except those for motor starting, are to be double wound (two or more separate windings).

1.1.2 Transformers are normally to be of the dry, air-cooled type.

1.1.3 When a forced air cooling system is used, an alarm is to be activated in the event of its failure.

1.1.4 Liquid-cooled transformers may be used provided that:

- the liquid is non-toxic and of a type which does not readily support combustion
- the construction is such that the liquid is not spilled in inclined position
- temperature and pressure relief devices with an alarm are installed
- drip trays or other suitable arrangements for collecting the liquid from leakages are provided
- a liquid gauge indicating the normal liquid level range is fitted.

1.1.5 Transformers are to have enclosures with a degree of protection in accordance with Ch 2, Sec 3, Tab 3.

1.2 Terminals

1.2.1 Suitable fixed terminal connections are to be provided in an accessible position with sufficient space for convenient connection of the external cables.

1.2.2 Terminals are to be clearly identified.

1.3 Voltage variation, short-circuit conditions and parallel operation

1.3.1 Under resistive load ($\cos \varphi = 1$), the voltage drop from no load to full load is not to exceed 2,5%.

For transformers with a power lower than 5 kVA per phase, this voltage drop is not to exceed 5%.

An exception is made for special transformers, such as starting and instrument transformers, for which a different voltage variation may be considered.

1.3.2 In determining the voltage ratio and the impedance voltage of transformers, account is to be taken of the total permitted voltage drop from the main switchboard's busbars to the consumers (see Ch 2, Sec 3, [9.11.4]).

1.3.3 Transformers are to be constructed to withstand, without damage, the thermal and mechanical effects of a secondary terminal short-circuit for 2 s, with rated primary voltage and frequency.

For transformers of 1 MVA and over, this is to be justified with appropriate tests or documentation.

1.3.4 When transformers are so arranged that their secondary windings may be connected in parallel, they are to be identical and in particular they are to be of the same rated power, their winding connections are to be compatible, their rated voltage ratios are to be equal (with tolerances allowed) and their short-circuit impedance values, expressed as a percentage, are to have a ratio within 0,9 to 1,1.

1.4 Electrical insulation and temperature rise

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2.

1.4.2 All windings of air-cooled transformers are to be suitably treated to resist moisture, air salt mist and oil vapours.

1.4.3 The permissible limits of temperature rise with an ambient air temperature of 45°C for (natural or forced) air-cooled transformers are given in Tab 1. The temperature rises shown for windings refer to measurement by the resistance method while those for the core refer to the thermometer method.

1.4.4 For dry-type transformers cooled with an external liquid cooling system, the permissible limits of temperature rise with a sea water temperature of 32°C are 13°C higher than those specified in Tab 1.

Table 1 : Temperature rise limits for transformers

No.	Part of machine	Temperature rise by class of insulation °C				
		A	E	B	F	H
1	Windings	55	70	75	95	120
2	Cores and other parts: a) in contact with the windings b) not in contact with the windings	a) the same values as for the windings b) in no case is the temperature to reach values such as to damage either the core itself or other adjacent parts or materials				

1.4.5 For liquid-cooled transformers, the following temperature rises measured by the resistance method apply:

- 55°C where the fluid is cooled by air
- 68°C where the fluid is cooled by water.

2 Testing

2.1 General

2.1.1 On new transformers intended for essential services the tests specified in [2.2] are to be carried out.

2.1.2 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the transformer, as well as the results of the tests required.

Such test reports are to be made available to the Society.

2.1.3 In the case of transformers which are completely identical in rating and in all other constructional details, it will be acceptable for the temperature rise test to be performed on only one transformer.

The results of this test and the serial number of the tested transformer are to be inserted in the test reports for the other transformers.

2.1.4 Where the test procedure is not specified, the requirements of IEC 60076 and 60726 apply.

2.1.5 The tests and, if appropriate, manufacture of transformers of 50 kVA and over (30 kVA when single phase) intended for essential services are to be attended by a Surveyor of the Society.

Transformers of 5 kVA up to the limit specified above are approved on a case by case basis, at the discretion of the Society, subject to the submission of adequate documentation and routine tests.

2.2 Tests on transformers

2.2.1 Tests to be carried out on transformers are specified in Tab 2.

Table 2 : Tests to be carried out on transformers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)**	X	X
2	Insulation resistance measurement	X	X
3	Voltage drop	X	X
4	High voltage test	X	X
5	Temperature rise measurement	X	
6	Induced voltage test	X	X
7	Voltage ratio	X	X

(1) Type test on prototype transformer or test on at least the first batch of transformers.
(2) The certificates of transformers routine tested are to contain the manufacturer's serial number of the transformer which has been type tested and the test result.
(3) A visual examination is to be made of the transformer to ensure, as far as practicable, that it complies with technical documentation.

2.3 Insulation tests

2.3.1 Transformers are to be subjected to a high voltage test in accordance with the procedure defined in Ch 2, Sec 4.

2.3.2 The test voltage is to be applied between each winding under test and the other windings not under test, core and enclosure all connected together.

Single-phase transformers for use in a polyphase group are to be tested in accordance with the requirements applicable to that group.

2.3.3 The r.m.s. value of the test voltage is to be equal to 2 U + 1000 V, with a minimum of 2500 V, where U is the rated voltage of the winding. The full voltage is to be maintained for 1 minute.

2.3.4 Partially rewound windings are to be tested at 75% of the test voltage required for new machines.

2.3.5 The insulation resistance of a new, clean and dry transformer, measured after the temperature rise test has been carried out (at or near operating temperature) at a voltage equal to 500 V d.c., is to be not less than 5 MΩ.

2.3.6 Transformers are to be subjected to an induced voltage insulation test by applying to the terminals of the winding under test a voltage equal to twice the rated voltage. The duration of the test is to be 60 s for any test frequency fp up to and including twice the rated frequency fn.

If the test frequency exceeds twice the rated frequency, the test time in seconds will be 120 f_n/f_p with a minimum of 15 s.

Section 6 Semiconductor Converters

1 Constructional and operational requirements

1.1 Construction

1.1.1 Semiconductor convertors are generally to comply with the requirements for switchgear assemblies (see Ch 2, Sec 8).

1.1.2 The design of semi-conductor converters is to comply with the requirements of IEC Publication 60146-1-1 with applicable requirements modified to suit marine installations like e.g. environmental requirements stated in Ch 2, Sec 2.

1.1.3 The design of semi-conductor converters for power supply is to comply with the requirements of IEC 62040 serie (see Article [2]).

1.1.4 The design of semi-conductor converters for motor drives is to comply with the requirements of IEC 61800 serie.

1.1.5 The monitoring and control circuits are generally to comply with the requirements of Part C, Chapter 3.

1.1.6 For liquid-cooled convertors the following provisions are to be satisfied:

- liquid is to be non-toxic and of low flammability
- drip trays or other suitable means are to be provided to contain any liquid leakages
- the resistivity of the cooling fluid in direct contact with semiconductor or other current carrying parts is to be monitored and an alarm initiated if the resistivity is outside the specified limits.

1.1.7 For semiconductor convertors over 1 KVA where forced cooling is used, the temperature of the heated cooling medium is to be monitored.

If the temperature exceeds a preset value an alarm is to be given and the shutdown of the convertor is to be activated.

1.1.8 For semiconductor convertors over 1 KVA where forced (air or liquid) cooling is provided, it is to be so arranged that the convertor cannot be or remain loaded unless effective cooling is maintained.

Alternatively, other effective means of protection against overtemperature may be provided.

1.1.9 Stacks of semiconductor elements, and other equipment such as fuses, or control and firing circuit boards etc., are to be so arranged that they can be removed from equipment without dismantling the complete unit.

1.1.10 Semiconductor convertors are to be rated for the required duty having regard to the peak loads, system transient and overvoltage and to be dimensioned so as to withstand the maximum short-circuit currents foreseen at the point of installation for the time necessary to trip the protection of the circuits they supply.

1.1.11 Harmonic distortion are to be kept within the limit specified in Ch 2, Sec 2, [2.4].

1.2 Protection

1.2.1 Semiconductor elements are to be protected against short-circuit by means of devices suitable for the point of installation in the network.

1.2.2 Overcurrent or overvoltage protection is to be installed to protect the convertor. When the semiconductor convertor is designed to work as an inverter supplying the network in transient periods, precautions necessary to limit the current are to be taken.

1.2.3 Semiconductor convertors are not to cause distortion in the voltage wave form of the power supply at levels exceeding the voltage wave form tolerances at the other user input terminals (see Ch 2, Sec 2, [2.4]).

1.2.4 An alarm is to be provided for tripping of protective devices against overvoltages and overcurrents in electric propulsion convertors and for convertors for the emergency source of power.

1.3 Parallel operation with other power sources

1.3.1 For convertors arranged to operate in parallel with other power sources, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1.4 Temperature rise

1.4.1 The permissible limit of temperature rise of the enclosure of the semiconductors is to be assessed on the basis of an ambient air temperature of 45°C or sea water temperature of 32°C for water-cooled elements, taking into account its specified maximum permissible temperature value.

1.4.2 The value of the maximum permissible temperature of the elements at the point where this can be measured (point of reference) is to be stated by the manufacturer.

1.4.3 The value of the mean rated current of the semiconductor element is to be stated by the manufacturer.

1.5 Creepage and clearance distances

1.5.1 Creepage and clearance distances are to comply with the requirements specified in IEC 61800-5-1. An interpolation of the specified values is permitted for high voltage semi-conductor converters.

2 Requirements for uninterruptible power system (UPS) units as alternative and/or transitional power

2.1 Definitions

2.1.1 Uninterruptible power system (UPS)

Combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power in case of input power failure (see IEC Publication 62040-3).

2.1.2 Off line UPS unit

A UPS unit where under normal operation the output load is powered from the bypass line (raw mains) and only transferred to the inverter if the bypass supply fails or goes outside preset limits. This transition will invariably result in a brief (typically 2 to 10 ms) break in the load supply.

2.1.3 Line interactive UPS unit

An off-line UPS unit where the bypass line switch to stored energy power when the input power goes outside the preset voltage and frequency limits.

2.1.4 On line UPS unit

A UPS unit where under normal operation the output load is powered from the inverter, and will therefore continue to operate without break in the event of the supply input failing or going outside preset limits.

2.2 Design and construction

2.2.1 UPS units are to be constructed in accordance with IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

2.2.2 The operation of the UPS is not to depend upon external services.

2.2.3 The type of UPS unit employed, whether off-line, line interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

2.2.4 An external bypass is to be provided.

2.2.5 The UPS unit is to be monitored and audible and visual alarm is to be given in a normally attended location for:

- power supply failure (voltage and frequency) to the connected load
- earth fault
- operation of battery protective device
- when the battery is being discharged
- when the bypass is in operation for on-line UPS units.

2.3 Location

2.3.1 The UPS unit is to be suitably located for use in an emergency.

2.3.2 UPS units utilising valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

2.4 Performance

2.4.1 The output power is to be maintained for the duration required for the connected equipment as stated in Ch 2, Sec 3, [3.5.3], Pt D, Ch 2, Sec 4, [3.2.3], Pt D, Ch 4, Sec 5, [3.1.1] or Pt D, Ch 5, Sec 5, [2.2.3] as applicable.

2.4.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity.

2.4.3 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in the regulations.

2.4.4 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3 Testing

3.1 General

3.1.1 Convertors intended for essential services are to be subjected to the tests stated in [3.2].

3.1.2 The manufacturer is to issue a test report giving information on the construction, type, serial number and all technical data relevant to the convertor, as well as the results of the tests required.

3.1.3 In the case of convertors which are completely identical in rating and in all other constructional details, it will be acceptable for the rated current test and temperature rise measurement stipulated in [3.2] not to be repeated.

3.1.4 The tests and, if appropriate, manufacture of converters of 5 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

3.2 Tests on convertors

3.2.1 Convertors are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype convertor or the first of a batch of convertors, and routine tests are the tests to be carried out on subsequent convertors of a particular type.

3.2.2 The electronic components of the convertors are to be constructed to withstand the tests required in Ch 3, Sec 6.

3.2.3 Final approval of convertors is to include complete function tests after installation on board, performed with all ship's systems in operation and in all characteristic load conditions.

Table 1 : Tests to be carried out on static convertors

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Light load function test to verify all basic and auxiliary functions	X	X
3	Rated current test	X	
4	Temperature rise measurement	X	
5	Insulation test (high voltage test and insulation resistance measurement)	X	X
6	Protection of the convertors in case of failure of forced cooling system	X	X

(1) Type test on prototype convertor or test on at least the first batch of convertors.
(2) The certificates of convertors routine tested are to contain the manufacturer's serial number of the convertor which has been type tested and the test result.
(3) A visual examination is to be made of the convertor to ensure, as far as practicable, that it complies with technical documentation.

3.3 Additional testing and survey for uninterruptible power system (UPS) units as alternative and/or transitional power

3.3.1 UPS units of 50 kVA and over are to be surveyed by the Society during manufacturing and testing.

3.3.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:

- functionality, including operation of alarms
- ventilation rate
- battery capacity.

3.3.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

3.4 Insulation test

3.4.1 The test procedure is that specified in IEC Publication 60146.

3.4.2 The effective value of the test voltage for the insulation test is to be as shown in Tab 2.

Table 2 : Test voltages for high voltage test on static convertors

$\frac{U_m}{\sqrt{2}} = U$ in V **(1)**	Test voltage in V
$U \le 60$	600
$60 < U \le 90$	900
$90 < U$	2 U + 1000 (at least 2000)

(1) U_m : Highest crest value to be expected between any pair of terminals.

Section 7 Storage Batteries and Chargers

1 Constructional requirements for batteries

1.1 General

1.1.1 The requirements of this Section apply to permanently installed storage batteries (not to portable batteries).

1.1.2 Storage batteries may be of the lead-acid or nickel-alkaline type, due consideration being given to the suitability for any specific application.

Other types of storage batteries of satisfactorily proven design (e.g. silver/zinc) may be accepted provided they are suitable for shipboard use to the satisfaction of the Society.

1.1.3 Cells are to be assembled in suitable crates or trays equipped with handles for convenient lifting.

1.2 Vented batteries

1.2.1 Vented batteries are those in which the electrolyte can be replaced and freely releases gas during periods of charge and overcharge.

1.2.2 Vented batteries are to be constructed to withstand the movement of the ship and the atmosphere (salt mist, oil etc.) to which they may be exposed.

1.2.3 Battery cells are to be so constructed as to prevent spilling of electrolyte at any inclination of the battery up to 40° from the vertical.

1.2.4 It is to be possible to check the electrolyte level and the pH.

1.3 Valve-regulated sealed batteries

1.3.1 Valve-regulated sealed batteries are batteries whose cells are closed under normal conditions but which have an arrangement which allows the escape of gas if the internal pressure exceeds a predetermined value. The cells cannot normally receive addition to the electrolyte.

Note 1: The cells of batteries which are marketed as “sealed” or “maintenance free” are fitted with a pressure relief valve as a safety precaution to enable uncombined gas to be vented to the atmosphere; they should more properly be referred to as valve-regulated sealed batteries. In some circumstances the quantity of gas vented can be up to 25% of the equivalent vented design. The design is to take into consideration provision for proper ventilation.

1.3.2 Cell design is to minimize risks of release of gas under normal and abnormal conditions.

1.4 Tests on batteries

1.4.1 The battery autonomy is to be verified on board in accordance with the operating conditions.

2 Constructional requirements for chargers

2.1 Characteristics

2.1.1 Chargers are to be adequate for the batteries for which they are intended and provided with a voltage regulator.

2.1.2 In the absence of indications regarding its operation, the battery charger is to be such that the completely discharged battery can be recharged to 80% capacity within a period of 10 hours without exceeding the maximum permissible charging current. A charging rate other than the above (e.g. fully charged within 6 hours for batteries for starting of motors) may be required in relation to the use of the battery.

2.1.3 For floating service or for any other condition where the load is connected to the battery while it is on charge, the maximum battery voltage is not to exceed the safe value of any connected apparatus.

Note 1: Consideration is to be given to the temperature variation of the batteries.

2.1.4 The battery charger is to be designed so that the charging current is set within the maximum current allowed by the manufacturer when the battery is discharged and the floating current to keep the battery fully charged.

2.1.5 Trickle charging to neutralize internal losses is to be provided. An indication is to be provided to indicate a charging voltage being present at the charging unit.

2.1.6 Protection against reversal of the charging current is to be provided.

2.1.7 Battery chargers are to be constructed to simplify maintenance operation. Indications are to be provided to visualize the proper operation of the charger and for troubleshooting.

2.2 Tests on chargers

2.2.1 Battery chargers are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype charger or the first of a batch of chargers, and routine tests are the tests to be carried out on subsequent chargers of a particular type.

2.2.2 The electronic components of the battery chargers are to be constructed to withstand the tests required in Ch 3, Sec 6.

2.2.3 The tests of battery chargers of 10 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

Table 1 : Tests to be carried out on battery chargers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Functional tests (current and voltage regulation, quick, slow, floating charge, alarms)	X	X
3	Temperature rise measurement	X	
4	Insulation test (high voltage test and insulation resistance measurement)	X	X

(1) Type test on prototype battery charger or test on at least the first batch of battery chargers.
(2) The certificates of battery chargers routine tested are to contain the manufacturer's serial number of the battery charger which has been type tested and the test result.
(3) A visual examination is to be made of the battery charger to ensure, as far as practicable, that it complies with technical documentation.

Section 8 Switchgear and Controlgear Assemblies

1 Constructional requirements for main and emergency switchboards

1.1 Construction

1.1.1 Construction is to be in accordance with IEC 60092-302.

1.1.2 Where the framework, panels and doors of the enclosure are of steel, suitable measures are to be taken to prevent overheating due to the possible circulation of eddy currents.

1.1.3 Insulating material for panels and other elements of the switchboard is at least to be moisture-resistant and flame-retardant.

1.1.4 Switchboards are to be of dead front type, with enclosure protection according to Ch 2, Sec 3, Tab 3.

1.1.5 Switchboards are to be provided with insulated handrails or handles fitted in an appropriate position at the front of the switchboard. Where access to the rear is necessary for operational or maintenance purposes, an insulated handrail or insulated handles are to be fitted.

1.1.6 Where the aggregate capacity of generators connected to the main busbars exceeds 100 kVA, a separate cubicle for each generator is to be arranged with flame-retardant partitions between the different cubicles. Similar partitions are to be provided between the generator cubicles and outgoing circuits.

1.1.7 Instruments, handles or push-buttons for switchgear operation are to be placed on the front of the switchboard. All other parts which require operation are to be accessible and so placed that the risk of accidental touching of live parts, or accidental making of short-circuits and earthings, is reduced as far as practicable.

1.1.8 Where it is necessary to make provision for the opening of the doors of the switchboard, this is to be in accordance with one of the following requirements:

a) opening is to necessitate the use of a key or tool (e.g. when it is necessary to replace a lamp or a fuse-link)
b) all live parts which can be accidentally touched after the door has been opened are to be disconnected before the door can be opened
c) the switchboard is to include an internal barrier or shutter with a degree of protection not less than IP2X shielding all live parts such that they cannot accidentally be touched when the door is open. It is not to be possible to remove this barrier or shutter except by the use of a key or tool.

1.1.9 All parts of the switchboard are to be readily accessible for maintenance, repair or replacement. In particular, fuses are to be able to be safely inserted and withdrawn from their fuse-bases.

1.1.10 Hinged doors which are to be opened for operation of equipment on the door or inside are to be provided with fixing devices for keeping them in open position.

1.1.11 Means of isolation of the circuit-breakers of generators and other important parts of the installation are to be provided so as to permit safe maintenance while the main busbars are alive.

1.1.12 Where components with voltage exceeding the safety voltage are mounted on hinged doors, the latter are to be electrically connected to the switchboard by means of a separate, flexible protective conductor.

1.1.13 All measuring instruments and all monitoring and control devices are to be clearly identified with indelible labels of durable, flame-retardant material.

1.1.14 The rating of each circuit, together with the rating of the fuse or the appropriate setting of the overload protective device (circuit-breaker, thermal relay etc.) for each circuit is to be permanently indicated at the location of the fuse or protective device.

1.1.15 When the switchboard location and arrangement is so that fumes from an internal fire can be harmful for persons on board, mica coins are recommended to be provided in the front part of all switchgear assemblies for possible internal fire extinction.

1.2 Busbars and bare conductors

1.2.1 Busbars are to be of copper or of copper-surrounded aluminium alloy if suitable for use in the marine environment and if precautions are taken to avoid galvanic corrosion.

1.2.2 All connections are to be so made as to inhibit corrosion.

1.2.3 Busbars are to be dimensioned in accordance with IEC 60092-302.

The mean temperature rise of busbars is not to exceed 45°C under rated current condition with an ambient air temperature of 45°C and is not to have any harmful effect on adjacent components. Higher values of temperature rise may be accepted to the satisfaction of the Society.

1.2.4 The cross-section of neutral connection on an a.c. three-phase, four-wire system is to be at least 50% of the cross-section for the corresponding phases.

1.2.5 Bare main busbars, excluding the conductors between the main busbars and the supply side of outgoing units, are to have the minimum clearances and creepage distances given in Tab 1. The values shown apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

Note 1: Clearance is the distance between two conductive parts along a string stretched the shortest way between such parts. Creepage distance is the shortest distance along the surface of an insulating material between two conductive parts.

Table 1 : Clearance and creepage distances

Rated insulation voltage a.c. r.m.s. or d.c. in V	Minimum clearance, in mm	Minimum creepage distance, in mm
≤ 250	15	20
> 250 to ≤ 690	20	25
> 690	25	35

1.2.6 Reduced values as specified in IEC 60092-302 may be accepted for type tested and partially type tested assemblies.

The reference values for the evaluation of the minimum clearances and creepage distances for these assemblies are based on the following:

- pollution degree 3 (conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation which is expected)
- overvoltage category III (distribution circuit level)
- unhomogenous field conditions (case A)
- rated operational voltage 1000 V a.c., 1500 V d.c.
- group of insulating material IIIa.

Special consideration is to be given to equipment located in spaces where a pollution degree higher than 3 is applicable, e.g. in diesel engine rooms.

1.2.7 Busbars and other bare conductors with their supports are to be mechanically dimensioned and fixed such that they can withstand the stresses caused by short-circuits.

Where maximum symmetrical short-circuit currents are expected to exceed 50 KA, calculation is to be submitted to the Society.

1.2.8 Busbars and bare conductors are to be protected, where necessary, against falling objects (e.g. tools, fuses or other objects).

1.3 Internal wiring

1.3.1 Insulated conductors for internal wiring of auxiliary circuits of switchboards are to be constructed in accordance with Ch 2, Sec 9, [1.1.5].

1.3.2 All insulated conductors provided for in [1.3.1] are to be of flexible construction and of the stranded type.

1.3.3 Connections from busbars to protective devices are to be as short as possible. They are to be laid and secured in such a way to minimize the risk of a short-circuit.

1.3.4 All conductors are to be secured to prevent vibration and are to be kept away from sharp edges.

1.3.5 Connections leading to indicating and control instruments or apparatus mounted in doors are to be installed such that they cannot be mechanically damaged due to movement of the doors.

1.3.6 Non-metallic trays for internal wiring of switchboards are to be of flame-retardant material.

1.3.7 Control circuits are to be installed and protected such that they cannot be damaged by arcs from the protective devices.

1.3.8 Where foreseen, fixed terminal connectors for connection of the external cables are to be arranged in readily accessible positions.

1.3.9 Colour of insulated conductors for internal wiring are preferably to be chosen as follows:

- 440 volts: red
- 115 volts: white
- 24 volts: black
- Intrinsically safe circuits: blue
- Optical fibre: orange

1.4 Switchgear and controlgear

1.4.1 Switchgear and controlgear are to comply with IEC 60947 series and to be chosen from among that type approved by the Society.

1.4.2 The characteristics of switchgear, controlgear and protective devices for the various consumers are to be in compliance with Ch 2, Sec 3, [7].

1.5 Auxiliary circuits

1.5.1 Auxiliary circuits are to be designed in such a manner that, as far as practicable, faults in such circuits do not impair the safety of the system. In particular, control circuits are to be designed so as to limit the dangers resulting from a fault between the control circuit and earth (e.g. inadvertent operation or malfunction of a component in the installation), also taking account of the earthing system of their supply.

1.5.2 Auxiliary circuits of essential systems are to be independent of other auxiliary circuits.

1.5.3 Common auxiliary circuits for groups of consumers are permitted only when the failure of one consumer jeopardizes the operation of the entire system to which it belongs.

1.5.4 Auxiliary circuits are to be branched off from the main circuit in which the relevant switchgear is used.

1.5.5 The supply of auxiliary circuits by specifically arranged control distribution systems will be specially considered by the Society.

1.5.6 Means are to be provided for isolating the auxiliary circuits as well when the main circuit is isolated (e.g. for maintenance purposes).

1.5.7 For the protection of auxiliary circuits see Ch 2, Sec 3, [7.13].

1.6 Instruments

1.6.1 The upper limit of the scale of every voltmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.2 The upper limit of the scale of every ammeter is to be not less than 130% of the normal rating of the circuit in which it is installed.

1.6.3 The upper limit of the scale of every wattmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.4 Wattmeters for use with a.c. generators which may be operated in parallel are to be capable of indicating 15% reverse power.

1.6.5 For wattmeters using one current circuit only, the measurement of the current of all generators is to be made in the same phase.

1.6.6 The rated value of the measure read, at full load, is to be clearly indicated on the scales of instruments.

1.6.7 Frequency meters are to have a scale at least ± 5% of the nominal frequency.

1.6.8 The secondary windings of instrument transformers are to be earthed.

1.6.9 Each a.c. generator not operated in parallel is to be provided with:

- 1 voltmeter
- 1 frequency meter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read
- 1 three-phase wattmeter in the case of generators rated more than 50 kVA.

1.6.10 Each a.c. generator operated in parallel is to be provided with:

- 1 three-phase wattmeter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read.

1.6.11 For paralleling purposes the following are to be provided:

- 2 voltmeters
- 2 frequency meters
- 1 synchroscope and synchronising indicating lamps or equivalent means.

A switch is to be provided to enable one voltmeter and one frequency meter to be connected to each generator before the latter is connected to the busbars.

The other voltmeter and frequency meter are to be permanently connected to the busbars.

1.6.12 Each secondary distribution system is to be provided with one voltmeter.

1.6.13 Switchboards are to be fitted with means for monitoring the insulation level of insulated distribution systems as stipulated in Ch 2, Sec 3, [3.2.1].

1.6.14 The main switchboard is to be fitted with a voltmeter or signal lamp indicating that the cable between the shore-connection box and the main switchboard is energized (see Ch 2, Sec 3, [3.6.7]).

1.6.15 For each d.c. power source (e.g. convertors, rectifiers and batteries), one voltmeter and one ammeter are to be provided, except for d.c. power sources for starting devices (e.g. starting motor for emergency generator).

2 Constructional requirements for section boards and distribution boards

2.1 Construction

2.1.1 Section boards and distribution boards are to be constructed, insofar as applicable, as specified for main and emergency switchboards.

2.1.2 All parts which require operation in normal use are to be placed on the front.

2.1.3 Distribution switchboards which are provided with two or more supply circuits arranged for automatic standby connection are to be provided with positive indication of which of the circuits is feeding the switchboard.

2.1.4 Where switchboard supplying essential services is provided with a forced air cooling system, the air temperature is to be monitored. An alarm is to be activated when temperature exceeds a preset value.

3 Testing

3.1 General

3.1.1 Switchboards are to be subjected to the tests specified from [3.2] to [3.4].

3.1.2 The manufacturer is to issue the relative test reports providing information concerning the construction, serial number and technical data relevant to the switchboard, as well as the results of the tests required.

3.1.3 The tests are to be carried out prior to installation on board.

3.1.4 The test procedures are as specified in IEC 60092-302.

3.2 Inspection of equipment, check of wiring and electrical operation test

3.2.1 It is to be verified that the switchboard:

- complies with the approved drawings
- maintains the prescribed degree of protection
- is constructed in accordance with the relevant constructional requirements, in particular as regards creepage and clearance distances.

3.2.2 The connections, especially screwed or bolted connections, are to be checked for adequate contact, possibly by random tests.

3.2.3 Depending on the complexity of the switchboard it may be necessary to carry out an electrical functioning test. The test procedure and the number of tests depend on whether or not the switchboard includes complicated interlocks, sequence control facilities, etc. In some cases it may be necessary to conduct or repeat this test following installation on board.

3.3 High voltage test

3.3.1 The test is to be performed with alternating voltage at a frequency between 25 and 100 Hz of approximately sinusoidal form.

3.3.2 The test voltage is to be applied:

- between all live parts connected together and earth
- between each polarity and all the other polarities connected to earth for the test.

During the high voltage test, measuring instruments, ancillary apparatus and electronic devices may be disconnected and tested separately in accordance with the appropriate requirements.

3.3.3 The test voltage at the moment of application is not to exceed half of the prescribed value. It is then to be increased steadily within a few seconds to its full value. The prescribed test voltage is to be maintained for 1 minute.

3.3.4 The value of the test voltage for main and auxiliary circuits is given in Tab 2 and Tab 3.

Table 2 : Test voltages for main circuits

Rated insulation voltage U_i in V	Test voltage c.a (r.m.s.), in V
$U_i \leq 60$	1000
$60 < U_i \leq 300$	2000
$300 < U_i \leq 660$	2500
$660 < U_i \leq 800$	3000
$800 < U_i \leq 1000$	3500

Table 3 : Test voltage for auxiliary circuits

Rated insulation voltage U_i in V	Test voltage c.a (r.m.s.), in V
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$U_i > 60$	$2\ U_i + 1000$ (at least 1500)

3.4 Measurement of insulation resistance

3.4.1 Immediately after the high voltage test, the insulation resistance is to be measured using a device with a direct current voltage of at least 500 V.

3.4.2 The insulation resistance between all current carrying parts and earth (and between each polarity and the other polarities) is to be at least equal to 1 MΩ.

Section 9 Cables

1 Constructional requirements

1.1 Construction

1.1.1 Cables and insulated wiring are generally to be constructed in accordance with the relevant recommendations of IEC Publications 60092-350, 60092-352, 60092-353, 60092-354, 60092-360, 60092-370, and 60092-376, as well with the provisions of this Chapter.

1.1.2 Regarding smoke emission and halogen acid gas content, subject to Ch 2, Sec 3, [9.1.5], cables are to be in compliance with IEC 60754-1, 60754-2, 61034-1, 61034-2.

1.1.3 Optical fibre cables are to be constructed in accordance with IEC 60794.

1.1.4 Flexible cables constructed according to national standards will be specially considered by the Society.

1.1.5 Cables and insulated wires manufactured and tested in accordance with standards other than those specified in [1.1.1] will be accepted provided they are in accordance with an acceptable and relevant international or national standard and are of an equivalent or higher safety level than those listed in [1.1.1]. However, cables such as flexible cable, fibre-optic cable, etc. used for special purposes may be accepted provided they are manufactured and tested in accordance with the relevant standards accepted by the Society.

1.1.6 Insulated wiring for auxiliary circuits of switchboards and control gears may be constituted by cables with a single conductor of the stranded type for all sections, in accordance with the Publications cited in [1.1.1] and without further protection.

The insulated wiring is to be at least of the flame-retardant type according to IEC 60332-1 and in accordance with IEC 60754-1, 60754-2, 61034-1 and 61034-2. Equivalent types of flame-retardant switchboard wires will be specially considered by the Society.

1.1.7 Fire resistant cables are to be designed and tested in accordance with the relevant IEC Publication 60092-series standards.

They are to comply with the requirements of:

- IEC Standard 60331-1 for cables with an overall diameter exceeding 20 mm, or
- IEC Standard 60331-2 for cables with an overall diameter not exceeding 20 mm,
- otherwise IEC 60331-21.

The minimum flame application time is to be at least 90 minutes.

Fire resistant type cables are to be easily distinguishable.

Note 1: For special cables, requirements in the following standards may be used:

- IEC 60331-23: Procedures and requirements - Electric data cables
- IEC 60331-25: Procedures and requirements - Optical fibre cables.

1.2 Conductors

1.2.1 Conductors are to be of annealed electrolytic copper with a resistivity not exceeding 17,241 Ω mm^2/km at 20°C according to IEC 60228.

1.2.2 Individual conductor wires of rubber-insulated cables and cables having cross sectional area less than 10 mm are to be tinned or coated with a suitable alloy.

1.2.3 All conductors are to be stranded, except for cables of nominal cross-sectional area 2,5 mm^2 and less (provided that adequate flexibility of the finished cable is assured).

1.2.4 For the minimum nominal cross-sectional areas permitted, see Ch 2, Sec 3, [9.10].

1.3 Insulating materials

1.3.1 The materials used for insulation are to comply with IEC 60092-360 and to have the thicknesses specified for each type of cable in the relevant standard. The maximum permissible rated temperature is specified for the various materials.

1.3.2 Materials and thicknesses other than those in [1.3.1] will be specially considered by the Society.

1.4 Inner covering, fillers and binders

1.4.1 The cores of a multicore cable are to be laid up. The spaces between the cores are to be filled so as to obtain an assembly having an essentially circular cross-section. The filling may be omitted in multicore cables having a conductor cross-sectional area not exceeding 4 mm^2.

When a non-metallic sheath is applied directly over the inner covering or the fillers, it may substitute partially for the inner covering or fillers.

1.4.2 The materials used, the binders and the thicknesses of the inner coverings are generally to be in accordance with IEC Publications of the series 60092-3.., in relation to the type of cable.

1.5 Protective coverings (armour and sheath)

1.5.1 Metallic armour, if not otherwise protected against corrosion, is to be protected by means of a coating of protective paint (see Ch 2, Sec 3, [9.3]).

1.5.2 The paint is to be non-flammable and of adequate viscosity. When dry, it is not to flake off.

1.5.3 The materials and construction used for (metal) armour are to be in accordance with IEC 60092-350 and their dimensions are to be those specified for each type of cable in the relevant standard.

1.5.4 The materials used for sheaths are to be in accordance with IEC 60092-360 and are to have the thicknesses specified for each type of cable in the relevant standard.

The quality of the materials is to be adequate to the service temperature of the cable.

1.5.5 Materials other than those in [1.5.3] and [1.5.4] will be specially considered by the Society.

1.6 Identification

1.6.1 Each cable is to have clear means of identification so that the manufacturer can be determined.

1.6.2 Fire non propagating cables are to be clearly labelled with indication of the standard according to which this characteristic has been verified and, if applicable, of the category to which they correspond.

1.6.3 An identification tag is to be fitted at both end of the cable.

2 Testing

2.1 Type tests

2.1.1 Type tests are to be in accordance with the relevant IEC 60092-3.. Series Publications and IEC 60332-1, IEC 60332-3 Category A, IEC 60754-1, IEC 60754-2, IEC 61034-1, IEC 61034-2, and IEC 60331 where applicable or with standard recognized by the Society.

2.2 Routine tests

2.2.1 Every length of finished cable is to be subjected to the tests specified in [2.2.2].

2.2.2 The following routine tests are to be carried out:

a) visual inspection

b) check of conductor cross-sectional area by measuring electrical resistance

c) high voltage test

d) insulation resistance measurement

e) dimensional checks (as necessary).

2.2.3 The manufacturer is to issue a statement providing information on the type and characteristics of the cable, as well as the results of the tests required and the Type Approval Certificates.

2.2.4 The test procedure is as specified in IEC 60092-350.

2.2.5 Where an alternative scheme, e.g. a certified quality assurance system, is recognized by the Society, attendance of the Surveyor may not be required.

Section 10 Miscellaneous Equipment

1 Switchgear and controlgear, protective devices

1.1 General

1.1.1 Switchgear and controlgear are to comply with IEC Publication 60947.

1.1.2 For materials and construction see Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.2 Circuit-breakers

1.2.1 Power-driven circuit-breakers are to be equipped with an additional separate drive operated by hand.

1.2.2 Power circuit-breakers with a making capacity exceeding 10 kA are to be equipped with a drive which performs the make operation independently of the actuating force and speed.

1.2.3 Where the conditions for closing the circuit-breaker are not satisfied (e.g. if the undervoltage trip is not energized), the closing mechanism is not to cause the closing of the contacts.

1.2.4 All circuit-breakers rated more than 16 A are to be of the trip-free type, i.e. the breaking action initiated by overcurrent or undervoltage releases is to be fulfilled independently of the position of the manual handle or other closing devices.

1.3 Protection devices

1.3.1 Short-circuit releases are generally to be independent of energy supplied from circuits other than that to be protected. Tripping due to short-circuit is to be reliable even in the event of a total loss of voltage in the protected circuit.

1.3.2 Short-circuit releases for generators are to be equipped with reclosing inhibitors and are to be delayed for selective tripping.

1.3.3 Overload releases or relays are to operate reliably at any voltage variation of the supply voltage in the protected circuit.

1.3.4 Undervoltage relays or releases are to cause the circuit-breaker to open if the voltage drops to 70%-35% of the rated voltage.

1.3.5 Shunt releases are to ensure the disconnection of the circuit-breaker even when the supply voltage of the release drops to 85% of the rated supply voltage.

1.3.6 The reverse power protection device is to respond to the active power regardless of the power factor, and is to operate only in the event of reverse power.

1.3.7 Single-phase failure devices in three-phase circuits are to operate without a time lag.

1.3.8 Insulation monitoring devices are to continuously monitor the insulation resistance to earth and trigger an alarm should the insulation resistance fall below a predetermined value.

The measuring current of such devices is not to exceed 30 mA in the event of a total short to earth.

2 Lighting fittings

2.1 Applicable requirements

2.1.1 Lighting fittings are to comply with IEC Publications 60598 and 60092-306.

Lighting fittings complying with other standards will be specially considered by the Society.

2.2 Construction

2.2.1 The temperature of terminals for connection of supplying cables is not to exceed the maximum conductor temperature permitted for the cable (see Ch 2, Sec 3, [9.9]).

Where necessary, luminaires are to be fitted with terminal boxes which are thermally insulated from the light source.

2.2.2 Wires used for internal connections are to be of a temperature class which corresponds to the maximum temperature within the luminaire.

2.2.3 The temperature rise of parts of luminaires which are in contact with the support is not to exceed 50°C. The rise is not to exceed 40°C for parts in contact with flammable materials.

2.2.4 The temperature rise of surface parts which can easily be touched in service is not to exceed 15°C.

2.2.5 High-power lights with higher surface temperatures than those in [2.2.2] and [2.2.3] are to be adequately protected against accidental contact.

3 Accessories

3.1 Applicable requirements

3.1.1 Accessories are to be constructed in accordance with the relevant IEC Publications, and in particular with Publication 60092-306.

3.2 Construction

3.2.1 Enclosures of accessories are to be of metal having characteristics suitable for the intended use on board, or of flame-retardant insulating material.

3.2.2 Terminals are to be suitable for the connection of stranded conductors, except in the case of rigid conductors for mineral-insulated cables.

4 Plug-and-socket connections

4.1 Applicable requirements

4.1.1 Plug-and-socket connections are to comply with IEC Publication 60092-306 and with the following additional standards in relation to their use:

- in accommodation spaces, day rooms and service rooms (up to 16 A, 250 V a.c.): IEC Publication 60083 or 60320, as applicable
- for power circuits (up to 250 A, 690 V a.c.): IEC Publication 60309
- for electronic switchgear: IEC Publications, e.g. 60130 and 60603
- for refrigerated containers: ISO 1496-2.

5 Heating and cooking appliances

5.1 Applicable requirements

5.1.1 Heating and cooking appliances are to comply with the relevant IEC Publications (e.g. those of series 60335), with particular attention to IEC 60092-307.

5.2 General

5.2.1 Heating elements are to be enclosed and protected with metal or refractory material.

5.2.2 The terminals of the power supply cable are not to be subjected to a higher temperature than that permitted for the conductor of the connection cable.

5.2.3 The temperature of parts which are to be handled in service (switch knobs, operating handles and the like) is not to exceed the following values:

- 55°C for metal parts
- 65°C for vitreous or moulded material.

5.3 Space heaters

5.3.1 The casing or enclosure of heaters is to be so designed that clothing or other flammable material cannot be placed on them.

5.3.2 The temperature of the external surface of space heaters is not to exceed 60°C.

5.3.3 Space heaters are to be provided with a temperature limiting device without automatic reconnection which automatically trips all poles or phases not connected to earth when the temperature exceeds the maximum permissible value.

5.4 Cooking appliances

5.4.1 Live parts of cooking appliances are to be protected such that any foods or liquids which boil over or spill do not cause short-circuits or loss of insulation.

5.4.2 An emergency stop for deep fryers to be installed outside the room where they are located.

5.5 Fuel oil and lube oil heaters

5.5.1 In continuous-flow fuel oil and lube oil heaters, the maximum temperature of the heating elements is to be below the boiling point of the oil.

5.5.2 Each oil heater is to be provided with a thermostat maintaining the oil temperature at the correct level.

5.5.3 In addition to the thermostat in [5.5.2], each oil heater is to be provided with a temperature limiting device without automatic reconnection, and with the sensing device installed as close as possible to the heating elements and permanently submerged in the liquid.

5.6 Water heaters

5.6.1 Water heaters are to be provided with a thermostat and safety temperature limiter.

Section 11 Location

1 General

1.1 Location

1.1.1 The degree of protection of the enclosures and the environmental categories of the equipment are to be appropriate to the spaces or areas in which they are located; see Ch 2, Sec 3, Tab 3 and Ch 2, Sec 2, [5.2.2].

1.2 Areas with a risk of explosion

1.2.1 Except where the installation of equipment for explosive gas atmosphere is provided for by the Rules, electrical equipment is not to be installed where flammable gases or vapours are liable to accumulate; see Ch 2, Sec 3, [10].

2 Main electrical system

2.1 Location in relation to the emergency system

2.1.1 The arrangement of the emergency electrical system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render inoperative the main electric lighting system and the other primary essential services.

2.2 Main switchboard

2.2.1 Main switchboards, lighting distribution boards, transformers and converting equipment are to be so placed relative to their associated generator(s) so that, as far as practicable, the integrity of the main system of supply is affected only by a fire or other casualty in one space. Switchboards are to be located, as close as practicable to their associated generators.

2.2.2 An environmental enclosure for a main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating switchboards from generators.

3 Emergency electrical system

3.1 Spaces for the emergency source

3.1.1 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard shall be located inside the V-lines.

They shall not be located forward of the collision bulkhead.

3.1.2 The spaces containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard are not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switch-board.

Where this is not practicable, the contiguous boundaries are to be Class A60.

3.2 Location in relation to the main electrical system

3.2.1 The location of the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency power, the emergency switch-board and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard shall be such as to ensure to the satisfaction of the Society that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power.

3.2.2 The arrangement of the main electrical system is to be such that a fire or other casualty in spaces containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperative the emergency electric lighting system and the other emergency services other than those located within the spaces where the fire or casualty has occurred.

3.3 Emergency switchboard

3.3.1 The emergency switchboard shall be installed as near as is practicable to the emergency source of electrical power.

3.3.2 Where the emergency source of electrical power is a generator, the emergency switchboard shall be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.4 Emergency battery

3.4.1 No accumulator battery fitted in accordance with the provisions of Ch 2, Sec 3, [2.3] shall be installed in the same space as the emergency switchboard.

4 Distribution boards

4.1 Distribution boards for cargo spaces and similar spaces

4.1.1 Distribution boards containing multipole switches for the control of power and lighting circuits in bunkers and cargo spaces are to be situated outside such spaces.

4.2 Distribution board for navigation lights

4.2.1 The distribution board for navigation lights is to be placed in an accessible position on the bridge.

5 Cable runs

5.1 General

5.1.1 Cable runs are to be selected so as to be as far as practicable accessible, with the exception of single cables, situated behind walls or ceilings constructed of incombustible materials, supplying lighting fittings and socket-outlets in accommodation spaces, or cables enclosed in pipes or conduits for installation purposes.

5.1.2 Cable runs are to be selected so as to avoid action from condensed moisture and from dripping of liquids.

5.1.3 Connection and draw boxes are to be accessible.

5.1.4 Cables are generally not to be installed across expansion joints. Where this is unavoidable, however, a loop of cable of length proportional to the expansion of the joint is to be provided (see Sec 12 [7.2.2]).

5.2 Location of cables in relation to the risk of fire and overheating

5.2.1 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are, so far as is practicable, to be routed clear of galleys, laundries, machinery spaces of Category A and their casings and other high fire risk areas, except for supplying equipment in those spaces.

5.2.2 When it is essential that a circuit functions for some time during a fire and it is unavoidable to carry the cable for such a circuit through a high fire risk area (e.g. cables connecting fire pumps to the emergency switchboard), the cable is to be of a fire-resistant type or adequately protected against direct exposure to fire.

5.2.3 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s).

They are to be of a fire resistant type, in accordance with Ch 2, Sec 9, [1.1.7], where they pass through other high fire risk areas.

5.2.4 Main cable runs (see Note 1) and cables for the supply and control of essential services are, as far as is practicable, to be kept away from machinery parts having an increased fire risk (see Note 2) unless:

- the cables have to be connected to the subject equipment,
- the cables are protected by a steel bulkhead or deck, or
- the cables in that area are of the fire-resisting type.

Note 1: Main cable runs are for example:

- cable runs from generators and propulsion motors to main and emergency switchboards
- cable runs directly above or below main and emergency switchboards, centralised motor starter panels, section boards and centralised control panels for propulsion and essential auxiliaries.

Note 2: Machinery, machinery parts or equipment handling combustibles are considered to present an increased fire risk.

5.2.5 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are to be arranged, as far as practicable, in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

5.2.6 Cables are to be arranged as remote as possible from sources of heat such as hot pipes, resistors, etc. Where installation of cables near heat sources cannot be avoided, and where there is consequently a risk of damage to the cables by heat, suitable shields are to be installed, or other precautions to avoid overheating are to be taken, for example use of ventilation, heat insulation materials or special heat-resisting cables.

5.3 Location of cables in relation to electromagnetic interference

5.3.1 For the installation of cables in the vicinity of radio equipment or of cables belonging to electronic control and monitoring systems, steps are to be taken in order to limit the effects of unwanted electromagnetic interference (see Ch 3, Sec 5).

5.4 Services with a duplicate feeder

5.4.1 Duplicated supplies and associated control cables for essential services (e.g. steering gear circuits) are to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

5.5 Emergency circuits

5.5.1 Cables supplying emergency circuits are not to run through spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, except for cables supplying emergency equipment located within such spaces (see [3.2.2]).

6 Storage batteries

6.1 General

6.1.1 Batteries are to be located where they are not exposed to excessive heat, extreme cold, spray, steam or other conditions which would impair performance or accelerate deterioration. They are to be installed in such a way that no damage may be caused to surrounding appliances by the vapours generated.

6.1.2 Storage batteries are to be suitably housed, and compartments (rooms, lockers or boxes) used primarily for their accommodation are to be properly constructed and efficiently ventilated so as to prevent accumulation of flammable gas.

6.1.3 Starter batteries are to be located as close as practicable to the engine or engines served.

6.1.4 Accumulator batteries shall not be located in sleeping quarters except where hermetically sealed to the satisfaction of the Society.

6.1.5 Lead-acid batteries and alkaline batteries are not to be installed in the same compartment (room, locker, box), unless of valve-regulated sealed type.

6.2 Large vented batteries

6.2.1 Batteries connected to a charging device of power exceeding 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery (hereafter referred to as "large batteries") are to be installed in a room assigned to batteries only.

Where this is not possible, they may be arranged in a suitable locker on deck.

6.2.2 Rooms assigned to large batteries are to be provided with mechanical exhaust ventilation.

Natural ventilation may be employed for boxes located on open deck.

6.2.3 The provisions of [6.2.1] and [6.2.2] also apply to several batteries connected to charging devices of total power exceeding 2 kW calculated for each one as stated in [6.2.1].

6.3 Moderate vented batteries

6.3.1 Batteries connected to a charging device of power between 0,2 kW and 2 kW calculated as stated in [6.2.1] (hereafter referred to as “moderate batteries”) are to be arranged in the same manner as large batteries or placed in a box or locker in suitable locations such as machinery spaces, storerooms or similar spaces. In machinery spaces and similar well-ventilated compartments, these batteries may be installed without a box or locker provided they are protected from falling objects, dripping water and condensation where necessary.

6.3.2 Rooms, lockers or boxes assigned to moderate batteries are to be provided with natural ventilation or mechanical exhaust ventilation, except for batteries installed without a box or locker (located open) in well-ventilated spaces.

6.3.3 The provisions of [6.3.1] and [6.3.2] also apply to several batteries connected to charging devices of total power between 0,2 kW and 2 kW calculated for each one as stated in [6.2.1].

6.4 Small vented batteries

6.4.1 Batteries connected to a charging device of power less than 0,2 kW calculated as stated in [6.2.1] (hereafter referred to as "small batteries") are to be arranged in the same manner as moderate or large batteries, or without a box or locker, provided they are protected from falling objects, or in a box in a ventilated area.

6.4.2 Boxes for small batteries may be ventilated only by means of openings near the top to permit escape of gas.

6.5 Ventilation

6.5.1 The ventilation of battery compartments is to be independent of ventilation systems for other spaces.

6.5.2 The quantity of air expelled (by natural or forced ventilation) for compartments containing vented type batteries is to be at least equal to:

$Q = 110 \cdot I \cdot n$

where:

Q	:	Quantity of air expelled, in litres per hour
I	:	Maximum current delivered by the charging equipment during gas formation, but not less than one quarter of the maximum obtainable charging current in amperes
n	:	Number of cells in series.

6.5.3 The quantity of air expelled (by natural or forced ventilation) for compartments containing valve-regulated sealed batteries is to be at least 25% of that given in [6.5.2].

6.5.4 Ducts are to be made of a corrosion-resisting material or their interior surfaces are to be painted with corrosion-resistant paint.

6.5.5 Adequate air inlets (whether connected to ducts or not) are to be provided near the floor of battery rooms or the bottom of lockers or boxes (except for that of small batteries).

Air inlet may be from the open air or from another space (for example from machinery spaces).

6.5.6 Exhaust ducts of natural ventilation systems:

a) are to be run directly from the top of the compartment to the open air above (they may terminate in the open or in well-ventilated spaces)

b) are to terminate not less than 90 cm above the top of the battery compartment

c) are to have no part more than 45° from the vertical

d) are not to contain appliances (for example for barring flames) which may impede the free passage of air or gas mixtures.

Where natural ventilation is impracticable or insufficient, mechanical exhaust ventilation is to be provided.

6.5.7 In mechanical exhaust ventilation systems:

a) electric motors are to be outside the exhaust ducts and battery compartment and are to be of safe type if installed within 3 m from the exhaust of the ventilation duct

b) fans are to be so constructed and of a material such as to render sparking impossible in the event of the impeller touching the fan casing

c) steel or aluminium impellers are not to be used

d) the system is to be interlocked with the charging device so that the battery cannot be charged without ventilation (trickle charge may be maintained)

e) a temperature sensor is to be located in the battery compartment to monitor the correct behaviour of the battery in cases where the battery element is sensitive to temperature.

6.5.8 For natural ventilation systems for deck boxes:

a) holes for air inlet are to be provided on at least two opposite sides of the box

b) the exhaust duct is to be of ample dimensions

c) the duct is to terminate at least 1,25 m above the box in a goose-neck or mushroom-head or the equivalent

d) the degree of protection is to be in accordance with Ch 2, Sec 3, Tab 3.

Section 12 Installation

1 General

1.1 Protection against injury or damage caused by electrical equipment

1.1.1 All electrical equipment is to be so installed as not to cause injury when handled or touched in the normal manner.

1.1.2 All electrical equipment is to be installed in such a way that live parts cannot be inadvertently touched, unless supplied at a safety voltage.

1.1.3 For protective earthing as a precaution against indirect contact, see Article [2].

1.1.4 Equipment is to be installed so as not to cause malfunctions due to electromagnetic interference.

1.2 Protection against damage to electrical equipment

1.2.1 Electrical equipment is to be so placed that as far as practicable it is not exposed to risk of damage from water, steam, oil or oil vapours.

1.2.2 The air supply for internal ventilation of electrical equipment is to be as clean and dry as practicable; cooling air for internal ventilation is not to be drawn from below the floor plates in engine and/or boiler rooms.

1.2.3 Equipment is to be so mounted that its enclosing arrangements and the functioning of the built-in equipment will not be affected by distortions, vibrations and movements of the ship's structure or by other damage liable to occur.

1.2.4 If electrical fittings, not of aluminium, are attached to aluminium, suitable provision is to be made to prevent galvanic corrosion.

1.3 Accessibility

1.3.1 Equipment is to be so installed that sufficient space is available for inspection and maintenance as required for all its parts (see [6.1.3]).

1.4 Environmentally controlled spaces

1.4.1 Where electrical equipment is installed in environmentally controlled spaces the ambient temperature for which the equipment is to be suitable may be reduced from 45°C to a value not less than 35°C provided:

a) the equipment is not for use for emergency services
b) temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature
c) the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45°C ambient temperature
d) audible and visual alarms are provided, at a continuously manned control station, to indicate any malfunction of the cooling units.

1.4.2 In accepting a lesser ambient temperature than 45°C, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

2 Earthing of non-current carrying parts

2.1 Parts which are to be earthed

2.1.1 Exposed metal parts of both fixed and portable electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live and similar metal parts inside non-metallic enclosures are to be earthed unless the machines or equipment are:

a) supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors, achieved without the use of auto-transformers (safety voltage); or
b) constructed in accordance with the principle of double insulation.

2.1.2 To minimize shock from high frequency voltage induced by the radio transmitter, handles, handrails and other metal elements on the bridge or open decks are to be in electrical connection with the hull or superstructures.

2.2 Methods of earthing

2.2.1 Metal frames or enclosures of apparatus and electrical machinery may be fixed to, and in metallic contact with, the ship's structure, provided that the surfaces in contact are clean and free from rust, scale or paint when installed and are firmly bolted together.

2.2.2 For metal frames or enclosures which are not earthed as specified in [2.2.1], earthing connections complying with [2.3] and [2.4] are to be used.

2.2.3 For requirements regarding the earthing of coverings of cables and the mechanical protection of cables, see [7.11] and [7.12].

Table 1 : Cross-sectional area of earth-continuity conductors and earthing connections

<table>
<tr><th colspan="2">Type of earthing connection</th><th>Cross-sectional area of associated current carrying conductor</th><th colspan="2">Minimum cross-sectional area of copper earthing connection</th></tr>
<tr><td>1</td><td>Earth-continuity conductor in flexible cable or flexible cord</td><td>Any</td><td colspan="2">Same as current carrying conductor up to and including 16 mm² and one half above 16 mm² but at least 16 mm²</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Earth-continuity conductor incorporated in fixed cable</td><td rowspan="3">Any</td><td colspan="2">a) for cables having an insulated earth-continuity conductor:
• a cross-section equal to the main conductors up to and including 16 mm², but minimum 1,5 mm²
• a cross-section not less than 50% of the cross-section of the main conductor when the latter is more than 16 mm², but at least 16 mm²
b) for cables with a bare earth wire in direct contact with the lead sheath</td></tr>
<tr><td>Cross-section of main conductor (mm²)</td><td>Earthing connection (mm²)</td></tr>
<tr><td>1 ÷ 2,5
4 ÷ 6</td><td>1
1,5</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Separate fixed earthing conductor</td><td>≤ 2,5 mm²</td><td colspan="2">Same as current carrying conductor subject to minimum of 1,5 mm² for stranded earthing connection or 2,5 mm² for unstranded earthing connection</td></tr>
<tr><td>> 2,5 mm²
but ≤ 120 mm²</td><td colspan="2">One half the cross-sectional area of the current carrying conductor, subjected to a minimum of 4 mm²</td></tr>
<tr><td>> 120 mm²</td><td colspan="2">70 mm²</td></tr>
</table>

2.3 Earthing connections

2.3.1 Every earthing connection is to be of copper or other corrosion-resistant material and is to be securely installed and protected, where necessary, against damage and electrolytic corrosion.

2.3.2 The nominal cross-sectional area of each copper earthing connection is to be not less than that required in Tab 1.

Earthing connections of other metals are to have conductance at least equal to that specified for a copper earthing connection.

2.3.3 Metal parts of portable appliances are to be earthed, where required (see [2.1.1]), by means of an earth-continuity conductor in the flexible supply cable or cord, which has the cross-sectional area specified in Tab 1 and which is earthed, for example, through the associated plug and socket.

2.3.4 The lead sheathing or armour of cables is never to be relied upon as the sole means of earthing.

2.3.5 The resistance of earth connection is to be less than 0,1 Ohms.

2.4 Connection to the ship's structure

2.4.1 Every connection of an earth-continuity conductor or earthing lead to the ship's structure is to be secured by means of a screw of brass or other corrosion-resistant material of diameter not less than 6 mm.

2.4.2 Such earthing connection is not to be used for other purposes.

2.4.3 The connection described in [2.4.1] is to be located in an accessible position where it may readily be checked.

2.5 Earthed distribution systems

2.5.1 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current carrying parts and is to be connected to the hull at one point only

2.5.2 In an earthed distribution system in which the earthing connection does not normally carry current, this connection is to conform with the requirements of [2.3], except that the lower limit of 70 mm^2 (see Tab 1) does not apply.

2.5.3 The earthing connection is to be in an accessible position where it may readily be inspected and disconnected for insulation testing.

2.6 Aluminium superstructures

2.6.1 When aluminium superstructures are insulated from the steel hull to prevent electrolytic corrosion, they are to be secured to the hull by means of a separate bonding connection.

2.6.2 The connections are to be adequately close together and are to have a resistance less than 0,1 Ω.

2.6.3 The connections are to be located where they may readily be inspected.

3 Rotating machines

3.1 General

3.1.1 Every rotating machine is preferably to be installed with the shaft in the fore-and-aft direction. Where a rotating machine of 100 kW and over is installed athwartship, or vertically, it is to be ensured that the design of the bearings and the arrangements for lubrication are satisfactory to withstand the rolling specified in Ch 2, Sec 2, Tab 4.

4 Semiconductor convertors

4.1 Semiconductor power convertors

4.1.1 Naturally air-cooled semiconductor convertors are to be installed such that the circulation of air to and from the stacks or enclosures is not impeded and that the temperature of the cooling inlet air to convertor stacks does not exceed the ambient temperature for which the stacks are specified.

5 Vented type storage batteries

5.1 General

5.1.1 Batteries are to be arranged so that each cell or crate of cells is accessible from the top and at least one side to permit replacement and periodical maintenance.

5.1.2 Cells or crates are to be carried on insulating supports of material non-absorbent to the electrolyte (e.g. treated wood).

5.1.3 Cells are to be securely chocked by means of insulating material non-absorbent to the electrolyte, e.g. strips of treated wood. Special mechanical precautions are to be taken to prevent the emergency battery from being damaged by the shock.

5.1.4 Provision is to be made for the free circulation of air.

5.1.5 The direct current cables laid between the batteries and the protective device are to be as short as possible, and each cable is to be protected with a isolating conduit or rigidly supported on isolating supports so as to constitute a short circuit proof installation

5.2 Protection against corrosion

5.2.1 The interior of battery compartments (rooms, lockers, boxes) including all metal parts subject to the electrolyte is to be protected against the deteriorating effect of the latter by electrolyte-resistant coating or other equivalent means, unless corrosion-resistant materials are used.

5.2.2 Interior surfaces of metal shelves for battery cells, whether or not grouped in crates or trays, are to be protected by a lining of electrolyte-resistant material, watertight and carried up to at least 75 mm on all sides. In particular, linings are to have a minimum thickness of 1,5 mm, if of lead sheet for lead-acid batteries, and of 0,8 mm, if of steel for alkaline batteries.

Alternatively, the floor of the room or locker is to be lined as specified above to a height of at least 150 mm.

5.2.3 Battery boxes are to be lined in accordance with [5.2.2] to a height of at least 75 mm.

6 Switchgear and controlgear assemblies

6.1 Main switchboard

6.1.1 A main switchboard is to be so arranged as to give easy access as may be needed to apparatus and equipment, without danger to personnel.

6.1.2 An unobstructed space is to be left in front of the switchboard wide enough to allow access for operation; such width is generally about 1 metre.

When withdrawable equipment is contained in the switchboard, the width of the space is to be not less than 0,5 m when the equipment is fully withdrawn.

Reduced widths may be considered for small ships.

6.1.3 Where necessary, an unobstructed space is to be provided at the rear of the switchboard ample to permit maintenance; in general, the width of this passage is to be not less than 0,6 m, except that this may be reduced to 0,5 m in way of stiffeners and frames, and the height sufficient for the operation foreseen.

6.1.4 If necessary, the clear height above the switchboard specified by the manufacturer is to be maintained for pressure relief in the event of a short-circuit.

6.1.5 When the voltage exceeds the safety voltage, non-conducting mats or gratings are to be provided at the front and rear of the switchboard as necessary,

6.1.6 Piping and conduits are not to be installed in the same space of main switchboards.

Where this is unavoidable, pipes and conduits are to have welded joints only or to be provided with protection against spray from steam or pressurised liquids or dripping.

Alternatively the degree of protection of the switchboard is to be adequately increased.

6.2 Emergency switchboard

6.2.1 For the installation of the emergency switchboard, the same requirements apply as given in [6.1] for the installation of the main switchboard.

6.3 Section boards and distribution boards

6.3.1 For the installation of section and distribution boards, the same requirements apply, as far as applicable, as given in [6.1] for the installation of the main switchboard.

6.3.2 Piping and conduits are not to be installed directly above boards, electrical panels and consoles or in their vicinity.

7 Cables

7.1 General

7.1.1 Cables having insulating materials with different maximum permissible conductor temperatures are not to be bunched together.

Where this is not practicable, the cables are to be so installed that no cable reaches a temperature higher than its rating.

7.1.2 Cables having a protective covering which may damage the covering of more vulnerable cables are not to be bunched with the latter.

7.1.3 Cables having a bare metallic sheath (e.g. of copper) or braid or armour are to be installed in such a way that galvanic corrosion by contact with other metals is prevented.

7.1.4 All cables and wiring external to equipment are to be so installed as not to impair their original flame-retarding properties.

To this end, the following methods may be used:

a) the use of cables which have been tested in accordance with IEC Publication 60332-3 Category A or an equivalent test procedure for cables installed in bunches, or

b) the use of fire stops having at least B0 penetrations fitted as follows (see Fig 1, Fig 2, Fig 3 and Fig 4):
   - cable entries at the main and emergency switchboard
   - where cables enter engine control rooms
   - cable entries at centralised control panels for propulsion machinery and essential auxiliaries
   - at each end of totally enclosed cable trunks
   - at every second deck or approximately 6 metres for verticals runs and every 14 metres for horizontal runs in enclosed and semi-enclosed spaces

c) the use of fire protection coating applied to at least 1 metre in every 14 metres on horizontal cable runs and over the entire length of vertical cable runs for cables installed in enclosed and semi-enclosed spaces.

The cable penetrations are to be installed in steel plates of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks.

These precautions apply in particular to bunches of 5 or more cables in areas with a high fire risk (such as Category A machinery spaces, galleys etc.) and to bunches of more than 10 cables in other areas.

7.1.5 The cable of different voltage are to be segregated, according to their mutual influence. There shall be at least a segregation between following type of cable:

- Control and measurement cable (sensitive cable)
- Power cable
- High emissivity cable.

Figure 1 : Totally enclosed trunks

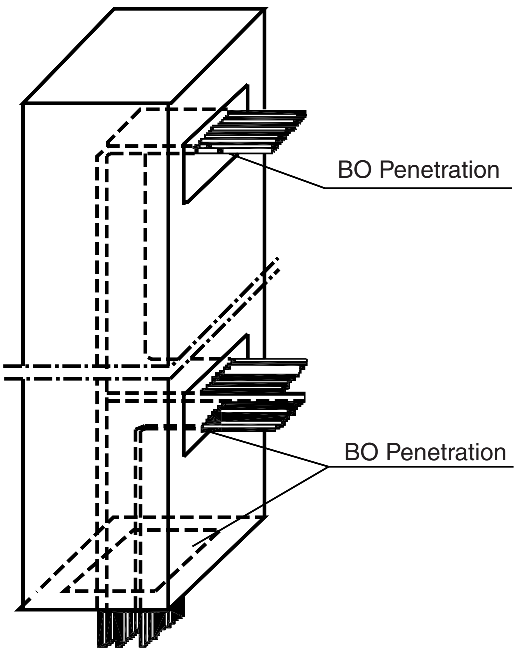


Figure 2 : Non-totally enclosed trunks, vertical

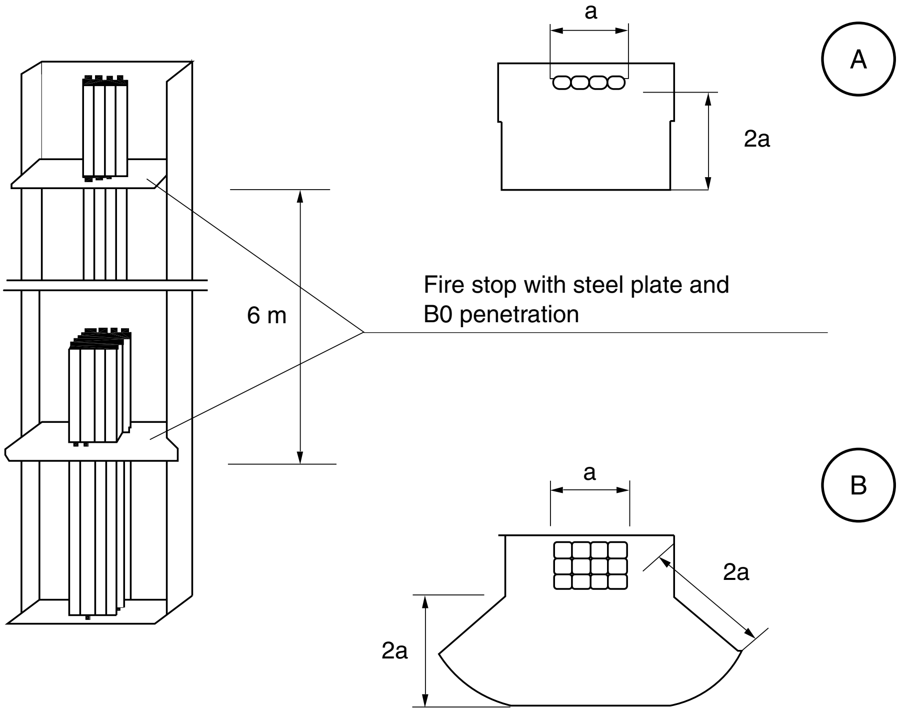


Figure 3 : Non-totally enclosed trunks, horizontal

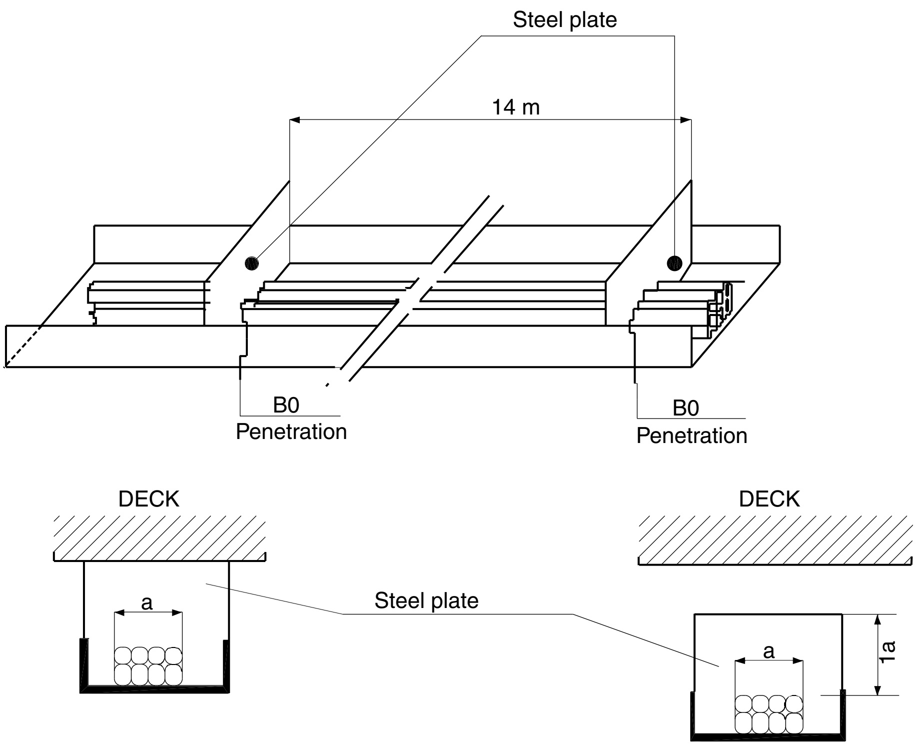
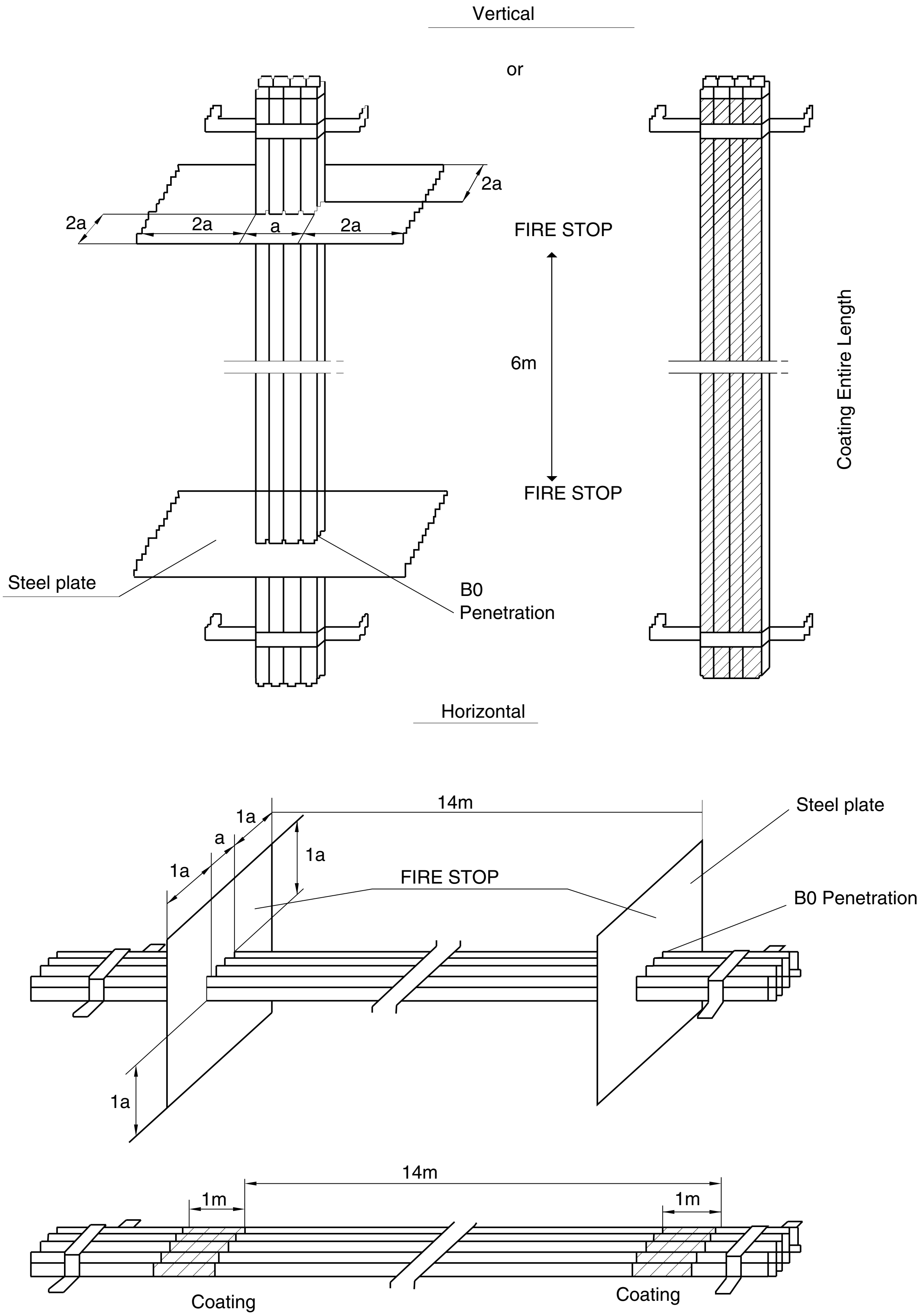


Figure 4 : Open cables runs



7.2 Radius of bend

7.2.1 The internal radius of bend for the installation of cables is to be chosen according to the type of cable as recommended by the manufacturer.

Its value is generally to be not less than the figure given in Tab 2.

7.2.2 Where the installation of cables across expansion joints is unavoidable, the minimum internal radius of the loop at the end of the travel of the expansion joint is to be not less than 12 times the external diameter of the cable.

7.3 Fixing of cables

7.3.1 Cables shall be installed and supported in such a manner as to avoid chafing or other damage.

7.3.2 The supports (tray plates, separate support brackets or hanger ladders) and the corresponding accessories are to be of robust construction and of corrosion-resistant material or suitably treated before erection to resist corrosion.

When cables are installed directly on aluminium structures, fixing devices of aluminium or suitably treated steel are to be used.

7.3.3 With the exception of cables installed in pipes, conduits, trunkings or special casings, cables are to be fixed by means of clips, saddles or straps of suitable material, in order to tighten the cables without their coverings being damaged.

7.3.4 Cable clips or straps made from a material other than metal are to be manufactured of a flame-retardant material.

Table 2 : Bending radii

Cable construction		Overall diameter of cable (D)	Minimum internal radius of bend
Insulation	Outer covering		
Thermoplastic or thermosetting with circular copper conductors	Unarmoured or unbraided	≤ 25 mm	4 D
		> 25 mm	6 D
	Metal braid screened or armoured	Any	6 D
	Metal wire armoured Metal tape armoured or metal-sheathed	Any	6 D
	Composite polyester/metal laminate tape screened units or collective tape screening	Any	8 D
Thermoplastic or thermosetting with shaped copper conductors	Any	Any	8 D

7.3.5 The distances between fastenings and between supports are to be suitably chosen according to the type and number of cables and the probability of vibration.

7.3.6 When cables are fixed by means of clips or straps made from a material other than metal and these cables are not laid on top of horizontal cable supports (e.g. in the case of vertical installation), suitable metal clips or saddles spaced not more than 1 metre apart are to be used in addition in order to prevent the release of cables during a fire.

7.3.7 Suspended cables of fire-resisting type are to be fixed by means of steel straps spaced not more than 500 mm apart.

7.4 Mechanical protection

7.4.1 Cables exposed to risk of mechanical damage are to be protected by metal casing, profiles or grids or enclosed in metal pipes or conduits, unless the cable covering (e.g. armour or sheath) provides adequate mechanical protection.

7.4.2 In situations where there would be an exceptional risk of mechanical damage, cables are to be protected by metal casing, trunkings or conduits, even when armoured, if the ship's structure or attached parts do not afford sufficient protection for the cables.

7.4.3 For the protection of cables passing through decks, see [7.5.3].

7.4.4 Metal casing used for mechanical protection of cables is to be effectively protected against corrosion.

7.5 Penetrations of bulkheads and decks

7.5.1 If cables have to pass without adequate support through non-watertight bulkheads and generally through holes drilled in sheets of structural steel, these holes are to be fitted with glands or bushings of suitable material.

7.5.2 If cables have to pass through a watertight bulkhead or deck, the penetration is to be effected in a watertight manner.

Either suitable individual watertight glands for single cables or boxes containing several cables and filled with a flame-retardant packing may be used for this purpose. Whichever type of penetration is used, the watertight integrity of the bulkheads or deck is to be maintained.

7.5.3 Cables passing through decks and continuing vertically are to be protected against mechanical damage to a suitable height above the deck.

7.5.4 Where cables pass through bulkheads or decks separating areas with a risk of explosion, arrangements are to be such that hazardous gas or dust cannot penetrate through openings for the passage of cables into other areas.

7.5.5 Where cables pass through a bulkhead or deck which is required to have some degree of fire integrity, penetration is to be so effected as to ensure that the required degree of fire integrity is not impaired.

7.5.6 If cables have to pass through deck or bulkhead specially designed for possible submersion of the room, the cable penetration is to reconstitute the tightness of the corresponding deck or bulkhead penetration, with an approved arrangement. test according to IEC 60529 is to be carried out.

7.6 Expansion joints

7.6.1 If there is reason to fear that a tray plate, pipe or conduit may break because of the motion of the ship, different load conditions and temperature variations, appropriate expansion joints are to be provided.

This may apply in particular in the case of cable runs on the weather deck.

7.7 Cables in closed pipes or conduits

7.7.1 Closed pipes or conduits are to have such internal dimensions and radius of bend as will permit the easy drawing in and out of the cables which they are to contain; the internal radius of bend is to be not less than that permitted for cables and, for pipes exceeding 63 mm external diameter, not less than twice the external diameter of the pipe where this value is greater.

7.7.2 Closed pipes and conduits are to be suitably smooth on the interior and are to have their ends shaped or bushed in such a way as not to damage the cable covering.

7.7.3 The space factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional areas of the pipe or conduit) is to be not greater than 0,4.

7.7.4 If necessary, openings are to be provided at the highest and lowest points so as to permit air circulation and ensure that the heat from the cables can be dissipated, and to obviate the possibility of water accumulating at any part of the pipe or conduit.

7.7.5 Vertical trunking for electrical cables is to be so constructed as not to jeopardize the required passive fire protection between the spaces.

7.7.6 Metal pipes or conduits are to be protected against corrosion.

7.7.7 Non-metallic pipes or conduits are to be flame-retardant.

7.8 Cables in casings or trunking and conduits with removable covers

7.8.1 Covers are to be removable and when they are open, cables are to be accessible.

7.8.2 Materials used are to comply with [7.7.6] and [7.7.7].

7.8.3 If the fixing of covers is by means of screws, the latter are to be of non-rusting material and arranged so as not to damage the cables.

7.8.4 Means are to be provided to ensure that the heat from the cables can be dissipated and water accumulation is avoided (see [7.7.4]).

7.9 Cable ends

7.9.1 Terminations in all conductors are to be so made as to retain the original electrical, mechanical, flame-retarding properties of the cable.

7.9.2 Where mechanical clamps are not used, the ends of all conductors having a cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets or compression-type sockets of sufficient size to contain all the strands of the conductor.

7.10 Joints and tappings (branch circuit)

7.10.1 Cable are not to include joints. Where absolutely necessary, cable joints are to be carried out by a junction method approved by the Society, with rebuilding of the insulation and protective coverings.

7.10.2 Joints in all conductors are to be so made as to retain the original electrical (continuity and isolation), mechanical (strength and protection), flame-retarding and, where necessary, fire-resisting properties of the cable.

7.10.3 Tappings (branch circuits) are to be made via suitable connections or in suitable boxes of such design that the conductors remain adequately insulated and protected from atmospheric action and are fitted with terminals or busbars of dimensions appropriate to the current rating.

7.10.4 Cables for safety voltages are not to terminate in the same connection boxes as cable for higher voltages unless separated by suitable means.

7.11 Earthing and continuity of metal coverings of cables

7.11.1 All metal coverings of cables are to be electrically connected to the metal hull of the ship.

7.11.2 Metal coverings are generally to be earthed at both ends of the cable, except for [7.11.3] and [7.11.4].

7.11.3 Single-point earthing is admitted for final sub-circuits (at the supply end), except for those circuits located in areas with a risk of explosion.

7.11.4 Earthing is to be at one end only in those installations (intrinsically safe circuits, control circuits, etc.) where it is required for technical or safety reasons.

7.11.5 Metal coverings of single-core a.c. cables and special d.c. cables with high "ripple" content (e.g. for thyristor equipment) are to be earthed at one point only (e.g. at the mid-point).

7.11.6 The electrical continuity of all metal coverings of cables throughout the length of the latter, particularly at joints and tappings, is to be ensured.

7.11.7 The metal covering of cables may be earthed by means of glands intended for the purpose and so designed as to ensure an effective earth connection.
The glands are to be firmly attached to, and in effective electrical contact with, a metal structure earthed in accordance with these requirements.

7.11.8 The metal covering of cables may also be earthed by means of clamps or clips of corrosion-resistant material making effective contact with the covering and earthed metal.

7.12 Earthing and continuity of metal pipes, conduits and trunking or casings

7.12.1 Metal casings, pipes, conduits and trunking are to be effectively earthed.

7.12.2 Pipes or conduits may be earthed by being screwed into a metal enclosure, or by nuts on both sides of the wall of a metallic enclosure, provided the surfaces in contact are clean and free from rust, scale or paint and that the enclosure is in accordance with these requirements on earthing.
The connection is to be painted immediately after assembly in order to inhibit corrosion.

7.12.3 Pipes and conduits may be earthed by means of clamps or clips of corrosion-resistant metal making effective contact with the earthed metal.

7.12.4 Pipes, conduits or trunking together with connection boxes of metallic material are to be electrically continuous.

7.12.5 All joints in metal pipes and conduits used for earth continuity are to be soundly made and protected, where necessary, against corrosion.

7.13 Precautions for single-core cables for a.c.

7.13.1 For the earthing of metal coverings see [7.11.5].

7.13.2 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of [7.13.3] to [7.13.7] are to be complied with.

7.13.3 Conductors belonging to the same circuit are to be contained within the same pipe, conduit or trunking, unless this is of non-magnetic material.

7.13.4 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

7.13.5 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event, the distance between the external covering of two adjacent cables is to be not greater than one diameter.

7.13.6 When single-core cables having a current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.13.7 Magnetic material is not to be used between single-core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is to be no less than 75 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.14 Cables in refrigerated spaces

7.14.1 For the types of cables permitted in refrigerated spaces, see Ch 2, Sec 3, [9.4].

7.14.2 Power cables installed in refrigerated spaces are not to be covered by thermal insulation. Moreover, such cables are not to be placed directly on the face of the refrigerated space unless they have a thermoplastic or elastomeric extruded.

7.14.3 Power cables entering a refrigerated space are to pass through the walls and thermal insulation at right angles, in tubes sealed at each end and protected against oxidation.

7.15 Cables in areas with a risk of explosion

7.15.1 For the types of cables permitted in areas with a risk of explosion, see Ch 2, Sec 3, [10.2].

7.15.2 For penetration of bulkheads or decks separating areas with a risk of explosion, see [7.5.4].

7.15.3 Cables of intrinsically safe circuits are to be separated from the cables of all other circuits (minimum 50 mm).

7.15.4 Cables for fire pump are to chosen according to Ch 2, Sec 3, [9.6].

7.15.5 Where cables are to go through fuel tank, the cable is to be protected with a pipe which is to be defined according to Ch 1, Sec 10, Tab 3.

7.16 Cables in the vicinity of radio equipment

7.16.1 All cables between antennas and transmitters are to be routed separately of any other cable.

7.16.2 Where it is necessary to use single-core cables, the arrangement of conductors is to be such as to avoid complete or partial loops.

7.17 Cables for submerged bilge pumps

7.17.1 See Ch 2, Sec 3, [9.7].

8 Various appliances

8.1 Lighting fittings

8.1.1 Lighting fittings are to be so arranged as to prevent temperature rises which could damage the cables and wiring.

Note 1: Where the temperature of terminals of lighting fittings exceeds the maximum conductor temperature permitted for the supplied cable (see Ch 2, Sec 3, [9.9]), special installation arrangements, such as terminal boxes thermally insulated from the light source, are to be provided.

8.1.2 Lighting fittings are to be so arranged as to prevent surrounding material from becoming excessively hot.

8.1.3 Lighting fittings are to be secured in place such that they cannot be displaced by the motion of the vessel.

8.2 Heating appliances

8.2.1 Space heaters are to be so installed that clothing, bedding and other flammable material cannot come in con-tact with them in such a manner as to cause risk of fire.

Note 1: To this end, for example, hooks or other devices for hanging garments are not to be fitted above space heaters or, where appropriate, a perforated plate of incombustible material is to be mounted above each heater, slanted to prevent hanging anything on the heater itself.

8.2.2 Space heaters are to be so installed that there is no risk of excessive heating of the bulkheads or decks on which or next to which they are mounted.

8.2.3 Combustible materials in the vicinity of space heaters are to be protected by suitable incombustible and thermal-insulating materials.

8.3 Heating cables and tapes or other heating elements

8.3.1 Heating cables and tapes or other heating elements are not to be installed in contact with combustible materials. Where they are installed close to such materials, they are to be separated by means of a non-flammable material.

Section 13 High Voltage Installations

1 General

1.1 Field of application

1.1.1 The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage being the voltage between phases.

If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.

1.2 Nominal system voltage

1.2.1 The nominal system voltage is not to exceed 15 kV. Nominal voltage below 11 KV are to be chosen according to Tab 1.

Note 1: Where necessary for special application, higher voltages may be accepted by the Society.

1.3 High-voltage, low-voltage segregation

1.3.1 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2 System design

2.1 Distribution

2.1.1 Network configuration for continuity of ship services

It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

2.1.2 Earthed neutral systems

In the event of an earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

2.1.3 Neutral disconnection

Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

2.1.4 Hull connection of earthing impedance

All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

2.1.5 Divided systems

In systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

2.1.6 Means of disconnection are to be fitted in the star point connected to earth of each alternator before the resistor so that the alternator may be disconnected for maintenance and insulation resistance measurement.

2.1.7 All earthing resistors are to be connected to the hull. In order to eliminate possible interference with radio, radar and communication systems, it is recommended that earthing resistors should be bonded together on the hull side of the resistors by means of bonding independent of that provided by the hull.

2.1.8 Alternators running in parallel may have a common neutral connection to earth provided they are suitably designed to avoid excessive circulating currents.

This is particularly important if the alternators are of different size and make. Alternators in which the third harmonic content does not exceed 5% may be considered adequate.

Note 1: This would mostly occur with a neutral bus with a single grounding resistor with the associated neutral switching. Where individual resistors are used, circulation of the third harmonic currents between paralleled alternators is minimised.

2.1.9 In systems with earthed neutral, resistors or other current-limiting devices for the connection of the neutrals to the hull are to be provided for each section in which the systems are split [2.1.2].

2.2 Degrees of protection

2.2.1 General

Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of Ch 2, Sec 3, Tab 3.

2.2.2 Rotating machines

The degree of protection of enclosures of rotating electrical machines is to be at least the one required by IP 23 (see Ch 2, Sec 3).

The degree of protection of terminals is to be at least IP44.

For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

2.2.3 Transformers

The degree of protection of enclosures of transformers is to be at least IP23.

For transformers installed in spaces accessible to unqualified personnel a degree of protection of at least IP4X is required.

For transformers not contained in enclosures, see [7.1].

2.2.4 Switchgear, controlgear assemblies and convertors

The degree of protection of metal enclosed switchgear, controlgear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static convertors installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

2.3 Insulation

2.3.1 In general, for non Type Tested equipment phase-to-phase air clearances and phase-to- earth air clearances between non-insulated parts are to be not less than those specified in Tab 1.

Intermediate values may be accepted for nominal voltages provided that the next highest air clearance is observed.

In the case of smaller distances, an appropriate voltage impulse test is to be applied.

Table 1 : Minimum clearances

Rated voltage kV	Minimum clearance mm
3 - 3,3	55
6 - 6,6	90
10 - 11	120

2.3.2 Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with relevant IEC Publications for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.

For non-standardized parts within the busbar section of a switchgear assembly, the minimum creepage distance is to be at least 25 mm/kV and behind current limiting devices, 16mm/kV.

2.4 Protection

2.4.1 Faults on the generator side of the circuit breaker

Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator.

In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

2.4.2 Any earth fault in the system is to be indicated by means of a visual and audible alarm.

In low impedance or direct earthed systems provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.

A system is defined effectively earthed (low impedance) when this factor is lower than 0.8. A system is defined non-effectively earthed (high impedance) when this factor is higher than 0,8.

Note 1: Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/3^{1/2}$ and 1.

2.4.3 Power transformers

Power transformers are to be provided with overload and short circuit protection.

When transformers are connected in parallel, tripping of the protective devices on the primary side is to automatically trip the switch connected on the secondary side.

2.4.4 Voltage transformers for control and instrumentation

Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

2.4.5 Fuses

Fuses are not to be used for overload protection.

2.4.6 Low voltage systems

Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:

a) direct earthing of the lower voltage system

b) appropriate neutral voltage limiters

c) earthed screen between the primary and secondary windings of transformers.

3 Rotating machinery

3.1 Stator windings of generators

3.1.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

3.2 Temperature detectors

3.2.1 Rotating machinery is to be provided with temperature detectors in its stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

3.3 Tests

3.3.1 In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with IEC 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

4 Power transformers

4.1 General

4.1.1 Transformers are to be of dry type according to IEC 60726.

5 Cables

5.1 General

5.1.1 Cables are to be constructed in accordance with IEC 60092-353 and 60092-354 or other equivalent Standard.

6 Switchgear and controlgear assemblies

6.1 General

6.1.1 Switchgear and controlgear assemblies are to be constructed according to IEC 60298 and the following additional requirements.

6.2 Construction

6.2.1 Mechanical construction

Switchgear is to be of metal - enclosed type in accordance with IEC 60298 or of the insulation - enclosed type in accordance with IEC 60466.

6.2.2 Locking facilities

Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

6.2.3 Shutters

The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

6.2.4 Earthing and short-circuiting

For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked on in safety.

6.3 Auxiliary systems

6.3.1 Source of supply

If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

6.3.2 Number of supply sources

At least two independent sources of supply for auxiliary circuits of each independent section of the system (see [2.1.1]) are to be provided. Where necessary one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

6.4 High voltage test

6.4.1 A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test procedure and voltages are to be according to IEC 60298.

7 Installation

7.1 Electrical equipment

7.1.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance to spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed indicating danger of high-voltage. As regards high-voltage electrical equipment installed outside the aforementioned spaces, similar marking is to be provided.

7.2 Cables

7.2.1 Runs of cables

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

7.2.2 Segregation

High voltage cables are to be segregated from cables operating at different voltage ratings; in particular, they are not to be run in the same cable bunch, in the same ducts or pipes, or in the same box.

Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in [2.3.1]. However, high voltage cables are not to be installed on the same cable tray for cables operating at the nominal system voltage of 1 kV and less.

7.2.3 Installation arrangements

High voltage cables are generally to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic castings effectively bonded to earth.

7.2.4 Terminations

Terminations in all conductors of high voltage cables are, as far as practicable, to be effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc).

7.2.5 Marking

High voltage cables are to be readily identifiable by suitable marking.

7.2.6 Test after installation

Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories.

The test is to be carried out after an insulation resistance test.

When a d.c. voltage withstand test is carried out, the voltage is to be not less than:

- 1,6 (2,5 Uo + 2 kV) for cables of rated voltage (Uo) up to and including 3,6 kV, or
- 4,2 Uo for higher rated voltages

where Uo is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.

The test voltage is to be maintained for a minimum of 15 minutes.

After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge.

An insulation resistance test is then repeated.

Alternatively, an a.c. voltage withstand test may be carried out on the advice of the high voltage cable manufacturer at a voltage not less than the normal operating voltage of the cable, to be maintained for a minimum of 24 hours.

Note 1: Tests specified in IEC 60502 will be considered adequate.

Section 14 Electric Propulsion Plant

1 General

1.1 Applicable requirements

1.1.1 The following requirements apply to ships for which the main propulsion plants are provided by at least one electric propulsion motor and its electrical supply. All electrical components of the propulsion plants are to comply with these requirements.

1.1.2 Prime movers are to comply with the requirements of Ch 1, Sec 2.

1.1.3 For the torsional vibration characteristics of the electric propulsion plant, the provisions of Ch 1, Sec 9 apply.

1.1.4 Cooling and lubricating oil systems are to comply with the requirements of Ch 1, Sec 10.

1.1.5 Monitoring and control systems are to comply with the requirements of Part C, Chapter 3.

1.1.6 Installations assigned an additional notation for automation are to comply with the requirements of Part E.

1.2 Operating conditions

1.2.1 The normal torque available on the electric propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at its maximum service speed.

1.2.2 Adequate torque margin is to be provided for three-phase synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 When an electric generating plant has a continuous rating greater than the electric propulsion motor rating, means are to be provided to limit the continuous input to the motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.4 The plant as a whole is to have sufficient overload capacity to provide the torque, power and reactive power needed during starting and manoeuvring conditions.

Locked rotor torque which may be required in relation to the operation of the vessel (e.g. for navigation in ice) is to be considered.

1.2.5 The electric motors and shaftline are to be constructed and installed so that, at any speed reached in service, all the moving components are suitably balanced.

2 Design of the propulsion plant

2.1 General

2.1.1 The electrical power for the propulsion system may be supplied from generating sets, dedicated to the propulsion system, or from a central power generation plant, which supplies the ship's services and electric propulsion.

The minimum configuration of an electric propulsion plant consists of one prime mover, one generator and one electric motor. When the electrical production used for propulsion is independent of the shipboard production, the diesel engines driving the electric generators are to be considered as main engines.

2.1.2 For plants having only one propulsion motor controlled via a static convertors, a standby convertors which it is easy to switch over to is to be provided. Double stator windings with one convertor for each winding are considered as an alternative solution.

2.1.3 In electric propulsion plants having two or more constant voltage propulsion generating sets, the electrical power for the ship's auxiliary services may be derived from this source. Additional ship's generators for auxiliary services need not be fitted provided that effective propulsion and the services mentioned in Ch 2, Sec 3, [2.2.3] are maintained with any one generating set out of service.

Where transformers are used to supply the ship's auxiliary services, see Ch 2, Sec 5.

2.1.4 Plants having two or more propulsion generators, two or more static convertors or two or more motors on one propeller shaft are to be so arranged that any unit may be taken out of service and disconnected electrically, without affecting the operation of the others.

2.2 Power supply

2.2.1 Where the plant is intended exclusively for electric propulsion, voltage variations and maximum voltage are to be maintained within the limits required in Ch 2, Sec 2.

2.2.2 In special conditions (e.g. during crash-stop manoeuvres), frequency variations may exceed the limits stipulated in Ch 2, Sec 2 provided that other equipment operating on the same network is not unduly affected.

2.2.3 The electric plant is to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor convertors, in accordance with Ch 2, Sec 2.

2.3 Auxiliary machinery

2.3.1 Propeller/thruster auxiliary plants are to be supplied directly from the main switchboard or from the main distribution board or from a distribution board reserved for such circuits, at the auxiliary rated voltage.

2.3.2 When the installation has one or more lubrication systems, devices are to be provided to ensure the monitoring of the lubricating oil return temperature.

2.3.3 Propelling machinery installations with a forced lubrication system are to be provided with alarm devices which will operate in the event of oil pressure loss.

2.4 Electrical Protection

2.4.1 Automatic disconnections of electric propulsion plants which adversely affect the manoeuvrability of the ship are to be restricted to faults liable to cause severe damage to the equipment.

2.4.2 The following protection of convertors is to be provided:

- protection against overvoltage in the supply systems to which convertors are connected
- protection against overcurrents in semiconductor elements during normal operation
- short-circuit protection.

2.4.3 Overcurrent protective devices in the main circuits are to be set sufficiently high so that there is no possibility of activation due to the overcurrents caused in the course of normal operation, e.g. during manoeuvring or in heavy seas.

2.4.4 Overcurrent protection may be replaced by automatic control systems ensuring that overcurrents do not reach values which may endanger the plant, e.g. by selective tripping or rapid reduction of the magnetic fluxes of the generators and motors.

2.4.5 In the case of propulsion plants supplied by generators in parallel, suitable controls are to ensure that, if one or more generators are disconnected, those remaining are not overloaded by the propulsion motors.

2.4.6 In three-phase systems, phase-balance protective devices are to be provided for the motor circuit which de-excite the generators and motors or disconnect the circuit concerned.

2.5 Excitation of electric propulsion motor

2.5.1 Where applicable, each propulsion motor is to have its own exciter.

2.5.2 For plants where only one generator or only one motor is foreseen, each machine is to be provided with a standby exciter, which it is easy to switch over to.

2.5.3 In the case of multi-propeller propulsion ships, one standby exciter which it is easy to switch over to is to be provided.

2.5.4 For the protection of field windings and cables, means are to be provided for limiting the induced voltage when the field circuits are opened. Alternatively, the induced voltage when the field circuits are opened is to be maintained at the nominal design voltage.

2.5.5 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor convertors.

3 Construction of rotating machines and semiconductor convertors

3.1 Ventilation

3.1.1 Where electrical machines are fitted with an integrated fan and are to be operated at speeds below the rated speed with full load torque, full load current, full load excitation or the like, the design temperature rise is not to be exceeded.

3.1.2 Where electrical machines or convertors are force-ventilated, at least two fans, or other suitable arrangements, are to be provided so that limited operation is possible in the event of one fan failing.

3.2 Protection against moisture and condensate

3.2.1 Machines and equipment which may be subject to the accumulation of moisture and condensate are to be provided with effective means of heating. The latter is to be provided for motors above 500 kW, in order to maintain the temperature inside the machine at about 3°C above the ambient temperature.

3.2.2 Provision is to be made to prevent the accumulation of bilge water, which is likely to enter inside the machine.

3.3 Rotating machines

3.3.1 Electrical machines are to be able to withstand the excess speed which may occur during operation of the ship.

3.3.2 The design of rotating machines supplied by static convertors is to consider the effects of harmonics.

3.3.3 The winding insulation of electrical machines is to be capable of withstanding the overvoltage which may occur in manoeuvring conditions.

3.3.4 The design of a.c. machines is to be such that they can withstand without damage a sudden short-circuit at their terminals under rated operating conditions.

3.3.5 The obtainable current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions, including short-circuit in the transient period.

3.4 Semiconductor convertors

3.4.1 The following limiting repetitive peak voltages U_{RM} are to be used as a base for each semiconductor valve:

- when connected to a supply specifically for propeller drives:

  $U_{RM} = 1,5\ U_P$

- when connected to a common main supply:

  $U_{RM} = 1,8\ U_P$

  where:

  U_P : Peak value of the rated voltage at the input of the semiconductor convertors.

3.4.2 For semiconductor convertors elements connected in series, the values in [3.4.1] are to be increased by 10%. Equal voltage distribution is to be ensured.

3.4.3 For parallel-connected convertors elements, an equal current distribution is to be ensured.

3.4.4 Means are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor convertors. Suitable filters are to be installed to keep the current and voltage within the limits given in Ch 2, Sec 2.

4 Control and monitoring

4.1 General

4.1.1 The control and monitoring systems, including computer based systems, are to be type approved, according to Ch 3, Sec 6.

4.2 Power plant control systems

4.2.1 The power plant control systems are to ensure that adequate propulsion power is available, by means of automatic control systems and/or manual remote control systems.

4.2.2 The automatic control systems are to be such that, in the event of a fault, the propeller speed and direction of thrust do not undergo substantial variations.

4.2.3 Failure of the power plant control system is not to cause complete loss of generated power (i.e. blackout) or loss of propulsion.

4.2.4 The loss of power plant control systems is not to cause variations in the available power; i.e. starting or stopping of generating sets is not to occur as a result.

4.2.5 Where power-aided control (for example with electrical, pneumatic or hydraulic aid) is used for manual operation, failure of such aid is not to result in interruption of power to the propeller, any such device is to be capable of purely manual operation.

4.2.6 The control system is to include the following main functions:

- monitoring of the alarms: any event critical for the proper operation of an essential auxiliary or a main element of the installation requiring immediate action to avoid a breakdown is to activate an alarm
- speed or pitch control of the propeller
- shutdown or slow down when necessary.

4.2.7 Where the electric propulsion system is supplied by the main switchboard together with the ship's services, load shedding of the non-essential services and /or power limitation of the electric propulsion is to be provided. An alarm is to be triggered in the event of power limitation or load shedding.

4.2.8 The risk of blackout due to electric propulsion operation is to be eliminated. At the request of the Society, a failure mode and effects analysis is to be carried out to demonstrate the reliability of the system.

4.3 Indicating instruments

4.3.1 In addition to the provisions of Part C, Chapter 3 of the Rules, instruments indicating consumed power and power available for propulsion are to be provided at each propulsion remote control position.

4.3.2 The instruments specified in [4.3.3]and [4.3.4] in relation to the type of plant are to be provided on the power control board or in another appropriate position.

4.3.3 The following instruments are required for each propulsion alternator:

- an ammeter on each phase, or with a selector switch to all phases
- a voltmeter with a selector switch to all phases
- a wattmeter
- a tachometer or frequency meter
- a power factor meter or a var-meter or a field ammeter for each alternator operating in parallel
- a temperature indicator for direct reading of the temperature of the stator windings, for each alternator rated above 500 kW.

4.3.4 The following instruments are required for each a.c. propulsion motor:

- an ammeter on the main circuit
- an embedded sensor for direct reading of the temperature of the stator windings, for motors rated above 500 kW
- an ammeter on the excitation circuit for each synchronous motor
- a voltmeter for the measurement of the voltage between phases of each motor supplied through a semiconductor frequency convertors.

4.3.5 Where a speed measuring system is used for control and indication, the system is to be duplicated with separate sensor circuits and separate power supply.

4.3.6 An ammeter is to be provided on the supply circuit for each propulsion semiconductor bridge.

4.4 Alarm system

4.4.1 An alarm system is to be provided, in accordance with the requirements of Part C, Chapter 3. The system is to give an indication at the control positions when the parameters specified in [4.4] assume abnormal values or any event occurs which can affect the electric propulsion.

4.4.2 Where an alarm system is provided for other essential equipment or installations, the alarms in [4.4.1] may be connected to such system.

4.4.3 Critical alarms for propulsion are to be indicated to the bridge separately.

4.4.4 The following alarms are to be provided, where applicable:

- high temperature of the cooling air of machines and semiconductor convertors provided with forced ventilation (see Note 1)
- reduced flow of primary and secondary coolants of machines and semiconductor convertors having a closed cooling system with a heat exchanger
- leakage of coolant inside the enclosure of machines and semiconductor convertors with liquid-air heat exchangers
- high winding temperature of generators and propulsion motors, where required (see [4.3])
- low lubricating oil pressure of bearings for machines with forced oil lubrication
- tripping of protective devices against overvoltages in semiconductor convertors (critical alarm)
- tripping of protection on filter circuits to limit the disturbances due to semiconductor convertors
- tripping of protective devices against overcurrents up to and including short-circuit in semiconductor convertors (critical alarm)
- voltage unbalance of three-phase a.c. systems supplied by semiconductor frequency convertors

- earth fault for the main propulsion circuit (see Note 2)
- earth fault for excitation circuits of propulsion machines (see Note 3).

Note 1: As an alternative to the air temperature of convertors or to the airflow, the supply of electrical energy to the ventilator or the temperature of the semiconductors may be monitored.

Note 2: In the case of star connected a.c. generators and motors with neutral points earthed, this device may not detect an earth fault in the entire winding of the machine.

Note 3: This may be omitted in brushless excitation systems and in the excitation circuits of machines rated up to 500 kW. In such cases, lamps, voltmeters or other means are to be provided to detect the insulation status under operating conditions.

4.5 Reduction of power

4.5.1 Power is to be automatically reduced in the following cases:

- low lubricating oil pressure of bearings of propulsion generators and motors
- high winding temperature of propulsion generators and motors
- fan failure in machines and convertors provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor convertors
- load limitation of generators or inadequate available power.

4.5.2 When power is reduced automatically, this is to be indicated at the propulsion control position (critical alarm).

4.5.3 Switching-off of the semiconductors in the event of abnormal service operation is to be provided in accordance with the manufacturer’s specification.

5 Installation

5.1 Ventilation of spaces

5.1.1 Loss of ventilation to spaces with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other. Equivalent arrangements using several independently supplied fans may be considered.

5.2 Cable runs

5.2.1 Instrumentation and control cables are to comply with the requirements of Ch 3, Sec 5 of the Rules.

5.2.2 Where there is more than one propulsion motor, all cables for any one machine are to be run as far as is practicable away from the cables of other machines.

5.2.3 Cables which are connected to the sliprings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manoeuvring.

6 Tests

6.1 Test of rotating machines

6.1.1 The test requirements are to comply with Ch 2, Sec 4.

6.1.2 For rotating machines, such as synchronous generators and synchronous electric motors, of a power of more than 3 MW, a test program is to be submitted to the Society for approval.

6.1.3 In relation to the evaluation of the temperature rise, it is necessary to consider the supplementary thermal losses induced by harmonic currents in the stator winding. To this end, two methods may be used:

- direct test method, when the electric propulsion motor is being supplied by its own frequency convertors, and/or back to back arrangement according to the supplier’s facility
- indirect test method, when a validation of the estimation of the temperature excess due to harmonics is to be documented. A justification based on a computer program calculation may be taken into consideration, provided that validation of such program is demonstrated by previous experience.

7 Specific requirements for PODs

7.1 General

7.1.1 The requirements for the structural part of a POD are specified in Pt B, Ch 9, Sec 1, [11].

7.1.2 When used as steering manoeuvring system, the POD is to comply with the requirements of Ch 1, Sec 12.

7.2 Rotating commutators

7.2.1 As far as the electrical installation is concerned, the electric motor is supplied by a rotating commutator which rotates with the POD. The fixed part of the power transmission is connected to the ship supply, which uses the same components as a conventional propulsion system. Sliding contacts with a suitable support are used between the fixed and rotating parts.

7.2.2 The rotating commutator is to be type approved. Type tests are to be carried out, unless the manufacturer can produce evidence based on previous experience indicating the satisfactory performance of such equipment on board ships.

7.2.3 A test program is to be submitted to the Society for approval. It is to be to demonstrated that the power transmission and transmission of low level signals are not affected by the environmental and operational conditions prevailing on board. To this end, the following checks and tests are to be considered:

- check of the protection index (I.P.), in accordance with the location of the rotating commutator
- check of the clearances and creepage distances
- check of insulation material (according to the test procedure described in IEC Publication 60112)
- endurance test:

  After the contact pressure and rated current are set, the commutator is subjected to a rotation test. The number of rotations is evaluated taking into consideration the ship operation and speed rotation control system. The possibility of turning the POD 180° to proceed astern and 360° to return to the original position is to be considered. The commutator may be submitted to cycles comprising full or partial rotation in relation to the use of the POD as steering gear. The voltage drops and current are to be recorded.

  An overload test is to be carried out in accordance with Ch 2, Sec 4 (minimum 150%, 15 seconds)
- check of the behaviour of the sliprings when subjected to the vibration defined in Ch 3, Sec 6
- check of the behaviour of the sliprings, after damp heat test, as defined in Part C, Chapter 3, and possible corrosion of the moving parts and contacts

  After the damp heat test, the following are to be carried out:
- Insulation measurement resistance test. The minimum resistance is to be in accordance with Ch 2, Sec 4, Tab 2.
- Dielectric strength test as defined in Ch 2, Sec 4.

7.3 Electric motors

7.3.1 The thermal losses are dissipated by the liquid cooling of the bulb and by the internal ventilation of the POD. The justification for the evaluation of the heating balance between the sea water and air cooling is to be submitted to the Society.

Note 1: The calculation method used for the evaluation of the cooling system (mainly based on computer programs) is to be documented. The calculation method is to be justified based on the experience of the designer of the system. The results of scale model tests or other methods may be taken into consideration.

7.3.2 Means to adjust the air cooler characteristics are to be provided on board, in order to obtain an acceptable temperature rise of the windings. Such means are to be set following the dock and sea trials.

7.4 Instrumentation and associated devices

7.4.1 Means are to be provided to transmit the low level signals connected to the sensors located in the POD.

7.5 Additional tests

7.5.1 Tests of electric propulsion motors are to be carried out in accordance with Ch 2, Sec 4, and other tests in accordance with Ch 2, Sec 15.

7.5.2 Tests are to be performed to check the validation of the temperature rise calculation.

Section 15 Testing

1 General

1.1 Rule application

1.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service, the electrical equipment is to be tested in accordance with Articles [3], [4] and [5] to the satisfaction of the Surveyor in charge.

1.2 Insulation-testing instruments

1.2.1 Insulation resistance may be measured with an instrument applying a voltage of at least 500 V. The measurement will be taken when the deviation of the measuring device is stabilized.

Note 1: Any electronic devices present in the installation are to be disconnected prior to the test in order to prevent damage.

1.2.2 For high voltage installation, the measurement is to be taken with an instrument applying a voltage adapted to the rated value and agreed with the Society

2 Type approved components

2.1

2.1.1 The following components are to be type approved or in accordance with [2.1.2]:

- electrical cables
- transformers
- electric motors
- electrical convertors for primary essential services
- switching devices (circuit-breakers, contactors, disconnectors, etc.) and overcurrent protective devices
- sensors, alarm panels, electronic protective devices, automatic and remote control equipment, actuators, safety devices for installations intended for essential services (steering, controllable pitch propellers, propulsion machinery, etc.), electronic speed regulators for main or auxiliary engines
- computers used for tasks essential to safety.

2.1.2 Case by case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

3 Insulation resistance

3.1 Lighting and power circuits

3.1.1 The insulation resistance between all insulated poles (or phases) and earth and, where practicable, between poles (or phases), is to be at least 1 MΩ in ordinary conditions.

The installation may be subdivided to any desired extent and appliances may be disconnected if initial tests give results less than that indicated above.

3.2 Internal communication circuits

3.2.1 Circuits operating at a voltage of 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 MΩ.

3.2.2 Circuits operating at voltages below 50 V are to have an insulation resistance between conductors and between each conductor and earth of at least 0,33 MΩ.

3.2.3 If necessary, any or all appliances connected to the circuit may be disconnected while the test is being conducted.

3.3 Switchboards

3.3.1 The insulation resistance between each busbar and earth and between each insulated busbar and the busbar connected to the other poles (or phases) of each main switchboard, emergency switchboard, section board, etc. is to be not less than 1 MΩ.

3.3.2 The test is to be performed before the switchboard is put into service with all circuit-breakers and switches open, all fuse-links for pilot lamps, earth fault-indicating lamps, voltmeters, etc. removed and voltage coils temporarily disconnected where otherwise damage may result.

3.4 Generators and motors

3.4.1 The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded.

3.4.2 The test is to be carried out with the machine hot immediately after running with normal load.

3.4.3 The insulation resistance of generator and motor connection cables, field windings and starters is to be at least 1 MΩ.

4 Earth

4.1 Electrical constructions

4.1.1 Tests are to be carried out, by visual inspection or by means of a tester, to verify that all earth-continuity conductors and earthing leads are connected to the frames of apparatus and to the hull, and that in socket-outlets having earthing contacts, these are connected to earth.

4.2 Metal-sheathed cables, metal pipes or conduits

4.2.1 Tests are to be performed, by visual inspection or by means of a tester, to verify that the metal coverings of cables and associated metal pipes, conduits, trunking and casings are electrically continuous and effectively earthed.

5 Operational tests

5.1 Generating sets and their protective devices

5.1.1 Generating sets are to be run at full rated load to verify that the following are satisfactory:

- electrical characteristics
- commutation (if any)
- lubrication
- ventilation
- noise and vibration level.

5.1.2 Suitable load variations are to be applied to verify the satisfactory operation under steady state and transient conditions (see Ch 2, Sec 4, [2]) of:

- voltage regulators
- speed governors.

5.1.3 Generating sets intended to operate in parallel are to be tested over a range of loading up to full load to verify that the following are satisfactory:

- parallel operation
- sharing of the active load
- sharing of the reactive load (for a.c. generators).

Synchronizing devices are also to be tested.

5.1.4 The satisfactory operation of the following protective devices is to be verified:

- overspeed protection
- overcurrent protection (see Note 1)
- load-shedding devices
- any other safety devices.

For sets intended to operate in parallel, the correct operation of the following is also to be verified:

- reverse-power protection for a.c. installations (or reverse-current protection for d.c. installations)
- minimum voltage protection.

Note 1: Simulated tests may be used to carry out this check where appropriate.

5.1.5 The satisfactory operation of the emergency source of power and of the transitional source of power, when required, is to be tested. In particular, the automatic starting and the automatic connection to the emergency switchboard, in case of failure of the main source of electrical power, are to be tested.

5.2 Switchgear

5.2.1 All switchgear is to be loaded and, when found necessary by the attending Surveyor, the operation of overcurrent protective devices is to be verified (see Note 1).

Note 1: The workshop test is generally considered sufficient to ensure that such apparatus will perform as required while in operation.

5.2.2 Short-circuit tests may also be required at the discretion of the Society in order to verify the selectivity characteristics of the installation.

5.3 Consuming devices

5.3.1 Electrical equipment is to be operated under normal service conditions (though not necessarily at full load or simultaneously) to verify that it is suitable and satisfactory for its purpose.

5.3.2 Motors and their starters are to be tested under normal operating conditions to verify that the following are satisfactory:

- power
- operating characteristics
- commutation (if any)
- speed
- direction of rotation
- alignment.

5.3.3 The remote stops foreseen are to be tested.

5.3.4 Lighting fittings, heating appliances etc. are to be tested under operating conditions to verify that they are suitable and satisfactory for their purposes (with particular regard to the operation of emergency lighting).

5.4 Communication systems

5.4.1 Communication systems, order transmitters and mechanical engine-order telegraphs are to be tested to verify their suitability.

5.5 Installations in areas with a risk of explosion

5.5.1 Installations and the relevant safety certification are to be examined to ensure that they are of a type permitted in the various areas and that the integrity of the protection concept has not been impaired.

5.6 Voltage drop

5.6.1 Where it is deemed necessary by the attending Surveyor, the voltage drop is to be measured to verify that the permissible limits are not exceeded (see Ch 2, Sec 3, [9.11.4]).

CHAPTER 3
AUTOMATION

Section 1	General Requirements
Section 2	Design Requirements
Section 3	Computer Based Systems
Section 4	Constructional Requirements
Section 5	Installation Requirements
Section 6	Testing

Section 1 General Requirements

1 General

1.1 Field of application

1.1.1 The following requirements apply to automation systems, installed on all ships, intended for essential services as defined in Ch 2, Sec 1. They also apply to systems required in Part C, Chapter 1 and Part C, Chapter 2, installed on all ships.

1.1.2 This chapter is intended to avoid that failures or malfunctions of automation systems associated with essential and non-essential services cause danger to other essential services.

1.1.3 Requirements for unattended machinery spaces and for additional notations are specified in Part E.

1.2 Regulations and standards

1.2.1 The regulations and standards applicable are those defined in Ch 2, Sec 1.

1.3 Definitions

1.3.1 Unless otherwise stated, the terms used in this chapter have the definitions laid down in Ch 2, Sec 1 or in the IEC standards. The following definitions also apply:

- Alarm indicator is an indicator which gives a visible and/or audible warning upon the appearance of one or more faults to advise the operator that his attention is required.
- Alarm system is a system intended to give a signal in the event of abnormal running condition.
- Application software is a software performing tasks specific to the actual configuration of the computer based system and supported by the basic software.
- Automatic control is the control of an operation without direct or indirect human intervention, in response to the occurrence of predetermined conditions.
- Automation systems are systems including control systems and monitoring systems.
- Basic software is the minimum software, which includes firmware and middleware, required to support the application software.
- Cold standby system is a duplicated system with a manual commutation or manual replacement of cards which are live and non-operational. The duplicated system is to be able to achieve the operation of the main system with identical performance, and be operational within 10 minutes.
- Control station is a group of control and monitoring devices by means of which an operator can control and verify the performance of equipment.
- Control system is a system by which an intentional action is exerted on an apparatus to attain given purposes.
- Fail safe is a design property of an item in which the specified failure mode is predominantly in a safe direction with regard to the safety of the ship, as a primary concern.
- Full redundant is used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function and operate simultaneously.
- Hot standby system is used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function, one of which is in operation while the other is on standby with an automatic change-over switch.
- Instrumentation is a sensor or monitoring element.
- Local control is control of an operation at a point on or adjacent to the controlled switching device.
- Manual control is control of an operation acting on final control devices either directly or indirectly with the aid of electrical, hydraulic or mechanical power.
- Monitoring system is a system designed to observe the correct operation of the equipment by detecting incorrect functioning (measure of variables compared with specified value).
- Safety system is a system intended to limit the consequence of failure and is activated automatically when an abnormal condition appears.
- Redundancy is the existence of more than one means for performing a required function.
- Remote control is the control from a distance of apparatus by means of an electrical or other link.
- Inspection of components (only hardware) from sub-suppliers: proof that components and/or sub-assemblies conform to specification.
- Quality control in production: evidence of quality assurance measures on production.

- Final test reports: reports from testing of the finished product and documentation of the test results.
- Hardware description:
  - system block diagram, showing the arrangement, input and output devices and interconnections
  - connection diagrams
  - details of input and output devices
  - details of power supplies.
- Failure analysis for safety related functions only (e.g. FMEA): the analysis is to be carried out using appropriate means, e.g.:
  - fault tree analysis
  - risk analysis
  - FMEA or FMECA.

  The purpose is to demonstrate that for single failures, systems will fail to safety and that systems in operation will not be lost or degraded beyond acceptable performance criteria when specified by the Society.

1.4 General

1.4.1 The automation systems and components, as indicated in Ch 2, Sec 15, [2], are to be type approved according to the applicable requirements of these Rules and in particular those stated in this Chapter

Case by case approval may also be granted at the discretion of the Society, based on submission of adequate documentation and subject to the satisfactory outcome of any required tests.

1.4.2 Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control.

1.4.3 Control, alarm and safety systems are to be based on the fail-to-safety principle.

1.4.4 Failure of automation systems is to generate an alarm.

1.4.5 Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in tables located in Part C, Chapter 1 and in Part E, Chapter 3.

Each row of these tables is to correspond to one independent sensor.

2 Documentation

2.1 General

2.1.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in this Section.

2.2 Documents to be submitted

2.2.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	I	The general specification for the automation of the ship
2	A	The detailed specification of the essential service systems
3	A	The list of components used in the automation circuits, and references (Manufacturer, type, etc.)
4	I	Instruction manuals
5	I	Test procedures for control, alarm and safety systems
6	A	A general diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers
7	A	The diagrams of the supply circuits of automation systems, identifying the power source
8	A	The list of monitored parameters for alarm/monitoring and safety systems
9	A	Diagram of the engineers' alarm system
10	I	List of computerized systems as mentioned in Ch 3, Sec 3, [1.2.1]
11	A/I	Documentation as mentioned in Ch 3, Sec 3, Tab 2
12	I	Software registry as mentioned in Ch 3, Sec 3, [4.3.1]
(1) A = to be submitted for approval I = to be submitted for information.		

2.3 Documents for type approval of equipment

2.3.1 Documents to be submitted for type approval of equipment are listed hereafter:

- a request for type approval from the manufacturer or his authorized representative
- the technical specification and drawings depicting the system, its components, characteristics, working principle, installation and conditions of use and, when there is a computer based system, the documents listed in Ch 3, Sec 3, Tab 2
- any test reports previously prepared by specialised laboratories.

2.3.2 Modifications

Modifications are to be documented by the manufacturer. For computer based systems, requirements are mentioned in Ch 3, Sec 3.

3 Environmental and supply conditions

3.1 General

3.1.1 General

The automation system is to operate correctly when the power supply is within the range specified in Ch 3, Sec 2.

3.1.2 Environmental conditions

The automation system is to be designed to operate satisfactorily in the environment in which it is located. The environmental conditions are described in Ch 2, Sec 2.

3.1.3 Failure behaviour

The automation system is to have non-critical behaviour in the event of power supply failure, faults or restoration of operating condition following a fault. If a redundant power supply is used, it must be taken from an independent source.

3.2 Power supply conditions

3.2.1 Electrical power supply

The conditions of power supply to be considered are defined in Ch 2, Sec 2.

3.2.2 Pneumatic power supply

For pneumatic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

3.2.3 Hydraulic power supply

For hydraulic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

4 Materials and construction

4.1 General

4.1.1 The choice of materials and components is to be made according to the environmental and operating conditions in order to maintain the proper function of the equipment.

4.1.2 The design and construction of the automation equipment is to take into account the environmental and operating conditions in order to maintain the proper function of the equipment.

4.2 Type approved components

4.2.1 See Ch 2, Sec 15.

Section 2 Design Requirements

1 General

1.1

1.1.1 All control systems essential for the propulsion, control and safety of the ship shall be independent or designed such that failure of one system does not degrade the performance of another system.

1.1.2 Controlled systems are to have manual operation.

Failure of any part of such systems shall not prevent the use of the manual override.

1.1.3 Automation systems are to have constant performance.

1.1.4 Control, monitoring and safety systems are to be mutually independent, unless system design is such as failure of one of those system do not affect the operation of the other systems or machinery. Monitoring of safety function may be included in general monitoring function.

1.1.5 Control, monitoring and safety systems are to have self-check facilities. In the event of failure, an alarm is to be activated.

In particular, failure of the power supply of the automation system is to generate an alarm.

1.1.6 When a computer based system is used for control, alarm or safety systems, it is to comply with the requirements of Ch 3, Sec 3.

1.1.7 The automatic change-over switch is to operate independently of both systems. When change-over occurs, no stop of the installation is necessary and the latter is not to enter undefined or critical states.

1.1.8 When systems under control are required to be duplicated and in separate compartments, this is also to apply to control elements within computer based systems.

1.1.9 Emergency stops are to be hardwired and independent of any computer based system.

Note 1: Computerized systems may be admitted if evidence is given demonstrating they provide a safety level equivalent to a hardwired system.

2 Power supply of automation systems

2.1 General

2.1.1 Loss of power supplies to the automation system is to generate an alarm.

2.2 Electrical power supply

2.2.1 The power supply is to be protected against short circuit and overload for each independent automation system.

The power supply is to be isolated.

2.2.2 Automation systems are to be continuously powered.

2.2.3 The capacity of the batteries ensuring continuity of power supply is to be sufficient to allow the normal operation of the alarm, control and safety system for at least half an hour.

2.2.4 Their power sources are to be duplicated.

2.2.5 Batteries are not to be considered as power sources in respect of Article [2].

3 Control systems

3.1 General

3.1.1 In the case of failure, the control systems used for essential services are to remain in the last position they had before the failure, unless otherwise specified by these Rules.

3.2 Local control

3.2.1 Each system is to be able to be operated manually from a position located so as to enable visual control of operation. For detailed instrumentation for each system, refer to Part C, Chapter 1 and Part C, Chapter 2.

It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

3.3 Remote control systems

3.3.1 When several control stations are provided, control of machinery is to be possible at one station at a time and a hierarchy is to be defined.

3.3.2 At each location there shall be an indicator showing which location is in control of the propulsion machinery.

3.3.3 Remote control is to be provided with the necessary instrumentation, in each control station, to allow effective control (correct function of the system, indication of control station in operation, alarm display).

3.3.4 When transferring the control location, no significant alteration of the controlled equipment is to occur. Transfer of control is to be protected by an audible warning and acknowledged by the receiving control location. The main control location is to be able to take control without acknowledgement.

3.4 Automatic control systems

3.4.1 Automatic starting, operational and control systems shall include provisions for manually overriding the automatic controls.

3.4.2 Automatic control is to be stable in the range of the controller in normal working conditions.

3.4.3 Automatic control is to have instrumentation to verify the correct function of the system.

4 Control of propulsion machinery

4.1 Remote control

4.1.1 The requirements mentioned in Article [3] are to be applied for propulsion machinery.

The highest priority of propulsion control is to be assigned to the central position nearer to the principal machinery.

4.1.2 The design of the remote control system shall be such that in case of its failure an alarm will be given.

4.1.3 Supply failure (voltage, fluid pressure, etc.) in propulsion plant remote control is to activate an alarm at the control position. In the event of remote control system failure and unless the Society considers it impracticable, the preset speed and direction of thrust are to be maintained until local control is in operation. This applies in particular in the case of loss of electric, pneumatic or hydraulic supply to the system.

4.1.4 Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room, and at the manoeuvring platform.

4.1.5 The control shall be performed by a single control device for each independent propeller, with automatic performance of all associated services, including, where necessary, means of preventing overload of the propulsion machinery. Where multiple propellers are designed to operate simultaneously, they must be controlled by one control device.

4.1.6 Indicators shall be fitted on the navigation bridge, in the main machinery control room and at the manoeuvring platform, for:

- propeller speed and direction of rotation in the case of fixed pitch propellers; and
- propeller speed and pitch position in the case of controllable pitch propellers.

4.1.7 The main propulsion machinery shall be provided with an emergency stopping device on the navigation bridge which shall be independent of the navigation bridge control system.

4.2 Remote control from navigating bridge

4.2.1 Where propulsion machinery is controlled from the navigating bridge, the remote control is to include an automatic device such that the number of operations to be carried out is reduced and their nature is simplified and such that control is possible in both the ahead and astern directions. Where necessary, means for preventing overload and running in critical speed ranges of the propulsion machinery is to be provided.

4.2.2 On board ships fitted with remote control, direct control of the propulsion machinery is to be provided locally. The local direct control is to be independent from the remote control circuits, and takes over any remote control when in use.

4.2.3 Each local control position, including partial control (e.g. local control of controllable pitch propellers or clutches) is to be provided with means of communication with the remote control position. The local control positions are to be independent from remote control of propulsion machinery and continue to operate in the event of a blackout.

4.2.4 Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted.

4.2.5 The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another.

4.2.6 At the navigating bridge, the control of the routine manoeuvres for one line of shafting is to be performed by a single control device: a lever, a handwheel or a push-button board. However each mechanism contributing directly to the propulsion, such as the engine, clutch, automatic brake or controllable pitch propeller, is to be able to be individually controlled, either locally or at a central monitoring and control position in the engine room.

4.2.7 Remote starting of the propulsion machinery is to be automatically inhibited if a condition exists which may damage the machinery, e.g. shaft turning gear engaged, drop of lubrication oil pressure or brake engaged.

4.2.8 As a general rule, the navigating bridge panels are not to be overloaded by alarms and indications which are not required.

4.2.9 Automation systems shall be designed in a manner which ensures that threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems shall control, monitor, report, alert and take safety action to slowdown or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.

4.3 Automatic control

4.3.1 The requirements in Article [3] are applicable. In addition, the following requirements are to be considered, if relevant.

4.3.2 Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shutoff arrangements in the case of failures such as lubricating oil supply failure which could lead rapidly to complete breakdown, serious damage or explosion.

4.3.3 The automatic control system is to be designed on a fail safe basis, and, in the event of failure, the system is to be adjusted automatically to a predetermined safe state.

4.3.4 Operations following any setting of the bridge control device (including reversing from the maximum ahead service speed in case of emergency) are to take place in an automatic sequence and with acceptable time intervals, as prescribed by the manufacturer.

4.3.5 For steam turbines, a slow turning device is to be provided which operates automatically if the turbine is stopped longer than admissible. Discontinuation of this automatic turning from the bridge is to be possible.

4.4 Automatic control of propulsion and manoeuvring units

4.4.1 When the power source actuating the automatic control of propelling units fails, an alarm is to be triggered. In such case, the preset direction of thrust is to be maintained long enough to allow the intervention of engineers. Failing this, minimum arrangements, such as stopping of the shaft line, are to be provided to prevent any unexpected reverse of the thrust. Such stopping may be automatic or ordered by the operator, following an appropriate indication.

4.5 Clutches

4.5.1 Where the clutch of a propulsion engine is operated electrically, pneumatically or hydraulically, an alarm is to be given at the control station in the event of loss of energy; as far as practicable, this alarm is to be triggered while it is still possible to operate the equipment.

4.5.2 When only one clutch is installed, its control is to be fail-set. Other arrangements may be considered in relation to the configuration of the propulsion machinery.

4.6 Brakes

4.6.1 Automatic or remote controlled braking is to be possible only if:

- propulsion power has been shut off
- the turning gear is disconnected
- the shaftline speed (r.p.m.) is below the threshold stated by the builder.

5 Communications

5.1 Communications between navigating bridge and machinery space

5.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigating bridge, with audible alarm mismatch between order and response.

5.1.2 Appropriate means of communication shall be provided from the navigating bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled. The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

5.1.3 Where the main propulsion system of the ship is controlled from the navigating bridge by a remote control system, the second means of communication may be the same bridge control system.

5.1.4 The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended. An alarm is to be given at the navigation bridge in the event of failure of power supply to the engine room telegraph.

For ships assigned with a restricted navigation notation these requirements may be relaxed at the Society's discretion.

5.2 Engineers’ alarm

5.2.1 An engineers' alarm shall be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and shall be clearly audible in the engineers' accommodation

6 Remote control of valves

6.1

6.1.1 The following requirements are applicable to valves whose failure could impair essential services.

6.1.2 Failure of the power supply is not to permit a valve to move to an unsafe condition.

6.1.3 An indication is to be provided at the remote control station showing the actual position of the valve or whether the valve is fully open or fully closed. This indication may be omitted for quick-closing valves.

6.1.4 When valves are remote controlled, a secondary manual means of operating them is to be provided (see Ch 1, Sec 10, [2.7.3]).

7 Alarm system

7.1 General requirements

7.1.1 Alarms are to be visual and audible and are to be clearly distinguishable, in the ambient noise and lighting in the normal position of the personnel, from any other signals.

7.1.2 Sufficient information is to be provided for proper handling of alarms.

7.1.3 The alarm system is to be of the self-check type; failure within the alarm system, including the outside connection, is to activate an alarm. The alarm circuits are to be independent from each other. All alarm circuits are to be protected so as not to endanger each other.

7.2 Alarm functions

7.2.1 Alarm activation

Alarms are to be activated when abnormal conditions appear in the machinery, which need the intervention of personnel on duty, and on the automatic change-over, when standby machines are installed.

An existing alarm is not to prevent the indication of any further fault.

7.2.2 Acknowledgement of alarm

The acknowledgment of an alarm consists in manually silencing the audible signal and additional visual signals (e.g. rotating light signals) while leaving the visual signal on the active control station. Acknowledged alarms are to be clearly distinguishable from unacknowledged alarms. Acknowledgement should not prevent the audible signal to operate for new alarm.

Alarms shall be maintained until they are accepted and visual indications of individual alarms shall remain until the fault has been corrected, when the alarm system shall automatically reset to the normal operating condition.

Acknowledgement of alarms is only to be possible at the active control station.

Alarms, including the detection of transient faults, are to be maintained until acknowledgement of the visual indication.

Acknowledgement of visual signals is to be separate for each signal or common to a limited group of signals. Acknowledgement is only to be possible when the user has visual information on the alarm condition for the signal or all signals in a group.

7.2.3 Inhibition of alarms

Manual inhibition of separate alarms may be accepted when this is clearly indicated.

Inhibition of alarm and safety functions in certain operating modes (e.g. during start-up or trimming) is to be automatically disabled in other modes.

7.2.4 Time delay of alarms

It is to be possible to delay alarm activation in order to avoid false alarms due to normal transient conditions (e.g. during start-up or trimming).

7.2.5 Transfer of responsibility

Where several alarm control stations located in different spaces are provided, responsibility for alarms is not to be transferred before being acknowledged by the receiving location. Transfer of responsibility is to give an audible warning. At each control station it is to be indicated which location is in charge.

8 Safety system

8.1 Design

8.1.1 System failures

A safety system is to be designed so as to limit the consequence of failures. It is to be constructed on the fail-to-safety principle.

The safety system is to be of the self-check type; as a rule, failure within the safety system, including the outside connection, is to activate an alarm.

8.2 Function

8.2.1 Safety activation

The safety system is to be activated automatically in the event of identified conditions which could lead to damage of associated machinery or systems, such that:

- normal operating conditions are restored (e.g. by the starting of the standby unit), or
- the operation of the machinery is temporarily adjusted to the prevailing abnormal conditions (e.g. by reducing the output of the associated machinery), or
- the machinery is protected, as far as possible, from critical conditions by shutting off the fuel or power supply, thereby stopping the machinery (shutdown), or appropriate shutdown.

8.2.2 Safety indication

When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.

When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.

Override of safety functions in certain operating modes (e;g; during start-up or trimming) is to be automatically disabled in other modes

Automatic safety actions are to activate an alarm at predefined control stations.

8.3 Shutdown

8.3.1 For shutdown systems of machinery, the following requirements are to be applied:

- when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out
- the shutdown of the propulsion system is to be limited to those cases which could lead to serious damage, complete breakdown or explosion.

8.4 Standby systems

8.4.1 For the automatic starting system of the standby units, the following requirements are to be applied:

- faults in the electrical or mechanical system of the running machinery are not to prevent the standby machinery from being automatically started
- when a machine is on standby, ready to be automatically started, this is to be clearly indicated at its control position
- the change-over to the standby unit is to be indicated by a visual and audible alarm
- means are to be provided close to the machine, to prevent undesired automatic or remote starting (e.g. when the machine is being repaired)
- automatic starting is to be prevented when conditions are present which could endanger the standby machine.

8.5 Testing

8.5.1 The safety systems are to be tested in accordance with the requirements in Ch 3, Sec 6.

Section 3 Computer Based Systems

1 General requirements

1.1 Application

1.1.1 Systems covered

This section applies to design, construction, commissioning and maintenance of computer based systems where they depend on software for the proper achievement of their functions. These requirements focus on the functionality of the software and on the hardware supporting the software. These requirements apply to the use of computer based systems which provide control, alarm, monitoring, safety or internal communication functions which are subject to classification requirements.

Navigation systems required by SOLAS Chapter V, Radio-communication systems required by SOLAS Chapter IV, and vessel loading instrument/stability computer are not in the scope of these requirements.

Note 1: For loading instrument/stability computer, see Pt B, Ch 10, Sec 2, [4].

1.2 Requirement for ship

1.2.1 List of computerized systems

List of computerized systems covered by this section as described [1.1.1] are to be submitted to the Society as soon as possible during design stage of the ship. This list shall include:

- designation of system involved
- category of system according to [2.3]
- manufacturer of system (if available)
- supplier of control system (if available).

1.2.2 Software registry

Initial release of software registry as defined in [4.3.1] is to be submitted for information to the Society after ship sea trials.

1.3 Requirements for computerized systems

1.3.1 Computerized systems shall follow requirements mentioned in Articles [4], [5], [6], [8]and [9].

1.3.2 The response time between the detection of an event and the related action or signalization is to be compatible with the application. As a general requirement without other specification, this time is to be less than 5 seconds.

1.4 References

1.4.1 For the purpose of application of the requirements contained in this section, the following identified standards can be used for the development of hardware/software of computer based systems. Other industry standards may be considered:

- IEC 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems
- ISO/IEC 12207: Systems and software engineering - Software life cycle processes
- ISO 9001:2008 Quality Management Systems - Requirements
- ISO/IEC 90003: Software engineering - Guidelines for the application of ISO 9001:2008 to computer software
- IEC 60092-504: Electrical installations in ships - Part 504: Special features - Control and instrumentation
- ISO/IEC 25000: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE
- ISO/IEC 25041: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators
- IEC 61511: Functional safety - Safety instrumented systems for the process industry sector
- ISO/IEC 15288: Systems and software engineering - System life cycle process

2 Definitions

2.1 Stakeholders

2.1.1 Owner

The Owner is responsible for contracting the system integrator and/or suppliers to provide a hardware system including software according to the owner's specification. The Owner could be the Ship Builder Integrator (Builder or Shipyard) during initial construction. After vessel delivery, the owner may delegate some responsibilities to the vessel operating company.

2.1.2 System integrator

The role of system integrator shall be taken by the Yard unless an alternative organisation is specifically contracted/assigned this responsibility. The system integrator is responsible for the integration of systems and products provided by suppliers into the system invoked by the requirements specified herein and for providing the integrated system. The system integrator may also be responsible of integration of systems in the vessel.

If there are multiple parties performing system integration at any one time a single party is to be responsible for overall system integration and coordinating the integration activities. If there are multiple stages of integration different System Integrators may be responsible for specific stages of integration but a single party is to be responsible for defining and coordinating all of the stages of integration.

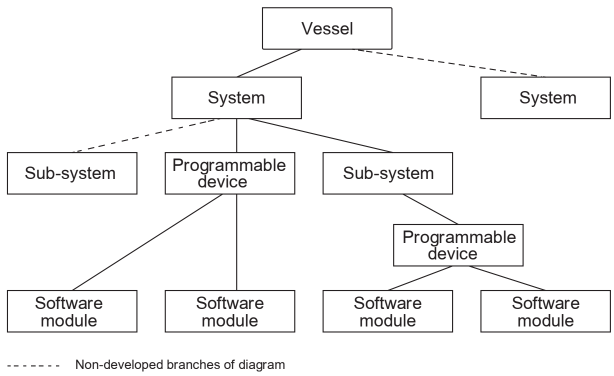
2.1.3 Supplier

The Supplier is any contracted or subcontracted provider of system components or software under the coordination of the System Integrator or Shipyard. The supplier is responsible for providing programmable devices, sub-systems or systems to the system integrator. The supplier provides a description of the software functionality that meets the Owner's specification, applicable international and national standards, and the requirements specified herein.

2.2 Objects

2.2.1 The following diagram (see Fig 1) shows the hierarchy and relationships of a typical computer based system.

Figure 1 : Illustrative System Hierarchy



2.2.2 Object definitions

a) Vessel: Ship where the system is to be installed

b) System: Combination of interacting programmable devices and/or sub-systems organized to achieve one or more specified purposes.

c) Sub-system: Identifiable part of a system, which may perform a specific function or set of functions.

d) Programmable device: Physical component where software is installed.

e) Software module: A module is a standalone piece of code that provides specific and closely coupled functionality.

2.3 System categories

2.3.1 The following Tab 1 shows how to assign system categories based on their effects on system functionality.

The following systems typically belong to Category III, the exact category being dependent on the risk assessment for all operational scenarios:

- Propulsion system of a ship, meaning the means to generate and control mechanical thrust in order to move the ship (devices used only during manoeuvring are not in the scope of this requirement such as bow tunnel thrusters)
- Steering system control system
- Electric power system (including power management system)
- Ship safety systems covering fire detection and fighting, flooding detection and fighting, internal communication systems involved in evacuation phases, ship systems involved in operation of life saving appliances equipment
- Dynamic positioning system of equipment classes 2 and 3 according to NR467, Pt F, Ch 11, Sec 5.
- Drilling systems

Table 1 : System categories

Category	Effects	Typical system functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Monitoring function for informational/administrative tasks.
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Alarm and monitoring functions • Control functions which are necessary to maintain the ship in its normal operational and habitable conditions.
III	Those systems, failure of which could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Control functions for maintaining the vessel's propulsion and steering • Vessel Safety functions.

The following systems typically belong to Category II, the exact category being dependent on the risk assessment for all operational scenarios:

- liquid cargo transfer control system
- bilge level detection and associated control of pumps
- fuel oil treatment system

  Ballast transfer valve remote control system

  Stabilization and ride control systems
- Alarm and monitoring systems for propulsion systems.

The example systems are not exhaustive.

2.4 Other terminology

2.4.1 Simulation tests

Control system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

2.4.2 Expert system

Expert system is an intelligent knowledge-based system that is designed to solve a problem with information that has been compiled using some form of human expertise.

2.4.3 Integrated system

Integrated system is a system consisting of two or more subsystems having independent functions connected by a data transmission network and operated from one or more workstations.

2.4.4 Data communication link

Data communication link includes point to point links, instrument net and local area networks, normally usedfor inter-computer communication on board units. The software and hardware which support the data communication are also included.

3 Documentation and test attendance

3.1

3.1.1 Documentation to be submitted and test to be attended are listed in Tab 2.

3.1.2 User interface description

The documentation is to contain:

- a description of the functions allocated to each operator interface (keyboard/screen or equivalent)
- a description of individual screen views (schematics, colour photos, etc.)
- a description of how menus are operated (tree presentation)
- an operator manual providing necessary information for installation and use.

Table 2 : Documentation and test attendance

Requirement	Supplier involved	System integrator involved	Owner involved	Category I	Category II	Category III
Quality Plan	X	X		A**(2)**	A	A
Risk assessment report		X		I**(2)**	I**(2)**	I**(2)**
Software modules functional description and associated hardware description	X (if necessary)	X			I	I
Evidence of verification of software code	X (if necessary)	X			I	I
Evidence of functional tests for elements included in systems of Category II and III at the level of software module, sub-system and system	X	X			I	I
Test programs and procedures for functional tests and failure tests including a supporting FMEA or equivalent, at the request of the Class Society		X			A	A
Factory acceptance test event including functional and failure tests	X	X			W	W
Test program for simulation tests for final integration		X			A	A
Simulation tests for final integration		X			W	W
Test program for on board tests (includes wireless network testing)		X			A	A
On board integration tests (includes wireless network testing)		X			W	W
Documents related to simulator		X			I	I
• List and versions of software installed in system • Functional description of software • User manual including instructions during software maintenance • List of interfaces between system and other ship systems		X			I	I
Updated Software Registry		X	X		I	I
Procedures and documentation related to Security Policy					I	I
Test reports according to Ch 3, Sec 6, [2.2] requirements	X	X		A**(3)**	A	A
User interface description see [3.1.2]	X	X		I	I	I

(1) Additional documentation may be required upon request
(2) Upon request
(3) If in the scope of Class requirement
Note 1: A = to be submitted fro approval, I = to be submitted for information, W = Test to be witnessed by the Surveyor.

4 Requirements for software and supporting hardware

4.1 Life cycle approach

4.1.1 A global top to bottom approach shall be undertaken regarding software and the integration in a system, spanning the software lifecycle. This approach shall be accomplished according to software development standards as listed herein or other standards recognized by the Society.

4.1.2 Quality system

System integrators and suppliers shall operate a quality system regarding software development and testing and associated hardware such as ISO 9001 taking into account ISO 90003.

Satisfaction of this requirement shall be demonstrated by either:

- The quality system being certified as compliant to the recognized standard by an organisation with accreditation under a national accreditation scheme, or
- The Society confirming compliance to the standard through a specific assessment.

This quality system shall include:

a) Relevant procedures regarding responsibilities, system documentation, configuration management and competent staff.

b) Relevant procedures regarding software lifecycle and associated hardware:
   - Organization set in place for acquisition of related hardware and software from suppliers
   - Organization set in place for software code writing and verification
   - Organization set in place for system validation before integration in the vessel.

c) Minimum requirements for approval of Quality system:
   - Having a specific procedure for verification of software code of Category II and III at the level of systems, sub-systems and programmable devices and modules
   - Having check points for the Class Society for Category II and III systems (see Tab 2 for the minimum check points , see Note 1)
   - Having a specific procedure for software modification and installation on board the vessel defining interactions with owners.

d) Quality Plan

   A document, referred to herein as a Quality Plan, shall be produced that records how the quality management system will be applied for the specific computer based system and that includes, as a minimum, all of material required by paragraphs [4.1.2], items a) to c) inclusively.

Note 1: Examples of check points can be a required submittal of documentation, a test event, a technical design review meeting, or peer review meeting.

4.1.3 Design phase

a) Risk assessment of system

   This step shall be undertaken to determine the risk to the system throughout the lifecycle by identifying and evaluating the hazards associated with each function of the system. A risk assessment report shall upon request be submitted to the Society:

   This document shall normally be submitted by the System Integrator or the Supplier, including data coming from other suppliers.

   IEC/ISO31010 “Risk management - Risk assessment techniques” may be applied in order to determine method of risk assessment. The method of risk assessment shall be agreed by the society.

   Based on the risk assessment, a revised system category might need to be agreed between Class and the system supplier.

   Where the risks associated with a computer based system are well understood, it is permissible for the risk assessment to be omitted, however in such cases the supplier or the system integrator shall provide a justification for the omission. The justification should give consideration to:
   - how the risks are known
   - the equivalence of the context of use of the current computer based system and the computer based system initially used to determine the risks
   - the adequacy of existing control measures in the current context of use

b) Code production and testing

   The following documentation shall be provided to the Class Society for Category II and III systems:
   - Software modules functional description and associated hardware description for programmable devices. This shall be provided by Supplier and System Integrator.
   - Evidence of verification (detection and correction of software errors) for software modules, in accordance with the selected software development standard. Evidence requirements of the selected software standard might differ depending on how critical the correct operation of the software is to the function it performs (i.e. IEC 61508 has different requirements depending on SILs, similar approaches are taken by other recognized standard). This shall be supplied by the Supplier and System Integrator.
   - Evidence of functional tests for programmable devices at the software module, sub-system, and system level. This shall be supplied by the Supplier via the System Integrator. The functional testing shall be designed to test the provisions of features used by the software but provided by the operating system, function libraries, customized layer of software and any set of parameters.

4.1.4 Integration testing before installation on board

Intra-system integration testing shall be done between system and sub-system software modules before being integrated on board. The objective is to check that software functions are properly executed, that the software and the hardware it controls interact and function properly together and that software systems react properly in case of failures. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. The results of any required failure analysis are to be observed. Functional and failure testing can be demonstrated by simulation tests.

For Category II and III systems:

a) Test programs and procedures for functional tests and failure tests shall be submitted to the Class Society. A FMEA may be requested by the Class Society in order to support containment of failure tests programs.

b) Factory acceptance test including functional and failure tests shall be witnessed by Class Society.

   Following documentation shall be provided:

   1) Functional description of software
   2) List and versions of software installed in system
   3) User manual including instructions for use during software maintenance
   4) List of interfaces between system and other ship systems
   5) List of standards used for data communication links
   6) Additional documentation as requested by the Class Society which might include an FMEA or equivalent to demonstrate the adequacy of failure test case applied.

For Category III systems:

Simulation tests required in [4.1.4] shall fulfill in following conditions :

- software of control system identical to those that shall be installed on board shall be used for testing
- the environment of the control system shall be simulated with sufficient details and accuracy to run functional and failure tests
- the devices used for simulating the environment of the control system need to be evaluated by the Society before test is undertaken.

4.1.5 Approval of programmable devices for Category II and III systems

Approval of programmable devices integrated inside a system shall be delivered to the system integrator or supplier. Approval can be granted on case by case basis, or as part of a product type approval, so long as above mentioned documents have been reviewed/approved (as per annex) and the required tests have been witnessed by the Class Society (also see Ch 3, Sec 6, [2.2] regarding hardware environmental type tests). Documentation should address the compatibility of the programmable device in the ship’s application, the necessity to have on board tests during ship integration and should identify the components of system using the approved programmable devices.

4.1.6 Final integration and on board testing

Simulation tests are to be undertaken before installation, when it is found necessary to check safe interaction with other computerized systems and functions that could not be tested previously.

On board tests shall check that a computer based system in its final environment, integrated with all other systems with which it interacts is:

- performing functions it was designed for
- reacting safely in case of failures originated internally or by devices external to the system
- interacting safely with other systems implemented on board vessel.

For final integration and on board testing of Category II and III systems:

- test specifications shall be submitted to the Society for approval
- the tests shall be witnessed by the Society.

4.2 Limited approval

4.2.1 Sub-systems and programmable devices may be approved for limited applications with service restrictions by the Class Society when the ship system where they will be integrated is not known. In this case, requirements about Quality systems under paragraph [4.1.2] might need to be fulfilled as required by the Class Society. Additional drawings, details, tests reports and surveys related to the Standard declared by the Supplier may be required by the Class Society upon request.

Sub-systems and programmable devices may in this case be granted with a limited approval mentioning the required checks and tests performed.

4.3 Modifications during operation

4.3.1 Responsibilities

Organizations in charge of software modifications shall be clearly declared by Owner to the Class Society. A System integrator shall be designated by the Owner and shall fulfil requirements mentioned in paragraph [4.1]. Limited life cycle steps may be considered for modifications already considered and accepted in the scope of initial approval. The level of documentation needed to be provided for the modification shall be determined by the Society.

At the vessel level, it is the responsibility of Owner to manage traceability of these modifications; the achievement of this responsibility shall be supported by system integrators updating the Software Registry. This Software Registry shall contain:

- List and versions of software installed in systems required in [4.1.4]
- Results of security scans as described in [4.4].

4.3.2 Change management

The owner shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure. All changes to computer based systems in the operational phase shall be recorded and be traceable by number, date or other appropriate means.

4.4 System security

4.4.1 Owner, system integrator and suppliers shall adopt security policies and include these in their quality systems and procedures.

For Category I, II, and III systems, physical and logical security measures shall be in place to prevent unauthorized or unintentional modification of software, whether undertaken at the physical system or remotely.

Prior to installation, all artefacts, software code, executables and the physical medium used for installation on the vessel are to be scanned for viruses and malicious software. Results of the scan are to be documented and kept with the Software Registry.

5 Requirements for hardware

5.1 Requirements for hardware regarding environment

5.1.1 Evidence of environmental type testing according to Ch 3, Sec 6, [2.2] regarding hardware elements included in the system and sub-systems shall be submitted to the Class Society for Category I, II and III computer based systems. This requirement is not mandatory for Category I computer based systems not considered by Class.

5.2 Requirements for hardware regarding construction

5.2.1 General

The construction of systems is to comply with the requirements of Ch 3, Sec 4.

5.2.2 Housing

a) The housing of the system is to be designed to face the environmental conditions, as defined in Ch 2, Sec 2, [1], in which it will be installed. The design will be such as to protect the printed circuit board and associated components from external aggression. When required, the cooling system is to be monitored, and an alarm activated when the normal temperature is exceeded.

b) The mechanical construction is to be designed to withstand the vibration levels defined in Ch 2, Sec 2, depending on the applicable environmental condition.

6 Requirements for data communication links for Category II and III systems

6.1 General requirements

6.1.1 Loss of a data link shall be specifically addressed in risk assessment analysis.

6.1.2 A single failure in data link hardware shall be automatically treated in order to restore proper working of system. For Category III systems a single failure in data link hardware shall not influence the proper working of the system.

6.1.3 Characteristics of data link shall prevent overloading in any operational condition of system.

6.1.4 Data link shall be self-checking, detecting failures on the link itself and data communication failures on nodes connected to the link. Detected failures shall initiate an alarm.

6.1.5 Loss of a data communication link is not to affect the ability to operate essential services by alternative means.

6.1.6 The data communication link is to be automatically started when power is turned on, or restarted after loss of power.

6.1.7 The choice of transmission cable is to be made according to the environmental conditions. Particular attention is to be given to the level characteristics required for electromagnetic interferences.

6.1.8 The installation of transmission cables is to comply with the requirements stated in Ch 2, Sec 11. In addition, the routing of transmission cables is to be chosen so as to be in less exposed zones regarding mechanical, chemical or EMI damage. As far as possible, the routing of each cable is to be independent of any other cable. These cables are not normally allowed to be routed in bunches with other cables on the cable tray.

6.1.9 The coupling devices are to be designed, as far as practicable, so that in the event of a single fault, they do not alter the network function. When a failure occurs, an alarm is to be activated.

Addition of coupling devices is not to alter the network function.

Hardware connecting devices are to be chosen, when possible, in accordance with international standards.

When a computer based system is used with a non-essential system and connected to a network used for essential systems, the coupling device is to be of an approved type.

6.2 Specific requirements for wireless data links

6.2.1 Category III systems shall not use wireless data links unless specifically considered by the Class Society on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to the Society.

6.2.2 Other categories of systems may use wireless data communication links with following requirements:

a) Recognised international wireless communication system protocols shall be employed, incorporating:
   - Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
   - Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
   - Message encryption. Protection of the confidentiality and or criticality of the data content.
   - Security management. Protection of network assets, prevention of unauthorized access to network assets.

b) The internal wireless system within the vessel shall comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.

   Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

c) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not its self-fail as a result of electromagnetic interference during expected operating conditions.

7 Man-machine interface

7.1 General

7.1.1 The design of the operator interface is to follow ergonomic principles. The standard IEC 60447 Man-machine interface or equivalent recognised standard may be used.

7.2 System functional indication

7.2.1 A means is to be provided to verify the activity of the system, or subsystem, and its proper function.

7.2.2 A visual and audible alarm is to be activated in the event of malfunction of the system, or subsystem. This alarm is to be such that identification of the failure is simplified.

7.3 Input devices

7.3.1 Input devices are to be positioned such that the operator has a clear view of the related display.

The operation of input devices, when installed, is to be logical and correspond to the direction of action of the controlled equipment.

The user is to be provided with positive confirmation of action.

Control of essential functions is only to be available at one control station at any time. Failing this, conflicting control commands are to be prevented by means of interlocks and/or warnings.

7.3.2 When keys are used for common/important controls, and several functions are assigned to such keys, the active function is to be recognisable.

If use of a key may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of 2 keys, repeated use of a key, etc.).

Means are to be provided to check validity of the manual input data into the system (e.g. checking the number of characters, range value, etc.).

7.3.3 If use of a push button may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of 2 push buttons, repeated use of push buttons, etc.). Alternatively, this push button is to be protected against accidental activation by a suitable cover, or use of a pull button, if applicable.

7.4 Output devices

7.4.1 VDU's (video display units) and other output devices are to be suitably lighted and dimmable when installed in the wheelhouse. The adjustment of brightness and colour of VDU's is to be limited to a minimum discernable level.

When VDU's are used for alarm purposes, the alarm signal, required by the Rules, is to be displayed whatever the other information on the screen. The alarms are to be displayed according to the sequence of occurrence.

When alarms are displayed on a colour VDU, it is to be possible to distinguish alarm in the event of failure of a primary colour.

The position of the VDU is to be such as to be easily readable from the normal position of the personnel on watch. The size of the screen and characters is to be chosen accordingly.

When several control stations are provided in different spaces, an indication of the station in control is to be displayed at each control station. Transfer of control is to be effected smoothly and without interruption to the service.

7.5 Workstations

7.5.1 The number of workstations at control stations is to be sufficient to ensure that all functions may be provided with any one unit out of operation, taking into account any functions which are required to be continuously available.

7.5.2 Multifunction workstations for control and display are to be redundant and interchangeable.

7.5.3 The choice of colour, graphic symbols, etc. is to be consistent in all systems on board.

7.6 Computer dialogue

7.6.1 The computer dialogue is to be as simple and self-explanatory as possible.

The screen content is to be logically structured and show only what is relevant to the user.

Menus are to be organised so as to have rapid access to the most frequently used functions.

7.6.2 A means to go back to a safe state is always to be accessible.

7.6.3 A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.

7.6.4 A 'wait' indication is to warn the operator when the system is executing an operation.

8 Integrated systems

8.1 General

8.1.1 Operation with an integrated system is to be at least as effective as it would be with individual, stand alone equipment.

8.1.2 Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependant on information from the defective part.

8.1.3 A failure in connection between parts, cards connections or cable connections is not to affect the independent functionality of each connected part.

8.1.4 Alarm messages for essential functions are to have priority over any other information presented on the display.

9 Expert system

9.1

9.1.1 The expert system software is not to be implemented on a computer linked with essential functions.

9.1.2 Expert system software is not to be used for direct control or operation, and needs human validation by personnel on watch.

Section 4 Constructional Requirements

1 General

1.1 General

1.1.1 Automation systems are to be so constructed as:

- to withstand the environmental conditions, as defined in Ch 2, Sec 2, [1], in which they operate
- to have necessary facilities for maintenance work.

1.2 Materials

1.2.1 Materials are generally to be of the flame-retardant type.

1.2.2 Connectors are to be able to withstand standard vibrations, mechanical constraints and corrosion conditions as given in Ch 3, Sec 6.

1.3 Component design

1.3.1 Automation components are to be designed to simplify maintenance operations. They are to be so constructed as to have:

- easy identification of failures
- easy access to replaceable parts
- easy installation and safe handling in the event of replacement of parts (plug and play principle) without impairing the operational capability of the system, as far as practicable
- facility for adjustment of set points or calibration
- test point facilities, to verify the proper operation of components.

1.4 Environmental and supply conditions

1.4.1 The environmental and supply conditions are specified in Ch 3, Sec 1. Specific environmental conditions are to be considered for air temperature and humidity, vibrations, corrosion from chemicals and mechanical or biological attacks.

2 Electrical and/or electronic systems

2.1 General

2.1.1 Electrical and electronic equipment is to comply with the requirements of Part C, Chapter 2 and Part C, Chapter 3.

2.1.2 A separation is to be done between any electrical components and liquids, if they are in a same enclosure. Necessary drainage will be provided where liquids are likely to leak.

2.1.3 When plug-in connectors or plug-in elements are used, their contacts are not to be exposed to excessive mechanical loads. They are to be provided with a locking device.

2.1.4 All replaceable parts are to be so arranged that it is not possible to connect them incorrectly or to use incorrect replacements. Where this not practicable, the replacement parts as well as the associated connecting devices are to be clearly identified. In particular, all connection terminals are to be properly tagged. When replacement cannot be carried out with the system on, a warning sign is to be provided.

2.1.5 Forced cooling systems are to be avoided. Where forced cooling is installed, an alarm is to be provided in the event of failure of the cooling system.

2.1.6 The interface connection is to be so designed to receive the cables required. The cables are to be chosen according to Ch 2, Sec 3.

2.2 Electronic system

2.2.1 Printed circuit boards are to be so designed that they are properly protected against the normal aggression expected in their environment.

2.2.2 Electronic systems are to be constructed taking account of electromagnetic interferences.

Special precautions are to be taken for:
- measuring elements such as the analogue amplifier or analog/digital converter; and
- connecting different systems having different ground references.

2.2.3 The components of electronic systems (printed circuit board, electronic components) are to be clearly identifiable with reference to the relevant documentation.

2.2.4 Where adjustable set points are available, they are to be readily identifiable and suitable means are to be provided to protect them against changes due to vibrations and uncontrolled access.

2.2.5 The choice of electronic components is to be made according to the normal environmental conditions, in particular the temperature rating.

2.2.6 All stages of fabrication of printed circuit boards are to be subjected to quality control. Evidence of this control is to be documented.

2.2.7 Burn-in tests or equivalent tests are to be performed.

2.2.8 The programmable components are to be clearly tagged with the program date and reference.
Components are to be protected against outside alteration when loaded.

2.3 Electrical system

2.3.1 Cables and insulated conductors used for internal wiring are to be at least of the flame-retardant type, and are to comply with the requirements in Part C, Chapter 2.

2.3.2 If specific products (e.g. oil) are likely to come into contact with wire insulation, the latter is to be resistant to such products or properly shielded from them, and to comply with the requirements in Part C, Chapter 2.

3 Pneumatic systems

3.1

3.1.1 Pneumatic automation systems are to comply with Ch 1, Sec 10, [17].

3.1.2 Pneumatic circuits of automation systems are to be independent of any other pneumatic circuit on board.

4 Hydraulic systems

4.1

4.1.1 Hydraulic automation systems are to comply with Ch 1, Sec 10, [14].

4.1.2 Suitable filtering devices are to be incorporated into the hydraulic circuits.

4.1.3 Hydraulic circuits of automation systems are to be independent of any other hydraulic circuit on board.

5 Automation consoles

5.1 General

5.1.1 Automation consoles are to be designed on ergonomic principles. Handrails are to be fitted for safe operation of the console.

5.1.2 For all mimic diagram located on consoles, switchboard or on screen, the ship is to be shown as follows:
- Portrait view:
  - the fore part of the ship is to be located on the top of the mimic
  - aft part of the ship is to be located on the bottom of the mimic
  - starboard part of the ship is to be located on the right of the mimic
  - port part of the ship is to be located on the left of the mimic
- Landscape view, which can be either a top view or a side view:
  - fore part of the ship is to be located on the right of the mimic
  - aft part of the ship is to be located on the left of the mimic
  - starboard part of the ship is to be located on the lower part of the mimic
  - port part of the ship is to be located on the upper part of the mimic.

5.2 Indicating instruments

5.2.1 The operator is to receive feed back information on the effects of his orders.

5.2.2 Indicating instruments and controls are to be arranged according to the logic of the system in control. In addition, the operating movement and the resulting movement of the indicating instrument are to be consistent with each other.

5.2.3 The instruments are to be clearly labelled. When installed in the wheelhouse, all lighted instruments of consoles are to be dimmable, where necessary.

5.3 VDU's and keyboards

5.3.1 VDU's in consoles are to be located so as to be easily readable from the normal position of the operator. The environmental lighting is not to create any reflection which makes reading difficult.

5.3.2 The keyboard is to be located to give easy access from the normal position of the operator. Special precautions are to be taken to avoid inadvertent operation of the keyboard.

Section 5 Installation Requirements

1 General

1.1

1.1.1 Automation systems are to be installed taking into account:

- the maintenance requirements (test and replacement of systems or components)
- the influence of EMI. The IEC 60533 standard is to be taken as guidance
- the environmental conditions corresponding to the location in accordance with Ch 2, Sec 1and Ch 2, Sec 3, [6].

1.1.2 Control stations are to be arranged for the convenience of the operator.

1.1.3 Automation components are to be properly fitted. Screws and nuts are to be locked, where necessary.

2 Sensors and components

2.1 General

2.1.1 The location and selection of the sensor is to be done so as to measure the actual value of the parameter. Temperature, vibration and EMI levels are to be taken into account. When this is not possible, the sensor is to be designed to withstand the local environment.

2.1.2 The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located.

2.1.3 Means are to be provided for testing, calibration and replacement of automation components. Such means are to be designed, as far as practicable, so as to avoid perturbation of the normal operation of the system.

2.1.4 When replacement of automation components is not possible, duplication of these components is required.

2.1.5 A tag number is to identify automation components and is to be clearly marked and attached to the component. These tag numbers are to be collected on the instrument list mentioned in Ch 3, Sec 1, Tab 1.

2.1.6 Electrical connections are to be arranged for easy replacement and testing of sensors and components. They are to be clearly marked.

2.1.7 Low level signal sensors are to be avoided. When installed they are to be located as close as possible to amplifiers, so as to avoid external influences. Failing this, the wiring is to be provided with suitable EMI protection and temperature correction.

2.2 Temperature elements

2.2.1 Temperature sensors, thermostats or thermometers are to be installed in a thermowell of suitable material, to permit easy replacement and functional testing. The thermowell is not to significantly modify the response time of the whole element.

2.3 Pressure elements

2.3.1 Three-way valves or other suitable arrangements are to be installed to permit functional testing of pressure elements, such as pressure sensors, pressure switches, without stopping the installation.

2.3.2 In specific applications, where high pulsations of pressure are likely to occur, a damping element, such as a capillary tube or equivalent, is to be installed.

2.4 Level switches

2.4.1 Level switches fitted to flammable oil tanks, or similar installations, are to be installed so as to reduce the risk of fire.

3 Cables

3.1 Installation

3.1.1 Cables are to be installed according to the requirements in Ch 2, Sec 12, [7].

3.1.2 Suitable installation features such as screening and/or twisted pairs and/or separation between signal and other cables are to be provided in order to avoid possible interference on control and instrumentation cables.

3.1.3 Specific transmission cables (coaxial cables, twisted pairs, etc.) are to be routed in specific cable-ways and mechanically protected to avoid loss of any important transmitted data. Where there is a high risk of mechanical damage, the cables are to be protected with pipes or equivalent.

3.1.4 The cable bend radius is to be in accordance with the requirements of Ch 2, Sec 12, [7.2].

For mineral insulated cables, coaxial cables or fibre optic cables, whose characteristics may be modified, special precautions are to be taken according to the manufacturer's instructions.

3.2 Cable terminations

3.2.1 Cable terminations are to be arranged according to the requirements in Part C, Chapter 2. Particular attention is to be paid to the connections of cable shields. Shields are to be connected only at the sensor end when the sensor is earthed, and only at the processor end when the sensor is floating.

3.2.2 Cable terminations are to be able to withstand the identified environmental conditions (shocks, vibrations, salt mist, humidity, etc.).

3.2.3 Terminations of all special cables such as mineral insulated cables, coaxial cables or fibre optic cables are to be arranged according to the manufacturer's instructions.

3.2.4 The optical fibre cables are not to be cut in their total length. Where necessary, junction are to be done with approved means and appropriate tools following manufacturer requirements.

4 Pipes

4.1

4.1.1 For installation of piping circuits used for automation purposes, see the requirements in Ch 1, Sec 10.

4.1.2 As far as practicable, piping containing liquids is not to be installed in or adjacent to electrical enclosures (see Ch 3, Sec 4, [2.1.2]).

4.1.3 Hydraulic and pneumatic piping for automation systems is to be marked to indicate its function.

5 Automation consoles

5.1 General

5.1.1 Consoles or control panels are to be located so as to enable a good view of the process under control, as far as practicable. Instruments are to be clearly readable in the ambient lighting.

5.1.2 The location is to be such as to allow easy access for maintenance operations.

5.1.3 Shock absorbers are to be installed for all consoles and switchboards fitted onboard, according to service notation requirements, where necessary.

Section 6 Testing

1 General

1.1 General

1.1.1 Automation systems are to be tested for type approval, at works and on board, when required. Tests are to be carried out under the supervision of a Surveyor of the Society.

1.1.2 The type testing conditions for electrical, control and instrumentation equipment, computers and peripherals are described in Article [2].

1.1.3 Automation systems are to be inspected at works, according to the requirements of Article [3], in order to check that the construction complies with the Rules.

1.1.4 Automation systems are to be tested when installed on board and prior to sea trials, to verify their performance and adaptation on site, according to Article [4].

2 Type approval

2.1 General

2.1.1 The following requirements are applicable, but not confined, to electrical and electronic equipment which are intended to be type approved for control, monitoring, alarm and protection systems for use in ships.

2.1.2 The necessary documents to be submitted, prior to type testing, are listed in Ch 3, Sec 1, [2.3.1] and Ch 3, Sec 3, [3.1.1]. The type approval of automation systems refers to hardware type approval or software type approval, as applicable.

2.2 Hardware type approval

2.2.1 Hardware type approval of automation systems is obtained subject to the successful outcome of the tests described in Tab 1. These tests are to demonstrate the ability of the equipment to function as intended under the specified test conditions.

2.2.2 The extent of testing (i.e. selection and sequence of carrying out tests and number of pieces to be tested) is to be determined upon examination and evaluation of the equipment or component subject to testing, giving due regards to its intended usage.

Equipment is to be tested in its normal position if otherwise not specified in the test specification.

Vibration and salt mist testing may be performed on different specimens, where applicable.

Reset of the automation system is accepted between each test, where necessary.

Note 1: As used in this Section, and in contrast to a complete performance test, a functional test is a simplified test sufficient to verify that the equipment under test (EUT) has not suffered any deterioration caused by the individual environmental tests.

2.2.3 The following additional tests may be required, depending on particular manufacturing or operational conditions:

- mechanical endurance test
- temperature shock test (e.g. 12 shocks on exhaust gas temperature sensors from 20°C ± 5°C to maximum temperature of the range)
- immersion test
- oil resistance test
- shock test.

The test procedure is to be defined with the Society in each case.

2.3 Software type approval

2.3.1 Software of computer based systems are to be approved in accordance with requirements mentioned in Ch 3, Sec 3.

Table 1 : Type tests

No.	Test	Procedure **(6)**	Test parameters	Other information
1	Visual inspection	–	–	• drawings, design data
2	Performance test	Manufacturer performance test programme based upon specification and relevant rule requirements When the EUT is required to comply with an international performance standard, e.g. protection relays, verification of requirements in the standard are to be part of the performance testing required in this initial test and subsequent performance tests after environmental testing where required as per [2.2].	• standard atmosphere conditions • temperature: 25°C ± 10°C • relative humidity: 60% ± 30% • air pressure: 96 KPa ± 10 KPa	• confirmation that operation is in accordance with the requirements specified for particular automatic systems or equipment • checking of self-monitoring features • checking of specified protection against an access to the memory • checking against effect of unerroneous use of control elements in the case of computer systems
3	Power supply failure	–	• 3 interruptions during 5 minutes • switching- off time 30 s each case	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed
4a	Electric A.C. power supply variations	–	COMBINATION Voltage variation permanent / Frequency variation permanent + 6% / + 5% + 6% / – 5% – 10% / – 5% – 10% / + 5% voltage transient (1,5s) / frequency transient (5s) + 20% / + 10% – 20% / – 10%	
4b	Electric D.C. power supply variations	–	Voltage tolerance continuous: ± 10% Voltage cyclic variation: 5% Voltage ripple: 10% Electric battery supply: • +30% to –25% for equipment connected to charging battery or as determined by the charging/discharging characteristics, including ripple voltage from the charging device • +20% to –25% for equipment not connected to the battery during charging	
4c	Pneumatic and hydraulic power supply variations	–	Pressure: ± 20% Duration: 15 minutes	

No.	Test	Procedure **(6)**	Test parameters	Other information
5	Dry heat**(1)**	IEC 60068-2-2 Test “Bb” for non-heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing • functional test**(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
		IEC 60068-2-2 Test “Be” for heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing with cooling system on if provided • functional test**(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
6	Damp heat	IEC 60068-2-30 Test Db	Temperature: 55°C Humidity: 95% Duration: 2 cycles (12 + 12 hours)	• measurement of insulation resistance before test • the test shall start with 25°C ± 3°C and at least 95% humidity • equipment operating during the complete first cycle and switched off during second cycle except for functional test • functional test during the first 2 hours of the first cycle at the test temperature and during the last 2 hours of the second cycle at the test temperature; Duration of the second cycle can be extended due to more convenient handling of the functional test • recovery at standard atmosphere conditions • insulation resistance measurements and performance test
7	Vibration	IEC 60068-2-6 Test Fc	• 2 Hz ± 3/0 Hz to 13,2 Hz amplitude: ± 1mm • 13,2 Hz to 100 Hz acceleration: ± 0,7 g For severe vibration conditions such as, e. g., on diesel engines, air compressors, etc.: • 2,0 Hz to 25 Hz amplitude: ± 1,6 mm • 25 Hz to 100 Hz acceleration: ± 4,0 g Note: More severe conditions may exist for example on exhaust manifolds or fuel oil injection systems of diesel engines. For equipment specified for increased vibration levels the vibration test is to be conducted at the agreed vibration level, frequency range and duration. Values may be required to be in these cases: • 40 Hz to 2000 Hz • acceleration: ± 10,0 g at 600°C	• duration 90 minutes at 30 Hz in case of no resonance condition • duration 90 minutes at each resonance frequency at which Q ≥ 2 is recorded • during the vibration test, functional tests are to be carried out • tests to be carried out in three mutually perpendicular planes • it is recommended as a guidance that Q does not exceed 5 • duration 120 minutes where sweep test is to be carried out instead of discrete frequency test and a number of resonant frequencies is detected close to each other. Sweep over a restricted frequency range between 0.8 and 1.2 times the critical frequencies can be used where appropriate. Note: Critical frequency is a frequency at which the equipment being tested may exhibit: • malfunction and/or performance deterioration • mechanical resonances and/or other response effects occur, e.g. chatter

No.	Test	Procedure **(6)**	Test parameters	Other information
8	Inclination	IEC 60092-504	Static 22,5°	a) inclined to the vertical at an angle of at least 22,5° b) inclined to at least 22,5° on the other side of the vertical and in the same plane as in a) c) inclined to the vertical at an angle of at least 22,5° in plane at right angles to that used in a) d) inclined to at least 22,5° on the other side of the vertical and in the same plane as in c) Note: The period of testing in each position should be sufficient to fully evaluate the behaviour of the equipment
			Dynamic 22,5°	Using the directions defined in a) to d) above, the equipment is to be rolled to an angle of 22,5° each side of the vertical with a period of 10 seconds The test in each direction is to be carried out for not less than 15 minutes Note: These inclination tests are normally not required for equipment with no moving parts.
9	Insulation resistance	Rated supply voltage / Test voltage (D.C. voltage) (V) Un ≤ 65 V / 2 x Un min. 24 V Un > 65V / 500 V	Minimum insulation resistance before / after 10 Mohms / 1,0 Mohms 100 Mohms / 10 Mohms	• insulation resistance test is to be carried out before and after: damp heat test, cold test, salt mist test and high voltage test • between all phases and earth, and where appropriate between the phases Note: Certain components, e. g. for EMC protection, may be required to be disconnected for this test
10	High voltage	Rated voltage Un Up to 65 V 66 V to 250 V 251 V to 500 V 501 V to 690 V	Test voltage (A.C. voltage 50 or 60Hz) 2 x Un + 500 V 1500 V 2000 V 2500 V	• separate circuits are to be tested against each other and all circuits connected with each other tested against earth • printed circuits with electronic components may be removed during the test • period of application of the test voltage: 1 minute Note: Certain components, e. g. printed circuits with electronic components, may be required to be disconnected for this test
11	Cold	IEC 60068-2-1	• Temperature: +5°C ± 3°C Duration: 2 hours, or • Temperature: –25°C ± 3°C Duration: 2 hours (see **(2)**)	• initial measurement of insulation resistance • equipment not operating during conditioning and testing except for functional test • functional test during the last hour at the test temperature • insulation resistance measurement and the functional test after recovery

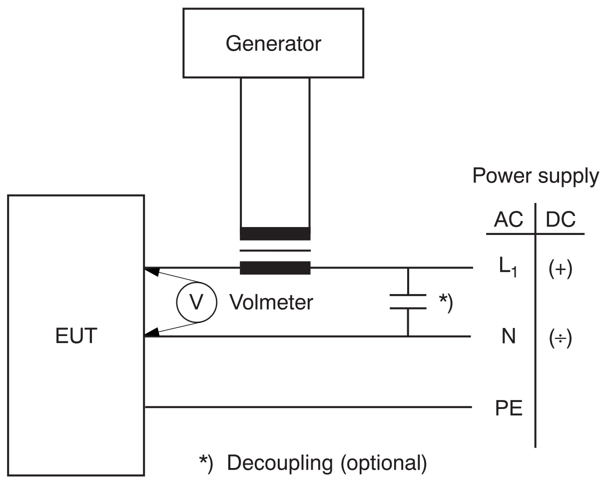
No.	Test	Procedure **(6)**	Test parameters	Other information
12	Salt mist	IEC 60068-2-52 Test Kb	Four spraying periods with a storage of seven days after each	• initial measurement of insulation resistance and initial functional test • equipment not operating during conditioning • functional test on the 7th day of each storage period • insulation resistance measurement and performance test 4 to 6h after recovery (see**(3)**) • on completion of exposure, the equipment shall be examined to verify that deterioration or corrosion (if any) is superficial in nature
13	Electrostatic discharge	IEC 61000-4-2	Contact discharge: 6 kV Air discharge: 2 kV, 4 kV, 8 kV Interval between single discharges: 1 sec. No. of pulses: 10 per polarity According to test level 3	• to simulate electrostatic discharge as may occur when persons touch the appliance • the test is to be confined to the points and surfaces that can normally be reached by the operator • performance criterion B (see**(4)**)
14	Electromagnetic field	IEC 61000-4-3	Frequency range: 80 MHz to 6 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1,5.10^{-3}$ decades/s (or 1% / 3 sec) According to test level 3	• to simulate electromagnetic fields radiated by different transmitters • the test is to be confined to the appliances exposed to direct radiation by transmitters at their place of installation • performance criterion A (see**(5)**) ** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen • If an equipment is intended to receive radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller), then the immunity limits at its communication frequency do not apply, subject to the provisions in Ch 3, Sec 3, [6.2].
15	Conducted low Frequency		A.C.: • Frequency range: rated frequency to 200th harmonic • Test voltage (rms): 10% of supply to 15th harmonic reducing to 1% at 100th harmonic and maintain this level to the 200th harmonic, min 3 V r.m.s, max. 2 W D.C.: • Frequency range: 50 Hz - 10 kHz • Test voltage (rms): 10% of supply, max. 2 W	• to simulate distortions in the power supply system generated, for instance, by electronic consumers and coupled in as harmonics • performance criterion A (see**(5)**) • see figure “Test set-up” (see**(8)**) • for keeping max. 2W, the voltage of the test signal may be lower

No.	Test	Procedure **(6)**	Test parameters	Other information
16	Conducted Radio Frequency	IEC 61000-4-6	AC, DC, I/O ports and signal/ control lines Frequency range: 150 kHz - 80 MHz Amplitude: 3 V rms (see **(7)**) Modulation***: 80% AM at 1000 Hz Frequency sweep range: ≤ 1,5.10^{-3} decades/s (or 1% / 3sec.) According to test level 2	• to simulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines • performance criterion A (see**(5)**) *** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen
17	Electrical Fast Transients / Burst	IEC 61000-4-4	Single pulse time: 5ns (between 10% and 90% value) Single pulse width: 50 ns (50% value) Amplitude (peak): 2 kV line on power supply port/earth; 1 kV on I/O data control and communication ports (coupling clamp) Pulse period: 300 ms Burst duration: 15 ms Duration/polarity: 5 min According to test level 3	• arcs generated when actuating electrical contacts • interface effect occurring on the power supply, as well as at the external wiring of the test specimen • performance criterion B (see**(4)**)
18	Surge	IEC 61000-4-5	Test applicable to AC and DC power ports. Open-circuit voltage: • Pulse rise time: 1,2 µs (front time) • Pulse width: 50 µs (time of half value) • Amplitude (peak): 1 kV line/earth; 0,5kV line/line Short circuit current: • Pulse rise time: 8 µs (front time) • Pulse width: 20 µs (time of half value) Repetition rate: ≥ 1 pulse/min No of pulses: 5 per polarity Application: continuous According to test level 2	• to simulate interference generated, for instance, by switching “ON” or “OFF” high power inductive consumers • test procedure in accordance with figure 10 of the standard for equipment where power and signal lines are identical • performance criterion B (see**(4)**)

No.	Test	Procedure **(6)**	Test parameters	Other information
19	Radiated Emission	CISPR 16-2-3 IEC 60945 for 156-165 MHz	Limits below 1000MHz: • For equipment installed in the bridge and deck zone: Frequency range: (MHz) / Quasi peak limits: (dBµV/m) 0,15 - 0,30 / 80- 52 0,30 - 30 / 52- 34 30 - 1000 / 54 except for: 156 - 165 / 24 • For equipment installed in the general power distribution zone: Frequency range: (MHz) / Quasi peak limits: (dBµV/m) 0,15 - 30 / 80 - 50 30 - 100 / 60 - 54 100 - 1000 / 54 except for: 156 - 165 / 24	• procedure in accordance with the standard but distance 3 m between equipment and antenna • for the frequency band 156 MHz to 165 MHz the measurement is to be repeated with a receiver bandwidth of 9 kHz (as per IEC 60945) • alternatively the radiation limit at a distance of 3 m from the enclosure port over the frequency 156 MHz to 165 MHz shall be 30 dB micro-V/m peak (as per IEC 60945)
			Limits above 1000MHz: Frequency range: (MHz) / Average limit: (dBµV/m) 1000-6000 / 54	• procedure in accordance with the standard (distance 3 m between equipment and antenna) Equipment intended to transmit radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller) may be exempted from limit, within its communication frequency range, subject to the provisions in Ch 3, Sec 3, [6.2]
20	Conducted Emission	CISPR 16-2-1	Test applicable to AC and DC power ports • For equipment installed in the bridge and deck zone: Frequency range: / Limits: (dBµV) 10 - 150 kHz / 96 - 50 150 - 350 kHz / 60 - 50 0,35 - 30 MHz / 50 • For equipment installed in the general power distribution zone: Frequency range: / Limits: (dBµV) 10 - 150 kHz / 120 - 69 150 - 500 kHz / 79 0,50 - 30 MHz / 73	
21	Flame retardant	IEC 60092-101 or IEC 60695-11-5	Flame application: 5 times 15 s each Interval between each application: 15 s or 1 time 30 s	• the burnt out or damaged part of the specimen by not more than 60mm long • no flame, no incandescence or in the event of a flame or incandescence being present, it shall extinguish itself within 30 s of the removal of the needle flame without full combustion of the test specimen • any dripping material shall extinguish itself in such a way as not to ignite a wrappin tissue. The drip height is 200 mm ± 5 mm

No.	Test	Procedure **(6)**	Test parameters	Other information

(1) Dry heat at 70 °C is to be carried out to automation, control and instrumentation equipment subject to high degree of heat, for example mounted in consoles, housings, etc. together with other heat dissipating power equipment.
(2) For equipment installed in non-weather protected locations or cold locations, test is to be carried out at –25°C.
(3) Salt mist test is to be carried out for equipment installed in weather exposed areas.
(4) Performance criterion B: (for transient phenomena): The Equipment Under Test shall continue to operate as intended after the tests. No degradation of performance or loss of function is allowed as defined in the technical specification published by the Manufacturer. During the test, degradation or loss of function or performance which is self recoverable is however allowed but no change of actual operating state or stored data is allowed.
(5) Performance criterion A (for continuous phenomena): The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed as defined in relevant equipment standard and the technical specification published by the Manufacturer.
(6) Column 3 indicates the testing procedure which is normally to be applied. However, equivalent testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled.
(7) For equipment installed on the bridge and deck zone, the test levels shall be increased to 10V rms for spot frequencies in accordance with IEC 60945 at 2,3,4,6.2, 8.2, 12.6, 16.5, 18.8, 22, 25 MHz.
(8) Figure - Test set-up for Conducted Low Frequency - Refer to IEC Publication 60945 (1996).



(9) See [2.2.2], Note 1.

2.4 Loading instruments

2.4.1 Loading instrument approval consists of:

- approval of hardware according to [2.2], unless two computers are available on board for loading calculations only
- approval of basic software according to [2.3]
- approval of application software, consisting in data verification which results in the Endorsed Test Condition according to Pt B, Ch 10, Sec 2, [4]
- installation testing according to Article [4].

3 Acceptance testing

3.1 General

3.1.1 Acceptance tests are generally to be carried out at the manufacturer's facilities before the shipment of the equipment, when requested.

Acceptance tests refer to hardware and software tests as applicable.

3.2 Hardware testing

3.2.1 Final acceptance will be granted subject to:

- the results of the tests listed in [3.2.2]
- the type test report or type approval certificate.

3.2.2 Hardware acceptance tests include, where applicable:

- visual inspection
- operational tests and, in particular:
  - tests of all alarm and safety functions
  - verification of the required performance (range, calibration, repeatability, etc.) for analogue sensors
  - verification of the required performance (range, set points, etc.) for on/off sensors
  - verification of the required performance (range, response time, etc.) for actuators
  - verification of the required performance (full scale, etc.) for indicating instruments
- endurance test (burn-in test or equivalent)
- high voltage test
- hydrostatic tests.

Additional tests may be required by the Society.

3.3 Software testing

3.3.1 Software acceptance tests of computer based systems are to be carried according to requirements mentioned in Ch 3, Sec 3

4 On board tests

4.1 General

4.1.1 Testing is to be performed on the completed system comprising actual hardware components with the final application software, in accordance with an approved test program.After test completion, installed versions of computer based systems software are to be recorded inside the software registry.

4.1.2 On board tests are to be carried out on automation systems associated with essential services to verify their compliance with the Rules, by means of visual inspection and the performance and functionality according to Tab 2.

On board testing is to verify that correct functionality has been achieved with all systems integrated.

When completed, automation systems are to be such that a single failure, for example loss of power supply, is not to result in a major degradation of the propulsion or steering of the ship. In addition, a blackout test is to be carried out to show that automation systems are continuously supplied.

Upon completion of on board tests, test reports are to be made available to the Surveyor.

4.1.3 For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not itself fail as a result of electromagnetic interference during expected operating conditions.

Note 1: Where electromagnetic interference caused by wireless data communication equipment is found to be causing failure of equipment required for Category II or III systems, the layout and/or equipment are/is to be changed to prevent further failures occurring.

Table 2 : On board tests

Equipment	Nature of tests
Electronic equipment	Main hardware and software functionalities with all systems integrated
Analogue sensors	Signal calibration, trip set point adjustment
On/off sensors	Simulation of parameter to verify and record the set points
Actuators	Checking of operation in whole range and performance (response time, pumping)
Reading instruments	Checking of calibration, full scale and standard reference value

Part C
Machinery, Systems and Fire Protection

CHAPTER 4
FIRE PROTECTION, DETECTION AND EXTINCTION

Section 1	General
Section 2	Prevention of Fire and Explosion
Section 3	Suppression of Fire and Explosion: Detection and Alarm
Section 4	Suppression of Fire and Explosion: Control of Smoke Spread
Section 5	Suppression of Fire and Explosion: Containment of Fire
Section 6	Suppression of Fire and Explosion: Fire-Fighting
Section 7	Suppression of Fire and Explosion: Structural Integrity
Section 8	Escape and Circulation
Section 9	Fire Control Plans
Section 10	Helicopter Facilities
Section 11	Alternative Design and Arrangements
Section 12	Protection of Vehicle and Ro-ro Spaces
Section 13	Fire Safety Systems

Section 1 General

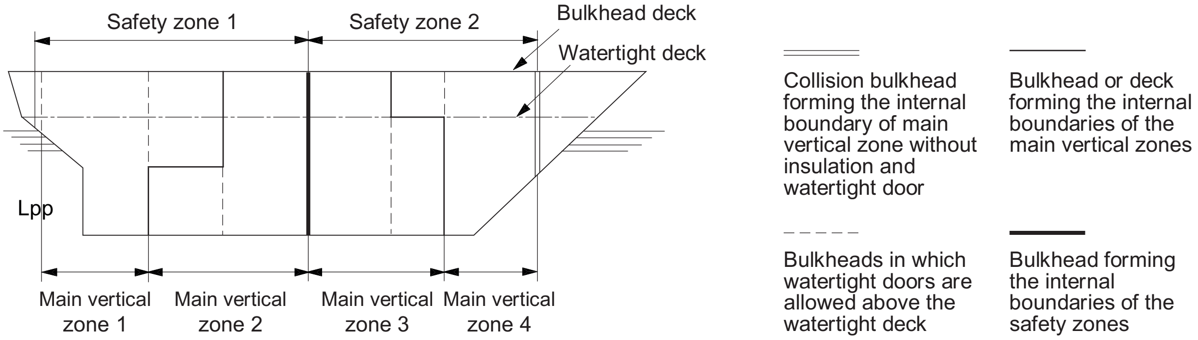
1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to naval surface ships. Fire protection of naval ships shall be achieved by provisions of passive and active fire protection systems for each space and by provisions of the subdivision of the ship spaces into main vertical zones and into safety zones.

1.1.2 The arrangement of the main vertical zones and safety zones can be represented by Fig 1.

Figure 1 : Sample arrangement of main vertical zones and safety zones



1.2 Exemptions

1.2.1 The Society may, if the position of spaces and/or of rooms is such as to render the application of any specific requirement of this Chapter unreasonable or unnecessary, exempt from those requirements individual ships.

1.3 Documentation to be submitted

1.3.1 The interested party is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Structural fire protection showing the purpose and category of the various spaces of the ships, the fire rating of bulkheads and decks, means of closings of openings in A and B class divisions, draught stops, and completed with the indication of material of other bulkhead and of ceilings and lining
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Means of escape and, where required, the relevant dimensioning calculation and the escape route signage
4	A	Automatic fire detection systems and manually operated call points
5	A	Fire pumps and fire main including pumps head and capacity, hydrant and hose locations **(2)**
6	A	Arrangement of fixed and semi-fixed fire-extinguishing systems **(2)**
7	A	Arrangement of sprinkler or sprinkler equivalent systems **(2)**
8	A	Fire-fighting equipment and firemen's outfits
9	A	Electrical diagram of the fixed gas fire-extinguishing systems, fixed fire detection systems, fire alarm and emergency lighting
10	A	Electrical diagram of the sprinkler systems
11	A	Electrical diagram of power control and position indication circuits for fire devices
12	I	General arrangement plan
13	I	Safety zone plan (for information), Main Vertical Zone plan (for approval)
14	A	Fire control plan
15	I	Smoke confinement zone arrangement

No.	I/A **(1)**	Document **(2)**

(1) A = to be submitted for approval
I = to be submitted for information.

(2) Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as:
- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, sprinkler, foam and powder fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

1.4 Type approved products

1.4.1 The following materials, equipment, systems or products in general used for fire protection, are to be type approved by the Society, except for special cases for which an authorisation of use may be given by the Society for individual ships on the basis of documented test reports or ad-hoc tests.

These products are to be installed on board in accordance with the requirements and possible limitations defined in the type approval certificate.

a) A, B class fire divisions (bulkheads or decks) and associated openings

b) C-class divisions

c) Materials for pipes penetrating A or B class divisions (where they are not of steel or other equivalent material)

d) Bulkhead or deck penetrations for electrical cables passing through A or B class divisions

e) Fire dampers

f) Prefabricated sanitary units

g) Prefabricated window casings

h) Fire door control systems

i) Flexible pipes and expansion bellows of non-conventional material for any type of fluid

j) Materials with low flame spread characteristic including paints, varnishes and similar, when they are required to have such characteristic

k) Non-combustible materials

l) Non-readily igniting materials for primary deck coverings

m) Fixed foam fire-extinguishing systems and associated foam-forming liquids

n) Fixed powder fire-extinguishing systems, including the powder

o) Equivalent water-mist fire-extinguishing systems

p) Equivalent fixed gas fire-extinguishing systems

q) Fixed water-based local application fire-extinguishing systems

r) Equivalent water-mist automatic sprinkler systems

s) Fixed fire-extinguishing systems for protection of galley cooking equipment

t) Portable fire-extinguishers

u) Non-portable and transportable extinguisher

v) Fire hoses

w) Portable foam applicators

x) Water and foam monitor

y) Foam proportioner/inductor

z) Sprinkler heads for automatic sprinkler systems

aa) Nozzles for fixed pressure water-spraying fire-extinguishing systems for machinery spaces, boiler rooms, ammunition spaces, deep fat cooking equipment fire-extinguishing systems, and spaces intended for the carriage of vehicles and for hangars

ab) Sensing heads for automatic fire alarm and fire detection systems

ac) Fixed fire detection and fire alarm systems ad) Flammable gas detection system

ae) Explosive mixture detecting systems

af) Portable explosive mixture detecting apparatus

ag) Fixed instruments for measuring the oxygen content for inert gas systems serving cargo tanks

ah) Portable instruments for measuring the oxygen content for inert gas systems serving cargo tanks

ai) Upholstered furniture, excluding the frame (for spaces in [2.29])

aj) Textile and non-textile materials suspended vertically, for example curtains (for spaces in [2.29])

ak) Bedding components (for spaces defined in [2.29])

al) Low location lighting systems

am)Inert gas systems serving cargo tanks

an) Fixed or mobile fire-extinguishing systems with twin agent.

The Society may request type approval for other materials, equipment, systems or products required by the applicable provisions for ships or installations of special types.

On the agreement of the Naval Authority, the Society may also issue a type approval certificate based on other standards recognised by the Naval Authority, and accept this certificate in equivalence of the type approval certificates issued for the classification of not military steel ships.

2 Definitions

2.1 A class divisions

2.1.1 A class divisions are those divisions formed by bulkheads and decks which comply with the following:

a) they shall be constructed of steel or other equivalent material

b) they shall be suitably stiffened

c) they shall be so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test

d) they shall be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

- class "A-60" : 60 minutes
- class "A-30" : 30 minutes
- class "A-15" : 15 minutes
- class "A-0" : 0 minutes

e) the Society shall require a test of a prototype bulkhead or deck in accordance with the “Fire Test Procedures Code” (see [2.17]) to ensure that it meets the above requirements for integrity and temperature rise.

2.1.2 The products indicated in Tab 2 may be installed without testing or approval. Accordingly to the relevant provisions of this chapter, alternative designs may also be accepted in equivalence.

Table 2 :

Classification	Product description
Class A-0 bulkhead	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 60 x 60 x 5 mm spaced at 600 mm or structural equivalent
Class A-0 deck	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 95 x 65 x 7 mm spaced at 600 mm or structural equivalent
Class A-0 to A-60 door	A steel watertight door when used below the bulkhead deck.

2.2 Accommodation spaces

2.2.1 Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, secretariats, meeting rooms, pantries containing no cooking appliances and similar spaces.

2.2.2 Pantries or isolated pantries containing no cooking appliances may contain:

- toasters, microwave ovens, induction heaters and similar appliances each of them with a maximum power of 5 kW; and
- electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 2 kW and a surface temperature not above 150°C.

These pantries may also contain coffee machines, dish washers and water boilers with no exposed hot surfaces regardless of their power. A dining room containing such appliances should not be regarded as a pantry.

2.3 Aircraft deck

2.3.1 Aircraft deck is a purpose-built aircraft landing and take-off deck located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of aircrafts.

2.4 Ammunition spaces

2.4.1 Ammunition spaces are the spaces (integral magazines, independent magazines, small magazines, magazines lockers, magazines boxes and pyrotechnics lockers) used for the storage of ammunition (missiles, shells, mines, demolition stores, etc. charged with explosives, propellant, pyrotechnics, initiating compositions or nuclear, biological or chemical material) for use in conjunction with offensive, defensive, training or non operating purposes, including those parts of the weapons systems containing explosives. Lifting spaces for ammunition are to be considered as ammunition spaces for the purpose of this chapter.

2.5 B class divisions

2.5.1 B class divisions are those formed by bulkheads, decks, ceilings or linings which comply with the following:

a) they shall be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test

b) they shall have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:
   - class "B-15" : 15 minutes
   - class "B-0" : 0 minutes

c) they shall be constructed of approved non-combustible materials and all materials entering into the construction and erection of B class divisions shall be non-combustible, with the exception that combustible veneers may be permitted provided they meet the other relevant requirements of this Chapter

d) the Society shall require a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code (see [2.17]) to ensure that it meets the above requirements for integrity and temperature rise.

2.5.2 In order to be defined as B class, a metal division is to have plating thickness not less than 3 mm when constructed of steel, and not less than 4 mm when constructed of light alloy, and is to have suitable stiffeners or beams.

Lower thickness may be accepted on a case by case basis provided structural calculation accounting also impacts, shocks and vibrations are carried out. Such calculation are to be submitted to the Society for approval.

2.6 Bulkhead deck

2.6.1 The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

2.7 C class divisions

2.7.1 C class divisions are constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the other relevant requirements of this Chapter.

2.8 Cargo spaces

2.8.1 Cargo spaces are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.9 Closed ro-ro spaces

2.9.1 Closed ro-ro spaces are those ro-ro spaces which are neither open ro-ro spaces nor weather decks.

2.10 Closed vehicle spaces

2.10.1 Closed vehicle spaces are those vehicle spaces which are neither open vehicle spaces nor weather decks.

2.11 Continuous B class ceilings and linings

2.11.1 Continuous B class ceilings and linings are those B class ceilings and linings which terminate only at an A or B class division.

2.12 Control stations

2.12.1 Control stations are those spaces in which the ship's radio equipment for safety or ship navigation communication, the ship's main navigating equipment or the emergency source of power are located or where the fire recording or fire control equipment is centralized.

2.13 Damage control station

2.13.1 A damage control station is a control station (see [2.12]) in which the controls and indicators of functions and operations for fire, flooding, alarms, essential machineries, CBRN protection, intercommunication system, etc. as indicated in the present Rules, are centralized.

2.13.2 The list of the references for requirements concerning controls and indicators required to be centralized in the damage control stations as defined in [2.13.1] is indicated in Tab 3.

Table 3 : Controls and/or indicators required in damage control stations

Requirement reference	Related systems
Ch 4, Sec 2, [2.1.1]	Controls and indicators of ventilation systems and fire and smoke damper controls and monitoring
Ch 4, Sec 3, [8.2.1]	Fire detection alarms (see also Ch 4, Sec 3, [3.2.1]) and monitoring, position of fire doors, control and monitoring of ventilation fans
Ch 4, Sec 4, [2.1.3]	Controls for smoke release
Ch 4, Sec 5, [1.2.4]	Opening or closed position of any horizontal enclosure of stairway
Ch 4, Sec 5, [3.1.1], items d) and e)	Remote release of fire doors and status of the fire doors as appropriate
Ch 4, Sec 5, [5.1.1]	Position of fire doors leading to or from vehicle or ro-ro space
Ch 4, Sec 6, [3.2.1]	Controls for closing of ventilation openings and associated monitoring for spaces protected by fixed gas fire-extinguishing systems
Ch 4, Sec 6, [4.6.3]	Alarm of activation of any fixed water-based local application fire-extinguishing system
Ch 4, Sec 12, [2.1.2]	Controls of power ventilation systems for closed vehicle spaces and ro-ro spaces
Ch 4, Sec 12, [2.1.3]	Indication of any loss of capacity of the ventilation systems of close vehicle or ro-ro spaces
Ch 4, Sec 12, [4.1.2]	Position of discharge valves for scuppers in vehicle and ro-ro spaces when protected by water-based fire-extinguishing systems. Visual and audible alarm if fire-extinguishing system operating while the valves are closed
Ch 4, Sec 13, [5.1.4]	Visual and audible alarm in case of activation of local carbon dioxide systems
Ch 4, Sec 13, [6.1.2], items b) 4) and b) 5)	Controls and alarm for activation of high expansion foam fire-extinguishing system
Ch 4, Sec 13, [7.3.1], items l) and o)	Controls and alarms for equivalent water-based fire-extinguishing systems
Ch 4, Sec 13, [7.4.2], item e)	Means of control and monitoring of fixed thick water fire-extinguishing systems
Ch 4, Sec 13, [7.4.2], item i)	Indication of foam concentrate level for thick water systems
Ch 4, Sec 13, [8.2.1], item a)	Means of control of the valves connecting the sprinkler system to the fire main
Ch 4, Sec 13, [8.2.1], items h) and i) Ch 4, Sec 13, [8.3.5], item b) 1)	Visual and audible alarm in case of activation of any manual or automatic sprinkler section valve
Ch 4, Sec 13, [9.1.5], item a) 2)	Control panel for fire detection and fire alarm system
Pt E, Ch 1, Sec 4, [2.1.2], items b) 3) and d), Pt E, Ch 1, Sec 4, [2.3.4], item c), Pt E, Ch 1, Sec 4, [2.4.3]	For ships having the additional class notation **FFS**, position indicator for isolating valves, if provided and overboard discharge valves.
Pt E, Ch 8, Sec 3, [6] and **Tab 3**	For ships to be assigned the additional class notation **CBRN** or **CBRN-AIRBLAST RESISTANCE**, monitoring and control for the CBRN protection systems

2.14 Evacuation stations

2.14.1 The evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

2.15 Fire damper

2.15.1 Fire damper is a device installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of fire. In using the above definition the following terms may be associated:

a) automatic fire damper is a fire damper that closes independently in response to exposure to fire products

b) manual fire damper is a fire damper that is intended to be opened or closed by the crew by hand at the damper itself; and

c) remotely operated fire damper is a fire damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.16 Fire Safety Systems Code

2.16.1 Fire Safety Systems Code means the International Code for Fire Safety Systems as adopted by the Maritime Safety Committee of the IMO by Resolution MSC.98(73).

2.17 Fire Test Procedures Code

2.17.1 Fire Test Procedures Code means the "International Code for Application of Fire Test Procedures, 2010" (2010 FTP Code) as adopted by the Maritime Safety Committee of the IMO by resolution MSC.307(88), as may be amended by the IMO.

2.18 Flashpoint

2.18.1 Flashpoint is the temperature in degrees Celsius (closed cup test) at which the product will give off enough flammable vapour to be ignited, as determined by an approved flashpoint apparatus.

2.19 Fuel oil unit

2.19.1 The fuel oil unit is the equipment used for the preparation of fuel oil for delivery to an oil fired boiler, fuel cell systems or equipment used for the preparation for delivery of heated oil to an internal combustion engine and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 MPa.

2.19.2 "Fuel oil unit" includes any equipment used for the preparation and delivery of fuel oil, whether or not heated, to boilers (including inert gas generators) and engines (including gas turbines) at a pressure of more than 0,18 MPa. Fuel oil transfer pumps are not considered as oil fuel units.

2.20 Low flame spread

2.20.1 Low flame spread means the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the “Fire Test Procedures Code (see [2.17])”.

2.20.2 Non-combustible materials are considered as low flame spread. However, due consideration will be given by the Society to the method of application and fixing.

2.21 Machinery spaces

2.21.1 Machinery spaces are all machinery spaces of category A and all other spaces containing propulsion machinery, boilers, fuel cells systems, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

2.22 Machinery spaces of category A

2.22.1 Machinery spaces of category A are those spaces and trunks to such spaces which contain:

a) internal combustion machinery used for main propulsion, or

b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW or

c) Any oil fired boiler or fuel oil unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc., or

d) gas turbines.

2.23 Main passageways

2.23.1 The main passageways are the corridors giving access to the evacuation stations and located on the same deck level.

2.24 Main vertical zones

2.24.1 Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by A class divisions, the mean length and width of which on any deck does not in general exceed 40 m.

2.25 Non-combustible material

2.25.1 Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the "Fire Test Procedures Code (see [2.17]). Any other material is a combustible material.

2.25.2 In general, products made only of glass, concrete, ceramic products, natural stone, masonry units, common metals and metal alloys are considered as being non-combustible and may be installed without testing and approval.

2.26 Open ro-ro spaces

2.26.1 Open ro-ro spaces are those ro-ro spaces which are either open at both ends, or open at one end and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides (the total area of the space sides excludes the deck areas of the space).

2.27 Open vehicle spaces

2.27.1 Open vehicle spaces are those vehicle spaces which are either open at both ends, or open at one end and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides (the total area of the space sides excludes the deck areas of the space).

2.28 Public spaces

2.28.1 Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges recreational areas, ward rooms, brief rooms, print rooms and similar permanently enclosed spaces.

2.29 Rooms containing furniture and furnishings of restricted fire risk

2.29.1 Rooms containing furniture and furnishings of restricted fire risk are those rooms containing furniture and furnishings of restricted fire risk (whether cabins, public spaces, offices or other types of accommodation) in which:

a) all case furniture such as desks, wardrobes, dressing tables, bureaux, or dressers are constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm may be used on the working surface of such articles

b) all free-standing furniture such as chairs, sofas, or tables are constructed with frames of non-combustible materials

c) all draperies, curtains and other suspended textile materials have, to the satisfaction of the Society, qualities of resistance to the propagation of flame not inferior to those of wool having a mass of 0,8 kg/m^2, this being determined in accordance with the Fire Test Procedures Code (see [2.17])

d) all floor coverings have low flame-spread characteristics

e) all exposed surfaces of bulkheads, linings and ceilings have low flame-spread characteristics

f) all upholstered furniture has qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.17]), and

g) all bedding components have qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.17]).

2.30 Ro-ro spaces

2.30.1 Ro-ro spaces are spaces containing vehicles using internal combustion engines with fuel in their tanks for their own propulsion or vehicles using electrical motors for their own propulsion where power cell loading can be proceeded inside the space; spaces containing landing barges or similar spaces in which vehicles can be loaded and unloaded with their own propulsion and helicopter hangars except small helicopter hangars containing not more than two helicopters without any refuelling facility inside the space.

2.31 Safety zones

2.31.1 Safety zones are damage control zone(s) delimited by watertight bulkheads and decks and fitted with independent ventilation systems and independent fire detection, fire fighting and sea water flooding fighting systems.

2.32 Service spaces

2.32.1 Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, laundries, waste compactors, ironing rooms, laboratories, oven, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.32.2

a) Main pantries and pantries containing cooking appliances may contain:
   1) toasters, microwave ovens, induction heaters and similar appliances each of them with a power of more than 5 kW; and
   2) electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 5 kW.
   These pantries may also contain coffee machines, dish washers and water boilers regardless of their power.
b) Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 4, Sec 5, as galleys.

2.33 Smoke confinement zone

2.33.1 A smoke confinement zone is a smoke sector consisting of a space or group of spaces, in which it is possible to confine and extract the smoke out of the ship.

2.34 Smoke damper

2.34.1 Smoke damper is a device complying with a recognized standard and installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of smoke and hot gases. A smoke damper is not expected to contribute to the integrity of a fire rated division penetrated by a ventilation duct.

In using the above definition the following terms may be associated:

a) automatic smoke damper is a smoke damper that closes independently in response to exposure to smoke or hot gases
b) manual smoke damper is a smoke damper intended to be opened or closed by the crew by hand at the damper itself; and
c) remotely operated smoke damper is a smoke damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.35 Standard fire test

2.35.1 The standard fire test is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods shall be in accordance with the Fire Test Procedures Code (see [2.17]).

2.36 Steel or other equivalent material

2.36.1 Where the words "steel or other equivalent material" occur, "equivalent material" means any non-combustible material which, by itself or due to insulation provided, had structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy without magnesium and with appropriate insulation).

2.37 Vehicle spaces

2.37.1 Vehicle spaces are spaces intended for the carriage of vehicles such as tenders, rescue boats or operational boats having fuel in their tanks for their own propulsion but not using their own propulsion for being loaded or unloaded inside the space; or spaces containing vehicles using electrical motors for their own propulsion where no power cell loading is proceeded inside the space and small helicopter hangars containing not more than two helicopters and without any refuelling facility inside the space.

Note 1: Note 1: Where a connection to the helicopter refuelling piping is fitted inside the helicopter hangar, it is to be considered that the hangar does not fall under the definition of a "vehicle space" but is to be considered as a "ro-ro space" as defined in [2.30].

2.38 Vulnerability zones

2.38.1 Vulnerability zones are damage control zone(s), delimited by watertight bulkheads and decks, which may be specified by the Naval Authority according to its own vulnerability requirements.

2.39 Weather deck

2.39.1 Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.

Section 2 Prevention of Fire and Explosion

1 Probability of ignition

1.1 Arrangements for fuel oil, lubrication oil, JP5-NATO (F44) and other flammable oils

1.1.1 Limitation in the use of oils as fuel

See Ch 1, Sec 1, [2.9].

1.2 Arrangements for fuel oil and JP5-NATO (F44)

1.2.1 See Ch 1, Sec 10.

1.3 Arrangements for lubricating oil

1.3.1 See Ch 1, Sec 10.

1.4 Arrangements for other flammable oils

1.4.1 See Ch 1, Sec 10.

1.5 Use of gaseous fuel for domestic purpose

1.5.1 The use of gaseous fuel for domestic purpose is not allowed.

1.6 Miscellaneous items of ignition sources and ignitability

1.6.1 Electric radiators

Electric radiators, if used, shall be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiators shall be fitted with an element so exposed that clothing, curtains, or other similar materials can be scorched or set on fire by heat from the element.

1.6.2 Cellulose-nitrate based films

Cellulose-nitrate based films shall not be used for cinematograph installations.

1.6.3 Waste receptacles

All waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom.

1.6.4 Insulation surfaces against oil penetration

In spaces where penetration of oil products is possible, the surface of insulation shall be impervious to oil or oil vapours.

1.6.5 Primary deck coverings

Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not readily ignite, this being determined in accordance with the Fire Test Procedures Code (see Ch 4, Sec 1, [2.17]).

1.7 Non-sparking fans

1.7.1 General

Where non-sparking fans are required by the Rules, the provisions of the following [1.7.2] and [1.7.3] are also to be complied with.

1.7.2 Design criteria

a) The air gap between the impeller and the casing is to be not less than 1/10 of the shaft diameter in way of the impeller bearing and in any case not less than 2 mm, but need not exceed 13 mm.

b) Protective screens with square mesh of not more than 13 mm are to be fitted to the inlet and outlet of ventilation ducts to prevent objects entering the fan housing.

1.7.3 Materials

a) Except as indicated in the fourth bullet of item c) below, the impeller and the housing in way of the impeller are to be made of spark-proof materials which are recognised as such by means of an appropriate test to the satisfaction of the Society.

b) Electrostatic charges, both in the rotating body and the casing, are to be prevented by the use of antistatic materials. Furthermore, the installation on board of ventilation units is to be such as to ensure their safe bonding to the hull

c) Tests may not be required for fans having the following material combinations:
- impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
- impellers and housings of non-ferrous materials
- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous material is fitted in way of the impeller
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

d) The following impeller and housing combinations are considered as sparking and therefore are not permitted:
- impellers of an aluminium alloy or a magnesium alloy and a ferrous housing, regardless of tip clearance
- housings made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance
- any combination of ferrous impeller and housing with less than 13 mm design tip clearance.

e) Complete fans are to be tested in accordance either with the Society's requirements or national or international standards accepted by the Society.

2 Fire growth potential

2.1 Control of air supply and flammable liquid to the space

2.1.1 Application

The devices and means in [2.1.2] and [2.1.3] and fire and smoke dampers as required in the present Chapter, in addition to be operable as stated therein, are to be operable from a continuously manned damage control station.

2.1.2 Closing appliances and stopping devices of ventilation

a) The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated.

The controls are to be easily accessible as well as prominently and permanently marked and are to indicate whether the shut-off is open or closed.

Ventilation inlets and outlets located at outside boundaries are to be fitted with closing appliances as required above and need not comply with Ch 4, Sec 5, [6.4.2].

b) Power ventilation of any space shall be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served.

c) All power ventilation, except for ventilation of machinery space and vehicle and ro-ro spaces and any alternative system which may be required under Ch 4, Sec 4, [1.1.1], shall be fitted with controls so grouped that all fans may be stopped from either of two separate positions which shall be situated as far apart as practicable. Controls provided for the power ventilation serving machinery spaces shall also be grouped so as to be operable from two positions, one of which shall be outside such spaces. Fans serving power ventilation systems to vehicle and ro-ro spaces shall be capable of being stopped from a safe position outside such spaces.

2.1.3 Means of control in machinery spaces

a) Means of control shall be provided for closure of openings in funnels which normally allow exhaust ventilation, and closure of ventilator dampers.

b) Means of control shall be provided for stopping ventilating fans. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

Note 1: The ventilation fans and the fire dampers serving a machinery room equipped with internal combustion engines taking their combustion air directly inside the room are not to be automatically stopped or closed, in order to prevent depressurization of the room.

c) Means of control shall be provided for stopping forced and induced draught fans, fuel oil transfer pumps including JP5 pumps, fuel oil unit pumps and other similar fuel pumps.

This applies also to lubricating oil pumps and oil separators (purifiers) except oily water separators.

d) The controls required in a) to c) above shall be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve.

In machinery spaces of category A, controls to close off ventilation ducts and pipes are to be installed with due regard to the hot gases produced by a fire in the space concerned.

e) The controls required in the above items a) to d) and in Ch 4, Sec 4, [2.1.2] and in Ch 4, Sec 5, [4.2.2] and the controls for any required fire-extinguishing system shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society.

Means for stopping the fuel oil transfer pumps including JP5 pumps required in item c) are also to be capable of being operated from the inside of the space in which the pumps are situated.

2.2 Fire protection materials

2.2.1 Use of non-combustible materials

a) Insulating materials

Except in refrigerated compartments, insulating materials shall be non-combustible. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings, for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

Cold service means refrigeration systems and chilled water piping for air conditioning systems.

b) Ceilings and linings

Except in refrigerated compartments, all linings, grounds, draught stops, ceilings shall be of non combustible materials. Partial bulkheads or decks used to subdivide a space for utility shall also be of non-combustible material.The floor plating of normal passageways in machinery spaces of category A is to be made of steel.

2.2.2 Use of combustible materials

a) General

"A", "B" or "C" class divisions, which are faced with combustible materials and combustible facing, moulding, decorations, veneers and paints, may be used in accordance with the provisions of b) to d) and [3] below.

b) Maximum calorific value of combustible materials

Materials used on surfaces, and covered by the requirement of item a), shall not have a calorific value exceeding 45 MJ/m^2 of the area for the thickness used.

This requirement does not apply to the surfaces of furniture fixed to the linings and the walls.

c) Total volume of combustible materials

When combustible materials are used as permitted in the previous item a), the total volume of combustible components (facings, mouldings, decorations and veneers in any accommodation and service space) shall not exceed a volume equivalent to 2,5 mm veneer on the combined area of the walls and ceiling linings.

Furniture fixed to linings and walls or decks need not be included in the calculation of the maximum calorific values and volume of combustible material.

d) Low flame spread characteristics of surfaces

The following surfaces shall have low flame spread characteristics in accordance with the Fire Test Procedures Code:

1) exposed surfaces (deck, ceilings and bulkheads) in all spaces of the ship

2) surfaces including grounds in concealed or inaccessible spaces in all spaces of the ship.

2.2.3 Furniture

Furniture shall not be permitted in corridors and in stairway enclosures forming escape routes.

3 Smoke generation potential and toxicity

3.1 General

3.1.1 The following equipment/materials shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code, in all spaces of the ship:

- deck coverings and floor coverings
- veneers
- ceiling facings
- paints, varnishes and other finishes.

In general, non-combustible materials are considered to comply with the requirements for smoke generation potential and toxicity without further testing.

3.2 Primary deck coverings

3.2.1 Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not give rise to toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

Section 3 Suppression of Fire and Explosion: Detection and Alarm

1 General

1.1 Minimum number of detectors

1.1.1 Where a fixed fire detection and fire alarm system is required for the protection of spaces other than those specified in [4.1.1], at least one detector complying with the requirements given in Ch 4, Sec 13 shall be installed in each such space.

2 Initial and periodical test

2.1 General

2.1.1 After installation the function of the fire detection system required in the relevant sections of this chapter shall be tested under varying conditions of ventilation and engine operation. However, the arrangement of the fire detectors is not required to be tested for each space but only for a representative sampling of spaces.

Each detector is to be individually tested.

2.1.2 The function of the detection system shall be periodically tested to the satisfaction of the Society by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

3 Protection of machinery spaces

3.1 Installation

3.1.1 A fixed fire detection and fire alarm system complying with the relevant provisions given in Ch 4, Sec 13 shall be installed in any machinery space (see Ch 4, Sec 1, [2.21.1]).

For fire detecting system for unattended machinery spaces, see also to Pt E, Ch 4, Sec 1.

3.1.2 Both smoke and flame detectors are to be installed in machinery spaces of category A.

3.2 Design

3.2.1 The fire detection system required in [3.1.1] shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in recesses and in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors are not permitted.

The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigating bridge and in the damage control station(s) (see Ch 4, Sec 1, [2.13.1]and Ch 4, Sec 1, [2.31]).

4 Protection of accommodation, service spaces and control stations

4.1

4.1.1 A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors and stairways. Smoke detectors need not be fitted in private bathrooms.

4.1.2 In order to avoid any false alarm, installation of smoke detectors is not suitable for spaces where smoke, dust or fumes are regularly present and consequently special detectors adapted to the environmental conditions are to be selected. For instance, heat detectors may be installed in lieu of smoke detectors in galleys and laundries.

5 Protection of ammunition spaces

5.1 Application and general requirements

5.1.1 Ammunition spaces are to be provided with a fixed fire detection and alarm system complying with the requirements of Ch 4, Sec 13.

The detection system has to include smoke, temperature and temperature gradient detections.

Information concerning the surveillance and monitoring thresholds for temperature and temperature gradient is to be clearly indicated on the outside of main access points to these spaces and is to be available at a suitable continuously manned control position.

Smoke detectors are to be fitted in ammunition lifts trunks.

5.1.2 Sidescuttles may be fitted in the bulkheads or doors of ammunition spaces in order to provide clear view from outside of the space. In this case, the sidescuttle and its arrangement is to ensure that the strength and fire integrity of the division is maintained.

6 Manually operated call point

6.1 General requirements

6.1.1 Manually operated call points complying with the requirements of Ch 4, Sec 13, if required by the Naval Authority, shall be installed throughout the accommodation spaces, service spaces and control stations as follows:

- One manually operated call point shall be located at each exit of escape routes.
- Manually operated call points shall be readily accessible in the corridors of each deck so that no part of the corridor is more than 20 m from a manual call point.

Consideration is to be given to the installation of additional manually operated call points in spaces where high fire risk operations are conducted.

7 Inspection hatches and radiotelephone apparatus

7.1 Inspection hatches

7.1.1 The construction of ceiling and bulkheading shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible places.

7.2 Radiotelephone apparatus

7.2.1 Each member of the fire patrol shall be provided with a two-way portable radiotelephone apparatus.

7.2.2 Two-way portable telephone apparatuses are to be audible from most parts of the vessel. As a minimum, they are to be audible in areas where the fire patrol make their rounds such as key box locations and the routes specified on fire patrol check lists. If necessary, extra antennas are to be fitted to obtain effective communication.

8 Receiving systems of fire alarm

8.1 Control panel

8.1.1 The control panel of a fixed fire detection and fire alarm system shall be designed on the fail-safe principle, e.g. an open detector circuit shall cause an alarm condition.

8.2 Position of detection alarms, remote control and control panels

8.2.1 Ships shall have the detection alarms for the systems required in this Section centralized in a damage control stations. In addition, controls for shutting down the ventilation fans and, when remote closing appliances are provided for fire doors, the controls of those fire doors for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans shall be capable of reactivation by the crew at the continuously manned damage control stations. The control panels in the damage control stations shall be capable of indicating open or closed positions of fire doors, if any, closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and should have an automatic change-over to standby power supply in the event of loss of normal supply. The control panel shall be powered from at least two electrical switchboards which cannot be put out of service at the same time by any event. The separated feeders shall be so arranged as to avoid galleys, machinery spaces, ammunition spaces and other high fire risk spaces except in so far as it is necessary to reach the appropriate switchboards.

Section 4 Suppression of Fire and Explosion: Control of Smoke Spread

1 Protection of control stations outside machinery spaces

1.1 General

1.1.1 Practicable measures shall be taken for control stations, as defined in Ch 4, Sec 1, [2.12.1], outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained so that, in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided and air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. At the discretion of the Society, such requirements need not apply to control stations situated onto, an open deck or where local closing arrangements would be equally effective.

1.1.2 Equally effective local closing arrangements means that in the case of ventilators these are to be fitted with fire dampers or smoke dampers which are to be easily closed within the control station in order to maintain the absence of smoke in the event of fire.

2 Release of smoke from machinery spaces

2.1 General

2.1.1 Suitable arrangements shall be made to permit the release of smoke in the event of fire, from the space to be protected.

Usual ventilation systems are acceptable as arrangements for permitting the release of smoke.

2.1.2 Means of control shall be provided for permitting the release of smoke and the controls shall be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve.

2.1.3 The controls of [2.1.2] shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Furthermore controls of item [2.1.2] shall be also situated in the damage control station(s).

3 Draught stops

3.1 General

3.1.1 Air spaces enclosed behind ceilings, panelling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

4 Smoke extraction system

4.1 General

4.1.1 The purpose of the smoke extraction system is to confine the smoke during the fire-fighting operations and to extract out of the ship the smoke produced by a fire after the fire-fighting operations.

The ship is to be divided in smoke confinement zones (SCZ) in which the smoke is confined.

The smoke extraction after the fire-fighting operations shall be proceeded by means of portable, semi-fixed or fixed equipment.

The use of the machinery space ventilation system can be considered for smoke clearance during the fire-fighting operations provided that, at the end of the operation, the smoke to be extracted is not confined in any other space.

Drawings dealing with smoke extraction system are submitted to the Society for information.

4.2 Smoke confinement zones

4.2.1 A smoke confinement zone is not to extend out from a main vertical zone.

4.2.2 The smoke confinement zone is to be built within the existing A class bulkheads and decks as defined in Ch 4, Sec 5, including shell and hull boundaries.

Under the watertight deck, watertight sections constitute smoke confinement zones.

All enclosed spaces of the ship are to be included in the smoke confinement zones.

When it is not practical and to the satisfaction of the Society, individual spaces having direct access to the exterior may be excluded from the smoke confinement zones.

4.2.3 When a bulkhead acting as a boundary of a smoke confinement zone is fitted with a door, this door is to be provided with a curtain made of non combustible materials in order to contain the smoke in the smoke confinement zone when the door is opened.

It is not necessary to provide curtains on doors opening to the exterior of the ship.

4.2.4 When a deck acting as a boundary of a smoke confinement zone is fitted with a deck panel, this panel is to be provided with a blanket made of non combustible materials in order to contain the smoke in the smoke confinement zone when the panel is opened.

It is not necessary to provide curtains on panels opening to the exterior of the ship.

4.2.5 Ventilation ducts or balancing openings penetrating the boundaries of smoke confinement zones are to be provided with smoke dampers.

4.3 Means of smoke extraction

4.3.1

a) General

1) Above the highest waterline, some exterior openings on the ship shell side are to be provided to exhaust the smoke out of the ship. At least one such opening is to be provided for each main vertical zone.

Note 1: If the part of the ship located forward the collision bulkhead is a main vertical zone, the above requirement need not be complied with in this main vertical zone.

2) It is to be provided a sufficient number of portable flexible exhaust ducts of a sufficient length which can be easily connected to the fixed or portable exhaust fans and connected the ones to the others in order to conduct smoke from the smoke confinement zone to the exterior of the ship. In any case, the portable flexible exhaust ducts are to have a length of not less than the moulded depth of the ship.

3) Where the portable flexible exhaust ducts can not be connected directly to the exterior openings mentioned in 1) above, there shall be provided some fixed exhaust ducts upstream the exterior openings. These fixed exhaust ducts are to comply with the applicable requirements of Ch 4, Sec 5, [6].

4) There is to be provided at least a portable or fixed smoke exhaust fan for each safety zone. The number and position of the fixed or portable exhaust fans is to be such that in no part of the smoke confinement zones, it is necessary to use in length more than 30 m of portable flexible ducts.

5) Where the smoke to extract from a smoke confinement zone can contain any explosive vapours, the impeller of the fan is to be of a non-sparking type.

6) Fixed or portable exhaust fans and their portable flexible or fixed exhaust ducts are to be suitable for smoke temperature greater than 300°C. They are to be of a type easy to operate after the fire-fighting operations. The size of the portable flexible exhaust ducts is to be such as not to prevent from handling other safety equipment

b) Additional requirements

In machinery spaces of category A and in ro-ro spaces, the exhaust fans are to be sized such that the entire volume within the space can be exhausted in less than 10 minutes.

Section 5 Suppression of Fire and Explosion: Containment of Fire

1 Thermal and structural boundaries

1.1 Thermal and structural division

1.1.1 The ship shall be subdivided into spaces by thermal and structural divisions having regard to the fire risk of the space.

1.2 Main vertical zones and horizontal zones

1.2.1

a) The interior of the hull, superstructure and deckhouses shall be divided (see Ch 4, Sec 1, [2]) into main vertical zones by A-30 class divisions unless the requirements of Tab 1 and Tab 2 are more stringent. Steps and recesses shall be kept to a minimum, but where they are necessary, they shall have the same fire integrity of the vertical limits of the main vertical zones. Where a category (5), (9) or (10) space defined in item b) of [1.2.3] is on one side or where fuel or diesel oil or JP 5 NATO (F44) tanks or water capacities are on both sides of the division, the standard can be reduced to A-0.

b) As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of the main vertical zones may be extended to a maximum of 50 m to the satisfaction of the Society, as it may be necessary in order to bring the ends of the main vertical zones to coincide with watertight subdivision bulkheads or in order to accommodate a large space extending for the whole length of the main vertical zone, provided the total area of the main vertical zone is not greater than 1600 m^2 on any deck.

   The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it.

   If a stairway serves two main vertical zones, the maximum length of any one main vertical zone need not be measured from the far side of the stairway enclosure. In this case all boundaries of the stairway enclosure are to be insulated as main vertical zone bulkheads and access doors leading into the stairway are to be protected from the two outside zones.

Note 1: Locally, when the length or the width of one main vertical zone is more than 50 m and the total area is more than 1600 m^2, following the procedure mentioned in Ch 4, Sec 11, the Society may accept an alternative arrangement provided that additional measures are taken for the escape and fire-fighting.

Note 2: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need comply neither with the requirements of Ch 4, Sec 4, [4.3.1], item a) 1), neither with those of [6.3.7] of the present Section or of Ch 4, Sec 6, [8.2].

c) Such bulkheads shall extend from deck to deck and to the shell or other boundaries.

d) Not withstanding the provisions of Ch 4, Sec 12, on spaces designed for special purpose, such as vehicle and ro-ro spaces where the provisions of main vertical zone bulkheads would defeat the purpose for which such spaces are intended, equivalent means for controlling and limiting a fire shall be substituted and specifically approved by the Society.

1.2.2 Bulkheads within a main vertical zone and within a safety zone

a) All bulkheads which are not required to be A class divisions shall be at least B class or C class divisions as prescribed in Tab 1 and Tab 2.

b) Bulkheads required to be B class divisions shall extend from deck to deck and to the shell or other boundaries. However, where continuous B class ceiling or lining is fitted on both sides of a bulkhead which is at least of the same resistance as the adjoining bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

1.2.3 Fire integrity of bulkheads and decks

a) In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned in [1.2.1] and [1.2.2], the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tab 1 and Tab 2. Where, due to any particular structural arrangements in the ship, difficulty is experienced in determining from the Tables the minimum fire integrity value of any divisions, such values shall be determined to the satisfaction of the Society.

b) The following requirements govern application of the tables:

   1) Tab 1 and Tab 2 shall apply, respectively, to the bulkheads and decks separating adjacent spaces.

   2) For determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (15) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this Section, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have

less than 30% communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as described in Tab 1 and Tab 2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- (1) Control stations and equivalent spaces

  Space containing damage control equipment.

  Spaces containing emergency sources of power and lighting, if any (see also Ch 2, Sec 3, [2.3.1]).

  Wheelhouse and chartroom.

  Spaces containing the ship's radio equipment for safety or ship navigation communication.

  Fire-extinguishing rooms, fire control rooms and fire recording stations.

  Control room for propulsion machinery when located outside the propulsion machinery space.

  Spaces containing centralized fire alarm equipment.

  Spaces containing network cabinets for computer and control centers, electronic cabinet systems or control computers managing data related to the control of the ship.

  Spaces containing centralized emergency public address system stations and equipment.

  For the purpose of this section, the spaces normally manned containing naval systems for detection, command, defence, offence, communication, combat (e.g. COC) or weapon control/operation; aviation control room; bridge for command, defence, operation or planning rooms and spaces containing centralised ship's operation equipment (e.g. COP) are assimilated as a control station.

  In addition, the Naval Authority may specify a list of additional spaces judged critical for naval operations, to be considered as control stations.

- (2) Stairways

  Interior stairways, lifts, totally enclosed emergency trunks and escalators (other than those wholly contained within the machinery spaces or ammunition spaces or ro-ro spaces) for persons and enclosures thereto.

  In this connection a stairway which is enclosed at only one level shall be regarded as part of the space from which it is not separated by a fire door. Interior emergency exit ladders.

- (3) Corridors

  Lobbies and corridors including recess to punctually accommodate safety equipment.

Note 1: Electrical distribution boards may be located within accommodation spaces including corridors and stairway enclosures, without the need to categorize the space, provided no provision is made for storage.

- (4) Evacuation stations and external escape routes

  Survival craft stowage area.

  Open deck spaces and passageway forming lifeboat and liferaft embarkation and lowering stations.

  External stairs and open decks used for escape routes.

  The ship's side to the waterline in the lightest condition including superstructures and deckhouse sides situated below the evacuation areas.

  Internal and external assembly stations.

  The Note 2 to Note 3 of the category (5) below are also applicable for this category (4).

- (5) Open deck spaces

  Open deck spaces other than those defined in category (4) above.

  Open deck spaces for the stowage of any embarkation such as tender or operational boat excluding rescue boats, lifeboats and liferafts.

  Air spaces (the spaces outside superstructures and deckhouses).

Note 2: Non-enclosed spaces naturally ventilated can be assimilated to an open deck.

Note 3: Non-enclosed spaces are spaces for which their boundaries are provided with permanent openings with the exterior, reaching a minimum area of at least 30% of the total area of their boundaries adjacent to the exterior.

Note 4: The containers for the storage of the combustible oil used for the embarkations are allowed to be located in the category (4) and (5) spaces as far as practical of the embarkations.

Note 5: In case weapon systems are installed on open deck, specific requirements regarding structural fire protection and fire fighting to be applied to the weapon system area and adjacent spaces, may be defined by the Naval Authority.

In absence of specific requirement from Naval Authority, these areas are considered as open deck spaces.

- (6) Accommodation spaces of minor fire risk

  Cabins containing furniture and furnishings of restricted fire risk.

  Offices and dispensaries containing furniture and furnishings of restricted fire risk.

  Public spaces and berthing spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than 50 m^2.

- (7) Service spaces and accommodation spaces of moderate fire risk

  Spaces as in category (6) above but containing furniture and furnishings of other than restricted fire risk.

Public spaces and berthing spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m^2 or more.

Laboratories in which flammable liquids are not stowed.

Isolated lockers and stores in accommodation spaces in which flammable liquids are not stored and having a deck area of less than 4 m^2.

Cleaning gear lockers (in which flammable liquids are not stowed).

Pharmacies containing medicines in quantity not exceeding the daily use.

Operating rooms and other rooms for such purpose.

- (8) Accommodation spaces of greater fire risk

  Public and berthing spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 or more.

- (9) Sanitary and similar spaces

  Communal sanitary facilities, showers, baths, water closets, etc.

  Small laundries.

  Drying rooms having a deck area of 4 m^2 or less.

  Isolated pantries containing no cooking appliances in accommodation spaces.

  Private sanitary facilities shall be considered a portion of the space in which they are located.

- (10) Tanks, voids and auxiliary machinery spaces having little or no fire risk

  Water tanks forming part of the ship's structure.

  Voids and cofferdams.

  Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:

  - ventilation and air-conditioning rooms
  - windlass room
  - steering gear room
  - stabilizer equipment room
  - electric propulsion motor room having in the aggregate a total power output of not more than 1500 kW
  - rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA)
  - shaft alleys and pipe tunnels
  - spaces for pumps and refrigeration machinery (not handling or using flammable liquids).

  Technical galleries not serving as an escape route and not giving direct access to accommodation spaces, service spaces, control stations, vehicle and ro-ro spaces.

  Closed trunks serving the spaces listed above.

  Other closed trunks such as pipe and cable trunks.

- (11) Auxiliary machinery spaces and other similar spaces of moderate fire risk

  Refrigerated chambers.

  Fuel oil and JP5 tanks (where installed in a separate space with no machinery).

  Shaft alleys and pipe tunnels allowing storage of combustibles.

  Auxiliary machinery spaces as in category (10) which contain machinery having a pressure lubrication system or where storage of combustibles is permitted and rooms containing electrical motors having in the aggregate a total power output of more than 1500 kW.

  Pump rooms for the internal combustion machinery used for the purpose onboard the ship (such as, for propulsion, electrical power generation, etc., and excluding the internal combustion machinery of the vehicles carried onboard).

  Spaces containing oil-filled electrical transformers (above 10 kVA).

  Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.

  Vehicle spaces not forming a main horizontal zone.

  Rooms containing main low voltage and high voltage switchboards (above 600kW).

  Closed trunks serving the spaces listed above.

- (12) Machinery spaces of category A and equivalent spaces of high fire risk

  Machinery spaces as defined in Ch 4, Sec 1, [2.22.1].

  Auxiliary machinery spaces other than those in categories (10) and (11) which contain internal combustion machinery or other oil-burning, heating or pumping units.

  Main galleys and annexes.

Opened trunks to the spaces listed above.

Storage tanks for oil having a flash-point below 60°C.

Aircraft refuelling stations, JP5 pump rooms and other pump rooms used for the refuelling of vehicles carried onboard.

Note 6: If fire insulation is required above a machinery space of category A, this fire insulating material is not to be provided above the steel deck like for a floating floor but under the steel deck on the stiffened side of the steel deck.

- (13) Service spaces of high fire risk

  Main pantries not annexed to galleys as defined in Ch 4, Sec 1, [2.32.2].

  Garbage rooms.

  Main laundries.

  Drying rooms having an area greater than 4 m^2.

  Workshops other than those forming part of machinery spaces.

  Isolated lockers and store rooms having a deck area of more than 4 m^2 in which flammable liquids are not stowed.

- (14) Special purpose spaces

  Laboratories, isolated lockers and store rooms in which flammable liquids are stowed.

  Pharmacies other than those defined in (7).

  Paint lockers.

  Ro-ro spaces not forming a main horizontal zone.

  Aircraft or helicopter decks.

- (15) Ammunition spaces and other equivalent spaces

  Ammunition spaces as defined in Ch 4, Sec 1, [2.4.1] and ammunition transfer chambers and lifts to such spaces.

3) The Society shall determine in respect of category (5) spaces whether the insulation values in Tab 1 shall apply to ends of deckhouses and superstructures, and whether the insulation values in Tab 2 shall apply to weather decks. In no case shall the requirements of category (5) necessitate enclosure of spaces which in the opinion of the Society need not be enclosed.

1.2.4 Protection of stairways and lifts in accommodation spaces, service spaces and control stations

a) Stairways and lift trunks which penetrate more than one single deck are to be within enclosures formed of "A" class divisions, in accordance with Tab 1 and Tab 2, and be protected by self-closing doors at all levels.

b) A stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or self-closing doors in one `tweendeck space. When a stairway is closed in one `tweendeck space, the stairway enclosure is to be protected in accordance with Tab 2.

   The door provided at this stairway enclosure is to be of the self-closing type.

c) For the application of items a) and b), a deck fitted with a deck hatch at a stairway penetration is not considered to be penetrated by the stairway provided the deck hatch meets the following requirements:

   1) The hatch has the same fire integrity as the deck on which it is fitted.

   2) Indication is provided at the fire door indicator panel in the continuously manned damage control station whether the deck hatch is opened or closed.

   3) An instruction is given to the crew that the hatch is to be closed in case of fire detection in the main fire zone containing the deck hatch.

   4) The hatch is to be fitted with a notice indicating the normal position of the hatch at sea, to the satisfaction of the Society.

Note 1: The arrangement of item c) will not be accepted if the deck forms the boundary of a main vertical zone.

d) Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one ‘tweendeck to another and shall be provided with means of closing so as to permit the control of draught and smoke. Machinery for lifts located within the stairway enclosures shall be arranged in a separate room, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts which open into spaces other than corridors, public spaces, ro-ro spaces, stairways and external areas shall not open into stairways included in the means of escape.

1.2.5 Protection of ammunition spaces

Fire insulation for the boundaries of ammunition spaces is to be installed outside of the ammunition spaces as much as possible.

Table 1 : Bulkheads not bounding neither vertical zones nor horizontal zones nor safety zones

SPACES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces (1)	A-0 [e]	A-0	A-0	A-0	A-0	A-0	A-30 [c]	A-30 [c]	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Stairways (2)		A-0 [d]	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-15	A-30	A-15	A-30	A-30
Corridors (3)			C	A-0	A-0	B-0	B-0 [a]	B-0	B-0	A-0	A-15	A-30	A-15	A-30	A-30
Evacuation stations and external escape routes (4)				*	A-0	A-0	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Open deck spaces (5)					*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [b]
Accommodation spaces of minor fire risk (6)						C	C [a]	C	C	A-0	A-15	A-30	A-0	A-15	A-30
Services spaces and accommodation spaces of moderate fire risk (7)							C [a], [d]	C [a]	C [a]	A-0	A-15	A-60	A-15	A-30	A-30
Accommodation spaces of greater fire risk (8)								C	C	A-0	A-30	A-60	A-15	A-60	A-30
Sanitary and similar spaces (9)									C	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, void and auxiliary machinery spaces having little or no fire risk (10)										A-0 [d]	A-0	A-0	A-0	A-0	A-30 [b]
Auxiliary machinery spaces and other similar spaces of moderate fire risk (11)											A-0 [d]	A-0	A-0	A-0	A-30
Machinery spaces of category A and equivalent spaces of high fire risk (12)												A-0 [d]	A-60	A-60	A-60
Service spaces of high fire risk (13)													A-0 [d]	A-30	A-30
Special purpose spaces (14)														A-0	A-30
Ammunition spaces and other equivalent spaces (15)															A-30

[a] : If a laboratory, an isolated locker or a store having deck area of more than 4 m^2 and not containing liquid is concerned, a fire division of at least “A-0” fire class standard is required.

[b] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only “A-0” fire class standard is required.

[c] : If the ship is provided with the additional class notation **FIRE** the fire class standard can be reduced to “A-0” fire class standard.

[d] : Where adjacent spaces are in the same numerical category and subscript [d] appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g. a galley next to a galley does not require a bulkhead but a galley next to a paint room requires an “A-0” bulkhead.

[e] : Bulkheads separating the wheelhouse, chartroom and radio room from each other can have only a “B-0” rating.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of “A” class standard. However, where a deck, except an open deck of category (5), is penetrated for the passage of electrical cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

Note 1: (to be applied to Tab 1 and Tab 2, as appropriate).

Table 2 : Decks not forming steps in main vertical zones nor bounding horizontal zones nor safety zones

SPACE below	SPACE above														
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces (1)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-60	A-15	A-30	A-30
Stairways (2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-0	A-30
Corridors (3)	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-0	A-30
Evacuation stations and external escape routes (4)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Open deck spaces (5)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [b]
Accommodation spaces of minor fire risk (6)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-15	A-30
Services spaces and accommodation spaces of moderate fire risk (7)	A-30 [c]	A-0	A-0	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-30
Accommodation spaces of greater fire risk (8)	A-30 [c]	A-15	A-0	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-30
Sanitary and similar spaces (9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, void and auxiliary machinery spaces having little or no fire risk (10)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-0	A-30 [b]
Auxiliary machinery spaces and other similar spaces of moderate fire risk (11)	A-60 [f]	A-15 [f]	A-15 [f]	A-60 [f]	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-30 [f]
Machinery spaces of category A and equivalent spaces of high fire risk (12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30	A-30 [d]	A-60	A-60	A-60
Service spaces of high fire risk (13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-30	A-0	A-0	A-0	A-0	A-30	A-30
Special purpose spaces (14)	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-30	A-30	A-0	A-30
Ammunition spaces and other equivalent spaces (15)	A-30	A-30	A-30	A-30	A-30 [b]	A-30	A-30	A-30	A-30	A-30 [b]	A-30	A-60	A-30	A-30	A-30

[a] : If a laboratory, an isolated locker or a store having deck area of more than 4 m^2 and not containing liquid is concerned, a fire division of at least “A-0” fire class standard is required.

[b] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only “A-0” fire class standard is required.

[c] : If the ship is provided with the additional class notation **FIRE** the fire class standard can be reduced to “A-0” fire class standard.

[d] : Where adjacent spaces are in the same numerical category and subscript [d] appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g. a galley next to a galley does not require a bulkhead but a galley next to a paint room requires an “A-0” bulkhead.

[e] : Bulkheads separating the wheelhouse, chartroom and radio room from each other can have only a “B-0” rating.

[f] : Where fuel oil and JP5 fuel tanks (where installed in a separate space with no machinery) category (11) are located below, if permitted, the deck is only required to be of "A-0" class integrity.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of “A” class standard. However, where a deck, except an open deck of category (5), is penetrated for the passage of electrical cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

Note 1: The notes of Tab 1 apply to Tab 2, as appropriate.

2 Penetration in fire-retarding divisions and prevention of heat transmission

2.1 Penetrations in A class divisions

2.1.1 Unless otherwise specified, where A class divisions are penetrated, such penetrations shall be tested in accordance with the Fire Test Procedure Code.

2.1.2 A ventilation duct penetrating an A class division accordingly to the provisions of [6.3] below need not to be tested.

2.1.3 A pipe penetrating an A class division according to the provisions of [2.3.1] need not be tested.

2.1.4 Where A class divisions are penetrated by electrical cables, such penetrations shall always be tested in accordance with the Fire Test Procedure Code.

2.1.5 Specific requirements for shaft line penetrations in A-class divisions are detailed in Ch 1, Sec 7, [3.1.4].

2.2 Penetrations in B class divisions

2.2.1 Where B class divisions are penetrated for the passage of electrical cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired.

2.2.2 Where B class division divisions are penetrated for the passage of ventilation ducts, the provisions of [6.3] below are to be complied with.

2.2.3 Where B class ceilings are penetrated for the fitting of ventilation units, the assembly of the ventilation unit with the ceiling is to be tested in accordance with the Fire Test Procedure Code.

2.2.4 A pipe made of steel or cooper that penetrates B class divisions need not be tested. A pipe penetrating a B class division according to the provisions of [2.3.1] need not be tested. Other pipe penetrations through B class divisions shall be tested in accordance with the Fire Test Procedure Code.

2.2.5 Where B class divisions are penetrated by electrical cables, such penetrations shall always be tested in accordance with the Fire Test Procedure Code.

2.3 Pipes penetrating A or B class divisions

2.3.1 Where A or B class divisions are penetrated by pipes, such penetrations shall be tested in accordance with the Fire Test Procedures code. However the following arrangement, if adequately justified and installed, may be dispensed with the fire test:

a) In case of a pipe penetrating an A class fire division:

   1) the pipe is made of steel or other equivalent material, and

   2) the insulation provided for retarding the heat transmission is extended up to 450 mm from the fire division, and

   3) if the free cross-sectional area of the pipe is equal to or less than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 3 mm and a length of at least 200 mm (preferably divided into 100 mm on each side of the fire division) and there are no openings

   4) if the free cross-sectional area of the pipe is more than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 3 mm and a length of at least 900 mm (preferably divided into 450 mm on each side of the fire division) and there are no openings.

Note 1: For the provisions of this item, copper may be accepted as equivalent to steel, to the satisfaction of the Society.

b) In case of a pipe other than steel or copper penetrating a B class fire division:

   1) if the free cross-sectional area of the pipe is equal to or less than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 1,8 mm and a length of at least 600 mm (preferably divided into 300 mm on each side of the fire division)

   2) if the free cross-sectional area of the pipe is more than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 1,8 mm and a length of at least 900 mm (preferably divided into 450 mm on each side of the fire division)

   3) the pipe is connected to the ends of the sleeve by flanges or coupling; or any clearance between pipe and sleeve is made tight by means of non combustible or other suitable material.

c) Uninsulated metallic pipes are of a material having a melting temperature which exceeds 950°C for A-0 and 850°C for B-0 class divisions.

Note 2: The term “free cross-sectional area” means, even in the case of a pre-insulated pipe, the area calculated on the basis of the inner diameter of the pipe.

2.3.2 Where the Society may permit the conveying of oil or combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids shall be of a material approved by the Society having regard to the fire risk. The pipes conveying oil or combustible liquids shall not pass through ammunition spaces.

2.4 Prevention of heat transmission

2.4.1 In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers. The insulation of a deck or a bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and aluminum structures. If a space is divided with a deck or a bulkhead of A class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm.

3 Protection of openings in fire-resisting divisions

3.1 Openings in bulkheads and decks

3.1.1 Openings in A class divisions

a) Except for hatches between store and the weather decks, all openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.

b) The construction of all doors and door frames, as well as horizontal hatches and hatch coaming, in A class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkhead or deck in which the doors or hatches are situated, this being determined in accordance with the Fire Test Procedures Code. Such doors and door frames, as well as horizontal hatches and hatch coaming, shall be constructed of steel or other equivalent material. Watertight doors and hatches need not be qualified for fire resistance when intended for use below the bulkhead deck. Alternative designs may also be accepted subject to the provisions of this Chapter.

Note 1: Horizontal watertight hatches located within the bulkhead deck can be assimilated to below the bulkhead deck.

Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

c) The maximum force needed to open the hatch covers is not to exceed 150 N. A suitable device on the hinge side to reduce the force needed for opening is acceptable.

d) Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than watertight doors and those which are normally locked, shall satisfy the following requirements:

1) the doors shall be self-closing or normally closed and be capable of closing against an angle of inclination of up to 3,5° opposing closure

Note 2: A normally closed door is a door kept closed, used if authorized by the notice affixed on the door, and closed again after use.

2) the doors shall be fitted with a notice to show if the door is normally open, normally closed or permanently closed.

3) The doors, except those for emergency escape trunks, shall be capable of remote release from the continuously manned damage control station, either simultaneously or in groups, and shall be capable of release also individually from a position near the door. Release switches shall have an on-off function to prevent automatic resetting of the system.

Note 3: In case it is necessary to keep some doors in open position for smoke extraction, means of re-activation of the release switches is to be provided for this group of doors only, independently of other fire doors.

4) hold-back hooks not subject to remote release from the continuously manned damage control station are prohibited.

5) indication shall be provided at the fire door indicator panel in the continuously manned damage control station whether the door is opened or closed.

e) In any case horizontal hatches, exterior doors and machinery spaces doors shall be provided with a system signalling their closed position in the continuously manned damage control station.

Note 4: Weathertight exterior doors of spaces not opening onto other spaces need not be provided with such indication system.

f) The requirements for A class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows. The requirements for A class integrity of the outer boundaries of the ship shall not apply to exterior doors and hatches, except for those in superstructures and deckhouse facing life-saving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

g) Except for watertight doors, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gas-tight, all A class doors located in stairways, public spaces, main vertical zone bulkheads and limit of safety zones shall be equipped with a self-closing hose port. The material, construction and fire-resistance of the hose port shall be equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, adjacent to the opening edge of the door.

h) A class doors other than watertight doors and exterior doors, provided with hold back device are to comply with item d).

3.1.2 Openings in B class divisions

a) Doors and door frames in B class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions, this being determined in accordance with the Fire Test Procedures Code, except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door, the total net area of any such opening or openings shall not exceed 0,05 m^2. Alternatively, a non-combustible air balance duct arrangement between a cabin and a corridor, which is located below the sanitary unit leading through the corridor bulkhead, is permitted in order to achieve air balance of supply and exhaust air for the cabin provided that the cross-sectional area of the duct does not exceed 0,05 m^2. All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible.

   Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm.

b) Cabin doors in B class divisions shall be of a self-closing type. Hold-backs hooks are not permitted.

c) The requirements for B class integrity of the outer boundaries of a ship shall not apply to glass partitions windows and sidescuttles.

4 Protection of openings in machinery space boundaries

4.1 Application

4.1.1 The provisions of Article [4] shall apply to machinery spaces of category A and, to the satisfaction of the Society, to other machinery spaces.

4.2 Protection of openings in machinery space boundaries

4.2.1 The number of doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

4.2.2 Means of control shall be provided for closing power-operated doors, when provided or actuating the release mechanism on doors other than watertight doors. The control shall be located outside the space concerned, where it will not be cut off in the event of fire in the space it serves.

4.2.3 The control required in [4.2.2] shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society.

4.2.4 Doors other than power-operated watertight doors and watertight doors shall be arranged in compliance with [3.1.1] item d) except for item d) 3).

4.2.5 Windows shall not be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery spaces.

5 Protection of vehicle and ro-ro spaces

5.1 Indicators

5.1.1 Indicators shall be provided in the continuously manned damage control station which shall indicate when any fire door leading to or from vehicle and ro-ro spaces is closed.

6 Ventilation systems

6.1 Application

6.1.1 Ventilation systems intended to be used during normal operation are to comply with the requirements of the present article. This article is not intended to apply to alternative configurations used solely in casualty situations. In any case, arrangements intended for use solely in casualty situations are not to impair compliance of the ventilation systems intended for normal operation with the requirements of the present Article.

6.1.2 For ships provided with CBRN protection (Chemical, Biological, Radiological and Nuclear protection), parts of the ventilation system not fully complying with the requirements of the present article may be accepted provided that:

- they are used solely during CBRN operation, and suitably marked to this end, and
- they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and

- the ventilation system in use during normal operation is fully compliant with the requirements of the present Article, and
- suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 3, [2] for ships to be assigned the **CBRN** additional class notation.

6.2 Duct and dampers

6.2.1 Ventilation ducts, including single and double wall ducts, shall be of steel or equivalent material except flexible bellows of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in [6.2.7], any other material used in the construction of ducts, including insulation, shall also be non-combustible. However, short ducts, not generally exceeding 2 m in length and with a free cross sectional area not exceeding 0,02 m^2, need not be of steel or equivalent material, subject to the following conditions:

a) the ducts shall be made of non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value not exceeding 45 MJ/m^2 of their surface area for the thickness used;

b) the ducts are only used at the end of the ventilation device; and

c) the ducts are not situated less than 600 mm, measured along the duct, from an opening in an “A” or “B” class division, including continuous “B” class ceiling.

Note 1: The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.

6.2.2 The following arrangements shall be tested in accordance with the Fire Test Procedure Code:

a) fire dampers, including relevant means of operation. However, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct; and

b) duct penetrations through A class divisions. However the test is not required where steel sleeves complying with [6.4.1] and [6.4.4] are directly joined to ventilation ducts by means of riveted or screwed connections or by welding.

6.2.3 Ventilation ducts are to comply with Pt B, Ch 2, Sec 1, [5] when crossing a watertight bulkhead or deck.

6.2.4 Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection hatch on which the identification number of the fire damper is marked. The fire damper identification number shall also be marked on any remote controls provided.

6.2.5 Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

6.2.6 The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.

6.2.7 Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in “A” or “B” class divisions and in ducts required to be of "A" class construction.

6.2.8 Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by [3.1.2].

6.3 Arrangements of ducts

6.3.1 Ducts for machinery spaces of category A, galleys, vehicle and ro-ro spaces

a) The ventilation systems for machinery spaces of category A, vehicle and ro-ro spaces, and galleys shall in general be separated from each other and from ventilation systems serving other spaces.

b) Ducts provided for the ventilation of machinery spaces of category A, vehicle and ro-ro spaces, and galleys shall not pass through accommodation spaces, service spaces, or control stations unless they comply with [6.3.4].

6.3.2 Ducts for accommodation spaces, service spaces and control stations

Ducts provided for the ventilation of accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, vehicle and ro-ro spaces or galleys unless they comply with [6.3.4].

6.3.3 Ducts for ammunition spaces

a) The ventilation systems serving ammunition spaces shall be separated from the ventilation systems serving other types of space. No ventilation duct shall pass through any ammunition space except the ducts provided for the ventilation of this ammunition space. Torpedo magazines shall be provided with a dedicated ventilation system capable of being stopped locally.

Note 1: If a common duct serves several ammunition spaces, this common duct is to be located outside the served spaces.

b) Ducts provided for the ventilation of ammunition spaces shall not pass through other spaces unless:
   1) the ducts comply with [6.3.4] item a) 1) and item a) 2); and
   2) the penetrations of the ammunition space boundary comply with [6.3.6], and
   3) penetrations of main vertical zone divisions, if any, comply with [6.3.9], and
   4) the air conditioning units serving the ammunition spaces are located in ventilation rooms or other spaces of category (10).

6.3.4 As permitted by [6.3.1] item b) and [6.3.2], ducts shall be either:

a)
   1) constructed of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0,45 m^2;
   2) suitably supported and stiffened;
   3) fitted with automatic fire dampers close to the boundaries penetrated; and
   4) insulated to a standard in line with the most stringent fire insulation requirement between Tab 1 and Tab 2 from the boundaries of the spaces they serve to a point at least 5 m beyond each fire damper; or

b)
   1) constructed of steel in accordance with item a) 1) and item a) 2); and
   2) insulated to a standard in line with the most stringent fire insulation requirement between Tab 1 and Tab 2 throughout the spaces they pass through.

6.3.5 For the purposes of [6.3.4], item a) 4) and [6.3.4], item b) 2), ducts shall be insulated over their entire cross-sectional external surface. Ducts that are outside but adjacent to the specified space, and share one or more surfaces with it, shall be considered to pass through the specified space, and shall be insulated over the surface they share with the space for a distance of 450 mm past the duct.

6.3.6 Galley ventilation systems are to be independent from ventilation systems serving other spaces except on ships of less than 4,000 gross tonnage, for which the galley ventilation systems need not be completely separated from other ventilation systems, but may be served by separate ducts from a ventilation unit serving other spaces. In such a case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit.

6.3.7 In general, the ventilation fans shall be so arranged that the ducts reaching the various spaces remain within a main vertical zone. The air inlets and outlets may be common for more than one main vertical zone but the air inlets and outlets are not permitted to be common for more than one safety zone.

6.3.8 Stairway enclosures shall be served by an independent ventilation fan and duct system (exhaust and supply) which shall not serve any other spaces in the ventilation systems.

6.3.9 Where it is necessary that a ventilation duct passes through a main vertical zone division, an automatic fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The control location shall be readily accessible and be clearly and prominently marked so that it will be visible under white or red lighting conditions, as relevant. The duct between the division and the damper shall be constructed of steel in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2) and insulated to at least the same fire integrity as the division penetrated. The damper shall be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.

The duct shall be insulated to A-30 class standard throughout the main vertical zone which is not served by the ventilation duct.

6.4 Details of fire dampers and duct penetrations

6.4.1 Ducts passing through “A” class divisions shall meet the following requirements:

a) Where a thin plated duct with a free cross sectional area equal to, or less than, 0,02 m^2 passes through “A” class divisions, the opening shall be fitted with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated;

b) Where ventilation ducts with a free cross-sectional area exceeding 0,02 m^2, but not more than 0,075 m^2, pass through “A” class divisions, the openings shall be lined with steel sheet sleeves. The ducts and sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the division through which the duct passes.

   Equivalent penetration protection may be provided to the satisfaction of the Society, and

c) Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0,075 m^2 that pass through “A” class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2). The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the division. The damper shall be fitted with a visible indicator which shows the operating position of the damper. Fire dampers are not required, however, where ducts pass through spaces surrounded by “A” class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they penetrate. A duct of cross- sectional area exceeding 0,075 m^2 shall not be divided into smaller ducts at the penetration of an “A” class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

6.4.2 A duct, irrespective of its cross-section, serving more than one 'tween-deck accommodation space, service space or control station, shall be fitted, near the penetration of each deck of such spaces, with an automatic smoke damper that shall also be capable of being closed manually from the protected deck above the damper. Where a fan serves more than one 'tween-deck space through separate ducts within a main vertical zone, each dedicated to a single 'tween-deck space, each duct shall be provided with a manually operated smoke damper fitted close to the fan.

6.4.3 Vertical ducts shall, if necessary, be insulated as required by Tab 1 and Tab 2. Ducts shall be insulated as required for decks between the space they serve and the space being considered, as applicable.

6.4.4 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through “B” class bulkheads shall be lined with steel sheet sleeves of 900 mm in length, divided preferably into 450 mm on each side of the bulk- heads unless the duct is of steel for this length.

6.4.5 All fire dampers shall be capable of manual operation. The dampers shall have a direct mechanical means of release or, alternatively, be closed by electrical, hydraulic, or pneumatic operation. All dampers shall be manually operable from both sides of the division. Automatic fire dampers, including those capable of remote operation, shall have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss. Remotely operated fire dampers shall be capable of being reopened manually at the damper.

Note 1: Manual closing may be achieved by mechanical means of release or by remote operation of the fire damper by means of a failsafe electrical switch or pneumatic release (spring-loaded, etc) on both sides of the division.

6.4.6 Duct penetration of ammunition space boundaries

All ventilation ducts serving ammunition spaces shall be provided with automatic fire dampers and flame arresters, in compliance with a recognized standard. The automatic fire damper shall be operable from outside the space. The automatic fire dampers and the flame arresters are to be fitted close to the boundaries of the ammunition space, on the outside of the space.

6.5 Exhaust ducts from galley ranges

6.5.1 In addition to the requirements in [6.2], [6.3] and [6.4], exhaust ducts from galley ranges shall be constructed in accordance with [6.3.4], item b) 1) and [6.3.4], item b) 2). They shall also be fitted with:

a) A grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted.

b) A fire damper located in the lower end of the duct at the junction between the duct and the galley range hood which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct close to the outlet of the duct.

c) A fixed means for extinguishing a fire within the duct.

d) Remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in item b) and for operating the fire-extinguishing system, which shall be placed in a position outside the galley close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

e) Suitably located hatches for inspection and cleaning, including one provided close to the exhaust fan and one fitted in the lower end where grease accumulates.

The requirements given in item a) to item e) apply to all exhaust ducts from galley ranges in which grease or fat is likely to accumulate from galley ranges.

6.6 Ventilation rooms serving machinery spaces of category A containing internal combustion machinery

6.6.1 Where a ventilation room serves only such an adjacent machinery space and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.

6.6.2 Where a ventilation room serves such a machinery space as well as other spaces and is separated from the machinery space by a “A-0” class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.

6.7 Ventilation systems for spaces containing dryers

6.7.1 Exhaust ducts from spaces of category (9) and category (13), as defined in [1.2.3], item b), containing dryers shall be fitted with:

a) filters readily removable for cleaning purposes

b) a fire damper located in the lower end of the duct which is automatically and remotely operated

c) remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in item b); and

d) suitably located hatches for inspection and cleaning.

6.8 Capacity of the ventilation systems

6.8.1 Ammunition spaces

Ammunition spaces are to be fitted with a mechanical ventilation system in order to avoid the formation of condensation inside the space. The ventilation system is to be such as to provide at least 0,5 air change per hour.

6.8.2 Spaces for the storage of gas fire-extinguishing medium

Spaces dedicated to the storage of bottles or vessels containing the gas fire-extinguishing medium as mentioned in Ch 4, Sec 6, [3.1.1], item a), are to be fitted with a mechanical ventilation system designed to exhaust air from the bottom of the space and capable of providing at least 6 air changes per hour unless access to the space is provided from the open deck.

6.8.3 Battery rooms

Spaces for the storage of batteries are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.3] and Ch 2, Sec 11, [6.5]. When the formula of Ch 2, Sec 11, [6.5.2] has not been applied, the ventilation system is to be capable of providing at least 15 air changes per hour.

6.8.4 Spaces dedicated to the storage of flammable liquids

Spaces dedicated to the storage of flammable liquids in closed containers are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.4] and capable of providing at least 6 air changes per hour.

6.8.5 Workshops for the handling of flammable liquids

Workshops which can be used for the handling of flammable liquids are to be fitted with a mechanical ventilation system capable of providing at least 10 air changes per hour.

6.8.6 Spaces containing welding gas (acetylene) bottles

In addition to the requirements of Ch 1, Sec 10, [18.4.1] applicable to the spaces for the storage of welding gas (acetylene), spaces for the storage of welding gas bottles, including the workshops where welding operations are performed, are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.5] and capable of providing at least 6 air changes per hour.

6.8.7 Workshops for the maintenance of internal combustion machinery

Workshops for the maintenance of any internal combustion machinery using fuel having a flash-point below 60°C are to be fitted with a mechanical ventilation system capable of providing at least 15 air changes per hour.

Section 6 Suppression of Fire and Explosion: Fire-Fighting

1 Water supply systems

1.1 General

1.1.1 Every ship shall be provided with fire pumps, fire mains, hydrants and hoses complying as applicable with the requirements of this Section.

1.1.2 For the purpose of this Section, hydrants and fire stations have the same meaning.

1.2 Fire mains and hydrants

1.2.1 General

Materials rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. The arrangements of pipes and hydrants shall be such as to avoid the possibility of freezing. In ships where deck cargo may be carried, the positions of the hydrants shall be such that they are always readily accessible and the pipes shall be arranged as far as practicable to avoid the risk of damage by such cargo.

1.2.2 Ready availability of water supply

The arrangements for the ready availability of water supply shall be such that at least two effective jets of water are immediately available from any two hydrants and so as to ensure the continuation of the output of water by the automatic starting of one required fire pump.

1.2.3 Diameter of the fire mains

The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge of water from fire pumps feeding simultaneously four hydrants, the most demanding fire-extinguishing systems and other systems supplied by the fire main.

The fire main shall be of type: single main, horizontal loop system, composite loop system or a combination thereof.

1.2.4 Isolating valves and relief valves

a) The firemain is to be divided at least as follows:

   1) Isolating valves are to be fitted on the boundaries of the space containing the fire pumps and if the space containing the fire pump is a machinery space the isolating valves are to be fitted outside the machinery space.

   2) At least one isolating valve is to be fitted at each safety zone bulkhead penetrated. It shall be possible to operate the isolating valve from both sides of the safety zone bulkhead unless isolating valves are fitted on both sides of the division.

   3) The fire main is to be so arranged that when the isolation valves of a space containing a fire pump are shut, all the hydrants on the ship, except those in this space, can be supplied with water by the remaining pumps.

   4) The fire main is to be so arranged that when the isolation valves of the safety zone bulkheads as requiremed in item 2) are shut, all the hydrants within each safety zone can be supplied with water by the pumps required in [1.3.2].

   5) Isolating valves are to be readily accessible and located outside of fire risk spaces. They shall be controlled and operated from the continuously manned damage control station and, in the case of operating energy failure, they shall remain in the previous closed or open position. Manual operation of isolating valves from above the damage control deck as mentioned in Pt B, Ch 1, Sec 2, [6.5.1] shall also be possible.

Note 1: If the part of the ship located forward of the collision bulkhead forms one safety zone, this safety zone need not to comply with item a) 4).

b) A valve shall be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are at work.

c) Relief valves shall be provided in conjunction with all fire pumps. These valves shall be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

d) Non return check valves shall be fitted on the delivery side of fire pumps and as well as isolating valves on their suction side.

1.2.5 Number and position of hydrants

a) The number and position of hydrants shall be such that with one hose length connected to any hydrant and with two hose lengths connected to the nearby hydrant it shall be possible to reach any part of the ship normally accessible to the crew while the ship is navigating as well as any part of vehicle and ro-ro spaces.

Furthermore, hydrants, as far as it is practicable, shall be located near the accesses to the protected spaces.

For the purpose of this item [1.2.5] at least two hydrants are to be provided in machinery spaces of category A which shall be located near the escape exit of the space.

b) In addition, ships shall comply with the following:

   1) In the accommodation, service, machinery spaces, vehicle and ro-ro spaces, the number and position of hydrants shall be such that the requirements of item a) above may be complied with when all watertight doors and all doors in safety zones bulkheads are closed.

   2) Where access is provided to a machinery space of category A at a low level from an adjacent shaft tunnel, two hydrants shall be provided external to, but near the entrance of that machinery space. Where such access is provided from other spaces, in one of those spaces two hydrants shall be provided near the entrance to the machinery space of category A. Such provision need not be made where the tunnel or adjacent spaces are not part of the escape route.

c) The safety zone bulkheads in between decks shall be provided with:

   1) A stub pipe passage of not less than 70 mm internal diameter provided on both side of the bulkhead with two couplings for 45 mm diameter fire hose, or

   2) Two stub pipe passages of not less 45 mm internal diameter provided on both sides of the bulkhead with coupling for 45mm diameter fire hose.

   The couplings shall be provided with screw plugs.

1.2.6 Pressure at hydrants

With any two pumps simultaneously delivering, through nozzles specified in [1.4.3], the quantity of water specified in [1.2.3], through any adjacent hydrants, the pressure at all hydrants shall be at least 7 bar.

The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire hose can be demonstrated.

1.2.7 International shore connection

Ships shall be provided with at least one international shore connection, complying with Ch 4, Sec 13. Facilities shall be available enabling such a connection to be used on either side of the ship.

1.3 Fire pumps

1.3.1 Pumps accepted as fire pumps

Sanitary, bilge or general service pumps are accepted as fire pumps provided that they are not used for pumping oil.

1.3.2 Number of fire pumps

Each vertical safety zone is to be equipped with one pump for continuous pressurization and at least:

- for ships less than 3000 t displacement, one large capacity pump
- for ships above 3000 t, two large capacity pumps.

1.3.3 Capacity of fire pumps

The large capacity fire pumps of each safety zone required by [1.3.2] shall be capable of supplying, at the pressure stated in [1.2.6], four hydrants and the ship most demanding fire-fighting system using the fire main as the main supply of sea water, including bilge pumping if bilge ejectors are used as mentioned in Ch 1, Sec 10, [6].

Note 1: The expression “the ship most demanding systems” means the most demanding room associated with its adjacent ammunition stores.

The fire-fighting system plan shall indicate the water systems to be in operation at the same time and the relevant water demand.

1.4 Fire hoses and nozzles

1.4.1 Specification of hoses

a) Fire hoses shall be of non-perishable material approved by the Society and shall have a length of at least 10 m, but not more than:

   - 15 m in machinery spaces
   - 20 m in other spaces and open decks, and
   - 25 m for open decks on ships with a maximum breath in excess of 30 m.

b) Each hose shall be provided with a nozzle and the necessary couplings and, together with any necessary fittings and tools, shall be kept ready for use in conspicuous positions near the water service hydrant.

c) One fire hose shall be provided for each hydrant of the ship and be connected at all times.

1.4.2 Diameter of hydrants and fire stations

Hydrants diameter shall be either 45 mm or 70 mm.

Fire station shall be equipped in accordance with Naval Authority standards.

1.4.3 Size and type of nozzles

a) Nozzles shall be in accordance with standards of the Naval Authority. In absence of such standards, nozzles sizes shall be 12 mm, 14 mm and 16 mm or as near thereto as possible. Larger diameter nozzles may be permitted at the discretion of the Society.

b) For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.

c) For machinery spaces and exterior locations the nozzle size, not exceeding 19 mm, shall be such as to obtain the maximum discharge possible from two jets at the pressure mentioned in [1.2.6] from the smallest pump.

d) All nozzles shall be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2 Portable fire extinguishers

2.1 Type and design

2.1.1 All fire extinguishers are to comply with the requirements of Ch 4, Sec 13.

2.2 Arrangement of fire extinguishers

2.2.1 Fire extinguishers shall be provided as follows:

- In the proximity of the main electric switchboards a semi-portable CO_2 fire extinguisher of a capacity of at least 18 kg of CO_2 shall be provided.
- In the proximity of any section board having a power of 20 kW and upwards at least one powder extinguisher or CO_2 extinguisher.
- Any service space where deep fat cooking equipment is installed shall be fitted with at least one powder fire extinguisher.
- In the proximity of any paint or flammable locker at least one powder or foam type extinguisher shall be provided.
- In control stations at least one CO_2 fire extinguisher shall be provided.

2.3 Periodical test

2.3.1 Fire extinguishers shall be periodically examined and subjected to such tests as the Society may require.

See Part A, Chapter 3.

3 Fixed fire-extinguishing systems

3.1 Types of fixed fire-extinguishing systems

3.1.1 A fixed fire-extinguishing system could be any of the following systems:

a) a fixed gas fire-extinguishing system complying with the provisions of Ch 4, Sec 13

b) a fixed high expansion foam fire-extinguishing system complying with the provisions of Ch 4, Sec 13

c) a fixed pressure water-spraying, thick water spraying or an equivalent water-based fire-extinguishing system complying with the provisions of Ch 4, Sec 13

d) in addition to the required systems in a), b) and c), a low expansion foam system, a thick water system, or any other approved system, is to be provided for the protection of bilge spaces under the machinery floors

e) any other fire-extinguishing system considered appropriate by the Society and the Naval Authority.

3.1.2 Where a fixed fire-extinguishing system not required by this Chapter is installed, such system shall meet the relevant requirements of this Chapter.

3.1.3 Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons are prohibited.

3.2 Closing appliances for fixed gas fire-extinguishing systems

3.2.1 Where a fixed gas fire-extinguishing system is used, means shall be provided to close, at the starting of the system, all openings which may admit air to or allow gas to escape from a protected space.

For machinery spaces, controls for the closing of those openings and associated monitoring means are to be operable from the damage control stations. These controls are to be operable even in the event of failure of the supply from the main source of electrical power. In addition, manual closing of those openings is to be possible.

3.3 Storage rooms for fire-extinguishing medium

3.3.1 Gas fire-extinguishing medium bottles or containers for fixed or semi-fixed systems shall have their safety device (rupture disc), and where appropriate their main safety valve (or rupture disc) provided with an exhausted pipe discharging to the open.

Dedicated storage rooms for gas fire-extinguishing medium bottles, or containers and foam concentrate tanks, shall have fire integrity complying with Ch 4, Sec 5, considering such rooms as control stations, and complying also with [3.3.2].

The arrangements of non dedicated storage rooms shall comply with the requirements for dedicated rooms as the Society may consider practicable and reasonable.

In any case the requirements of Ch 4, Sec 13 shall be comply with.

3.3.2 Requirements for dedicated storage room for fire-extinguishing medium

When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which is located behind the forward collision bulkhead, and is used for no other purposes. Any entrance to such a storage room shall preferably be from the open deck and shall be independent of the protected space. If the storage space is located below deck, it should be located not more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck. Spaces which are located below deck or spaces where access from the open deck is not provided shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards, and bulkheads and decks, including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces, shall be gastight.

3.4 Water pumps for other fire-extinguishing systems

3.4.1 Pumps other than those serving the fire main, required for the provision of water for other fire-extinguishing systems required by this chapter, their sources of power and their controls shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system out of action.

4 Fire-extinguishing arrangements in machinery spaces

4.1 Machinery spaces arrangement

4.1.1 General

a) The arrangement of machinery spaces is to be such that safe storage and handling of flammable liquids is ensured.

b) All spaces where oil-consuming installations, settling tanks or daily service fuel tanks are located are to be easily accessible and well ventilated.

c) Where leakage of flammable liquids may occur during normal service or routine maintenance work, a special arrangement is to be made to prevent these fluids from reaching other parts of the machinery where danger of ignition may arise.

d) Materials used in machinery spaces are not normally to have properties increasing the fire potential of these rooms. Neither combustible nor oil-absorbing materials are to be used as flooring, bulkhead lining, ceiling or deck in the control room, machinery spaces, shaft tunnel or rooms where oil tanks are located. Where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours.

e) Water extinguishing systems as mentioned in Ch 1, Sec 10, [11.5.1], item c), Note 2, are to be fitted to protect the bulkheads of service tanks located within machinery spaces from a fire. The effective average distribution of water is to be in compliance with Ch 4, Sec 13, [7.1.1].

4.1.2 Segregation of fuel oil purifiers, JP5-NATO (F44) purifiers and other systems for preparing flammable liquids

a) The system (such as purifiers) for preparing flammable liquids for use in boilers and machinery, and separate oil systems with working pressure above 1,5 MPa which are not part of the main engines, auxiliary engines or boilers etc., are subject to the following additional requirements.

b) The main components in the systems are to be placed in a separate room, enclosed by steel bulkheads extending from deck to deck and provided with self-closing steel doors.

c) Rooms in which flammable liquids are handled as specified in a) above are to be provided with:

- independent mechanical ventilation or ventilation arrangements which can be isolated from the machinery space ventilation
- a fire detecting system
- a fixed fire-extinguishing installation. The extinguishing installation is to be capable of being activated from outside the room. The extinguishing system is to be separated from the room, but may be a part of the main fire-extinguishing system for the machinery space. Closing of ventilation openings is to be effected from a position close to where the extinguishing system is activated.

d) Where the size of the engine room makes it impracticable to locate the main components of such systems in a separate space, specific measures with regard to the location, containment of possible leakages and shielding of the components, and to ventilation, are to be provided to the satisfaction of the Society, such as:
   - fitting of drip trays and shielding for leakage containment
     location close to ventilation exhaust so as to avoid flammable gas accumulation in vicinity
   - fitting of dedicated hood above for ventilation exhaust

   A local fixed fire-extinguishing system is to be provided, capable of being activated automatically or activated manually from the machinery control position or from another suitable location. If automatic release is provided, additional manual release is to be arranged.

4.2 Machinery spaces containing oil fired boilers or fuel oil units

4.2.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing oil fired boilers or fuel oil units shall be provided with any one of the fixed fire-extinguishing systems in [3.1].

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room, the combined engine and boiler rooms shall be considered as one compartment.

4.2.2 Additional fire-extinguishing arrangements

a) There shall be in each boiler room at least one set of portable foam applicator units complying with the provisions of Ch 4, Sec 13.

b) There shall be at least two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the fuel oil installation is situated. There shall be not less than one approved foam-type extinguisher of at least 135 l capacity or equivalent in each boiler room.

   For fire extinguishers in the proximity of any electric switchboard or section board see item [2.2.1].

c) The portable foam applicator in item a) and the 135 l capacity extinguisher in item b) may be omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

d) A fixed fire-extinguishing system for the protection of bilge spaces shall be provided, as required in [3.1.1], item d).

4.3 Machinery spaces containing internal combustion machinery

4.3.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing internal combustion machinery (such as gas turbines) shall be provided with one of the fire-extinguishing systems required in [3.1].

4.3.2 Additional fire-extinguishing arrangements

a) At least one set of portable foam applicator units complying with the provisions of Ch 4, Sec 13.

b) In each such space approved foam-type fire extinguishers, each of at least 45 l capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards.

c) In the case of machinery spaces containing both boilers and internal combustion engines [4.2] and [4.3] apply, with the exception that one of the foam fire extinguishers of at least 45 l capacity or equivalent may be omitted provided that the 135 l extinguisher can efficiently and readily protect the area covered by the 45 l extinguishers.

d) For fire extinguishers in the proximity of electric switchboard or section board see item [2.2.1].

e) The portable foam applicator in item a) and the fire extinguishers 45 l and 135 l in item b) may be omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

f) A fixed fire-extinguishing system for the protection of bilge spaces shall be provided, as required in [3.1.1], item d).

4.4 Machinery spaces containing steam turbines or enclosed steam engines

4.4.1 Fixed fire-extinguishing systems

In spaces containing steam turbines or enclosed steam engines used either for main propulsion or for other purposes when such machinery has in the aggregate a total power output of not less than 375 kW there shall be provided one of the fire-extinguishing systems required by [3.1] where such spaces are periodically unattended.

4.4.2 Additional fire-extinguishing arrangements

a) Approved foam fire extinguishers each of at least 45 l capacity or equivalent sufficient in number to enable foam or its equivalent to be directed on to any part of the pressure lubrication system, on to any part of the casings enclosing pressure lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. However, such extinguishers shall not be required if protection at least equivalent to that required by this item is provided in such spaces by a fixed fire-extinguishing system fitted in compliance with [3.1].

b) The 45 l capacity or equivalent fire extinguishers in item a) may be also omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

c) For fire extinguishes in the proximity of electric switchboard or section board see item [2.2.1].

4.5 Other machinery spaces

4.5.1 Where in the opinion of the Society, a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in [4.2], [4.3] and [4.4], there shall be provided in, or adjacent to, that space such a number of approved portable fire extinguishers or other means of fire extinction as the Society may deem sufficient.

4.6 Fixed local application fire-extinguishing systems

4.6.1 Machinery spaces of category A above 500 m^3 in volume shall, in addition to the fixed fire-extinguishing system required in the present Section, be protected by a fixed water-based or equivalent local application fire-extinguishing system complying with the provisions of Ch 4, Sec 13. In the case of periodically unattended machinery spaces, the fire-extinguishing system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-extinguishing system is only required to have a manual release capability.

4.6.2 Fixed local application fire-extinguishing systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:

- the hazard portions of internal combustion machinery
- boiler fronts
- oil fired equipment
- thermal oil heaters
- the fire hazard portions of incinerators, and
- purifiers for heated fuel oil.

4.6.3 Activation of any local application system shall give a visual and distinct audible alarm in the protected space, at a continuously manned damage control station. The alarms shall indicate the specific system activated. The alarm requirements described within this sub-article [4.6] are in addition to, and not to substitute for, the detection and fire alarm system required elsewhere in this Chapter.

4.6.4 The automatic release should be activated by a detection system capable of reliably identifying the local zones. Two different types of detectors should be fitted for each zone and the activation of both detectors shall be necessary for the release of the system. Other consideration should be given to avoid any accidental activation of the system.

5 Fire-extinguishing arrangements in accommodation spaces, service spaces and control stations

5.1 Sprinkler systems

5.1.1 Ships provided with the additional class notation **FIRE** shall comply with the requirements of Pt E, Ch 10, Sec 3.

5.1.2 Where accommodation spaces, service spaces or control stations are fitted with a fixed sprinkler system, this system shall be of an approved type complying with Ch 4, Sec 13, [8].

5.2 Spaces containing flammable liquid

5.2.1 Paint lockers and flammable liquid lockers shall be protected by an appropriate fire-extinguishing arrangement approved by the Society which could be any of the following systems:

a) a carbon dioxide system, designed to give a minimum volume of free gas equal to 40% of the gross volume of the protected space

b) a dry powder system, designed for at least 0,5 kg powder/m^3

c) a water spraying or sprinkler system, designed for 5 l/m^2 min. Water spraying systems may be connected to the fire main of the ship, or

d) a system providing equivalent protection, as determined by the Society.

In all cases, the system shall be operable from outside the protected space.

5.3 Equipment for frying

5.3.1 Deep-fat cooking equipment shall be fitted with the following:

a) an automatic or manual fire-extinguishing system which has been tested in conformity with an international standard and considered acceptable by the IMO.

Note 1: See the recommendations of the International Standards Organization, in particular the ISO 15371:2015 publication (Fire-extinguishing systems for protection of galley cooking equipment).

b) a primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat

c) arrangements for automatically shutting off the electrical power upon activation of the fire-extinguishing system

d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed, and

e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

6 Fire-extinguishing arrangements in ammunition spaces

6.1 Fixed fire-extinguishing systems

6.1.1 Ammunition spaces excluding lifts and transfer chambers shall be provided with a fixed water-spraying fire-extinguishing system complying with the provisions of Ch 4, Sec 13, [7].

a) spraying nozzles are to be provided in order to ensure the spraying of ceilings, bulkheads and shells above the waterline. The nozzles are to be arranged so as allow the spraying of the ceilings with a flow of at least 1000 l/h/m^2, and of the bulkheads and shells with a flow of at least 500 l/h/m^2.

b) pieces of equipment are to be watered by the water falling down from the ceilings.

6.1.2 For ammunition spaces located below the waterline, the waterspraying system may be fitted with an automatic closing system of the water supply valve when the water level reaches the top of the storage area.

The boundaries of the ammunition space and the ventilation ducts serving the space are to be designed according to Part B, Chapter 7 for the maximum water pressure.

7 Protection of fuel pump rooms

7.1 Fixed fire-extinguishing systems

7.1.1 Each fuel, diesel or JP5-NATO (F44) pump room shall be provided with a fixed pressure water-spraying system or an equivalent fixed water based fire-extinguishing system complying with the provisions of the Ch 4, Sec 13.

7.1.2 In addition to the system required in [7.1.1] and with consideration of the floor arrangement and of the fuel, diesel or JP5-NATO (F44) pump room, one of the fixed fire-extinguishing systems required in [3.1.1], item d) is to be provided for the fire protection under the machinery floor.

7.2 Quantity of fire-extinguishing medium

7.2.1 Where the extinguishing medium used in the fuel pump room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.

8 Firefighter’s outfits

8.1 Types of firefighter’s outfits

8.1.1 Firefighter’s outfits shall comply with Ch 4, Sec 13.

8.2 Number of firefighter’s outfits

8.2.1 Each safety zone shall be provided with at least 6 firefighter’s outfits.

8.3 Storage of firefighter’s outfits

8.3.1 The firefighter’s outfits or sets of personal protecting equipment shall be so stored as to be easily accessible and ready for use.

8.4 Means of communications between fire-fighting teams

8.4.1 Four two-way portable radiotelephone apparatus shall be provided in each safety zone. These apparatus are to be of an explosion proof type and intrinsically safe.

Section 7 Suppression of Fire and Explosion: Structural Integrity

1 Material of hull, superstructures, structural bulkheads, decks and deckhouses

1.1 General

1.1.1 The hull, superstructure, structural bulkheads, decks and deckhouses shall be constructed of steel or other equivalent material. For the purpose of applying the definition of steel or other equivalent material as given in Ch 4, Sec 1, [2.36.1], the "applicable fire exposure" shall be according to the integrity and insulation standards given in Tables 1 to 4 of Ch 4, Sec 5. Where an A class division is required by such Tables the applicable fire exposure shall be of an hour and where an B class division is required by the same Tables the applicable fire exposure shall be 30 minutes. Where steel is substituted by aluminium alloy, which is a non-combustible material, in item [2.1.1] a) the acceptance condition are given. Where other materials are intended to be used and are acceptable for Part B, the Society will determine the fire tests to which prototypes have to undergone as well as the additional fire safety measures to be provided accounting of international experiences and procedures to be applied when prescriptive requirements are substituted by performance requirements.

2 Structure of aluminium alloy

2.1 General

2.1.1 Unless otherwise specified in [1.1.1], in cases where any part of the structure is of aluminium alloy, the following shall apply:

a) The insulation of aluminium alloy components of A or B class divisions, except structures which, in the opinion of the Society, are non-load-bearing, shall be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure to the standard fire test.

b) Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural member required to support A class divisions (see Sec 5, Tab 1) to ensure that the temperature rise limitation specified in the preceding item a) shall apply at the end of one hour.

c) With reference to item a) above:

   1) When spaces of categories 1 to 10 in Sec 5, [1.2.3] are located on top of aluminium decks, the deck does not need to be insulated from the upper side.

   2) A load-bearing division is a deck or bulkhead including stiffeners, pillars, stanchions and other structural members which, if eliminated, would adversely affect the designated structural strength of the ship.

   3) Where spaces of low fire risks are concerned, upon special consideration by the Society, divisions may be insulated from one side only, depending on the nature and function of the space. Such arrangement shall be to the satisfaction of the Society.

3 Crowns and casings of machinery spaces of category A

3.1 General

3.1.1 Crowns and casings of machinery spaces of Category A shall be of steel construction adequately insulated and openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

4 Materials of overboard fittings

4.1 General

4.1.1 Materials readily rendered ineffective by heat shall not be used for overboard scuppers, sanitary discharges, and other outlets.

Section 8 Escape and Circulation

1 Notification of crew

1.1 General emergency alarm system

1.1.1 A general emergency alarm system as required in Ch 2, Sec 3 shall be installed to notify crew of a fire.

1.1.2 An inter-communication system shall be fitted in such a way as to be clearly heard throughout the accommodation and service spaces, control stations and open decks.

2 Means of escape

2.1 Purpose

2.1.1 The purpose of the following requirements of this section is to provide means of escape so that persons on board can safely and swiftly escape to adjacent main vertical zone, adjacent safety zone and to the evacuation stations. For this purpose, the following functional requirements shall be met:

- escape routes shall be maintained in a safe condition, clear of obstacles, and
- additional aids for escape shall be provided as necessary to ensure accessibility, clear marking and adequate design for emergency situations.

Note 1: Means of escape are all the available means to exit from any space continuously or occasionally manned at sea.

Note 2: Evacuation routes or escape routes are all the main and secondary ways to escape from any space to adjacent main vertical zones, adjacent safety zones and to evacuation stations.

Note 3: Evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

2.1.2 Application

For the provisions of this Section, "stairway" means either a stairway enclosure of category (2) or stairways penetrating a single deck and included in a corridor or lobby as permitted in Ch 4, Sec 5, [1.2.4].

2.2 General requirements

2.2.1 Lifts shall not be considered as forming one of means of escape required in this section.

2.2.2 All stairways and ladders shall be of steel frame construction.

Inclined ladders/stairways with open treads in machinery spaces of category A being part of or providing access to escape routes but not located within a protected enclosure shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

2.3 Means of escape from accommodation spaces, service spaces and control stations

2.3.1 General requirements

a) As far as practicable and reasonable, a corridor, lobby, or part of a corridor from which there is only one escape route should not be built.

   No dead-end corridors having a length more 7 m shall be accepted. As an exception, when it is not practical, this length may be increased up to 9 m.

b) In general, at least two separated means of escape are to be provided from all spaces or group of spaces. For a given space, a secondary exit door may be requested with regard to its shape and deck area. The main doors or hatches shall have width appropriate to the number of persons.

c) Doors in escape routes shall, in general, open in way of the direction of escape, except that:
   - Individual cabin doors may open into the cabin in order to avoid injury to persons in the corridor when the door is opened, and
   - Doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and for access.

d) Normally locked doors that form part of an escape route

   Cabin and stateroom doors shall not require keys to unlock them from inside the room. Neither shall there be any doors along any designated escape route which require keys to make unlock them when moving in the direction of escape.

2.3.2 Means of escape

a) General

Stairways and ladders shall be so arranged as to provide ready means of escape to the evacuation stations from all the accommodation and service spaces and control stations in which the crew is normally employed.

b) Escape from spaces below the damage control deck

Below the damage control deck, two means of escape shall be provided, per deck, from each watertight compartment, at least one of which shall be a stairway. However when the greatest dimension of the compartment is not more than 5 m there may be provided only one means of escape.

c) Escape from spaces above the damage control deck

Above the damage control deck there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which shall give access to a stairway leading to the evacuation station.

Note 1: For the main vertical zones in the fore or aft end of the ship which are constituted by spaces mainly located below the bulkhead deck, it may be accepted to have a vertical steel ladder between the damage control deck and the bulkhead deck instead of the required stairway, provided the other escape route leads to the evacuation station through an adjacent main vertical zone.

Such arrangement shall be to the satisfaction of the Society.

Note 2: In spaces where no personnel are normally employed, the stairway required in item b) and f) may be replaced by a vertical steel ladder.

d) Escape from spaces on the damage control deck

In addition to the means of escape required in item c) above, two means of escape shall be provided on the damage control deck from each watertight compartment or similarly restricted group of spaces.

In general, at least one of those means of escape is to be independent of watertight doors.

However, those means of escape may be watertight doors in auxiliary watertight bulkheads as defined in Pt B, Ch 1, Sec 2, [6.5], provided the following requirements 1) to 4) are met:

1) The ship is fitted with a sea water flooding detection system such that each watertight compartment is fitted with water level detectors.
2) An alarm is given in the damage control stations in the event of flooding in one of the watertight compartments. This flooding alarm is to be separated from the others, individual for each watertight compartment.
3) Means are provided to give audible warning of the flooding to the crew in throughout all the accommodation and normal crew working spaces during normal operational condition. Visual alarm may be used in spaces where audible signals are not appropriate due to high noise levels.
4) Each of the two means of escape gives access to an escape route leading to the evacuation station.

e) Direct access to stairway enclosures

Where provided, stairway enclosures in accommodation spaces, service spaces and control stations shall have direct access to corridors.

f) Details of means of escape

Means of escape where required by the previous items b) and c) shall be arranged as per [4.1.1] and Ch 4, Sec 5, [1.2.4]. At least one of the escape required by the previous items b) and c) shall consist of a readily accessible stairway sized as per the requirements of Article [4].

Means of closing of the horizontal opening of stairways and ladders shall be as required by the Naval Authority for naval operations.

Note 3: For limited area where room in room arrangement has been permitted by the Society, local audible alarm inter-connected to fire detectors will have to be provided in addition of other required measures if any.

g) Marking of escape routes

The means of escape including stairways and exits shall be marked by lighting or photoluminescent strip indicators placed not more than 300 mm above the deck at all points of the escape route including angles and intersections. The marking must enable crew to identify all the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip will not result in the marking being ineffective. Additionally, all escape route signs and fire equipment location markings shall be of photoluminescent material of a type approved by the Society or marked by lighting. Such lighting or photoluminescent equipment shall be evaluated, tested and applied to the satisfaction of the Society in accordance with IMO Resolution A.752(18) and ISO 15370.

2.4 Means of escape from machinery spaces

2.4.1 Means of escape from each machinery space shall comply with the provisions given in the following items a) to d).

a) Escape from spaces below the bulkhead deck

Two sets of steel ladders and/or stairways as widely separated as possible, leading to doors or deck hatches in the upper part of the space, similarly separated and from which access is provided to the evacuation stations. For machinery spaces of category A, one of these ladders shall be located within a protected enclosure categorized (2) as per the requirements of Section 5 from the lower part of the space it serves to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800 x 800 mm, and shall have emergency lighting provisions. Alternative arrangement may be provided to the satisfaction of the Society.

b) Escape from spaces above the bulkhead deck

The two means of escape shall be as widely separated as possible and the doors or hatches leading from such means of escape shall be in position from which access is provided to the evacuation stations.

c) Dispensation from two means of escape

This requirement does not apply for machinery spaces of category A.

The Society may dispense with one of the means of escape from any such a space including a normally unattended auxiliary machinery space, so long as either a door, a steel ladder or a stairway provides a safe escape route to the evacuation stations, due regard being paid to the nature and location of this space.

Where no personnel are normally employed in the machinery space, the second mean of escape is not required.

d) Escape from machinery control stations

Two means of escape shall be provided from a machinery control station located within a machinery space at least one of which, as far as possible and practicable, should provide continuous fire shelter to a safe position outside the machinery space.

e) Access to vehicle spaces, ro-ro vehicle spaces or hangars

One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any vehicle space, ro-ro vehicle space or hangar.

f) As far as practicable, two means of escape shall be provided from the main workshop within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

2.5 Means of escape from special purpose spaces

2.5.1 In vehicle spaces, ro-ro vehicle spaces or aircraft hangars, the number and disposition of means of escape both below and above the bulkhead deck shall be to the satisfaction of the Society and in general shall be at least equivalent to that provided for in items b), c), and e) of [2.4].

2.6 Means of escape from ammunition spaces

2.6.1 Ammunition spaces need not be provided with a second means of escape, if agreed by the Naval Authority, provided that either a hatch, a door, a ladder or a stairway provides a safe access from these spaces to an escape route.

3 Emergency escape breathing devices (EEBD)

3.1 Types of EEBD

3.1.1 The emergency escape breathing devices shall be of a type approved by the Society and shall comply with Ch 4, Sec 13.

3.2 Number of EEBD

3.2.1 There shall be at least 4 EEBDs in each main vertical zone.

3.2.2 In machinery spaces of category A, there shall be at least:

a) One EEBD in the engine control room or equivalent

b) One EEBD in the workshop areas

c) One EEBD on each deck or platform level, in the vicinity of the escape ladder or stairway which is not enclosed by A class divisions.

3.2.3 In other machinery spaces, there shall be at least one EEBD on each deck or platform level, in the vicinity of the escape ladder or stairway which is not enclosed by A class divisions.

3.2.4 One additional EEBD for training is to be provided and clearly marked as limited to training use only.

4 Arrangement of the means of escape

4.1 Details of stairways, ladders and deck hatches

4.1.1

a) The minimum net width of a ladder or stairway is the minimum clearance distance between:
- its handrails when provided on both sides; and
- its handrail and the first obstacle on the opposite side if provided with handrail on one side only.

b) Ladders shall have a minimum net width of 400 mm between its two vertical main frames.

c) Stairways are inclined ladders having angle not more than 62° from the horizontal and provided with handrails at least at one side

d) In machinery spaces, stairways having angle up to 70° from the horizontal may be permitted

e) If a stairway used on the escape routes is not enclosed by vertical A class divisions, the net width of the horizontal hatch is not to be less than the required net width of the associated stairway.

f) In addition, for a deck hatch, consideration may be given to the minimum net length in order that a fire-fighter with his complete equipment can easily pass through this deck hatch.

g) The hatches mentioned in [2.3.2] item f), and located in internal watertight decks are to be fitted with a coaming having a height of at least 50 mm.

Other hatches located in internal watertight decks are to be fitted with coamings having a height of at least 50 mm, unless:
- the hatch is normally closed in all operational conditions, or
- the hatch is located on an escape route, and its coaming would be an obstacle to safe evacuation.

4.2 Width of escape routes

4.2.1 Main passageways as defined in Ch 4, Sec 1, [2.23.1], and doors included therein, including exit door leading to the evacuation station, are not to be less than 900 mm in net width.

In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per [4.6].

4.2.2 Other passageways used as escape route, and doors included therein, are not to be less than 700 mm net width.

In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per [4.6]. Doors, stairways and hatches along these passageways are to be sized in the same manner as the passageways.

Note 1: On a case by case basis, the width of hatches and associated ladders used solely as secondary means of escape may be reduced to the satisfaction of the Society.

4.2.3 Prohibition of decrease in width in the direction to the evacuation stations

The means of escape shall not decrease in width in the direction of evacuation to the evacuation stations. Where several evacuation stations are in one main vertical zone, the means of escape width shall not decrease in the direction of the evacuation to the most distant evacuation station.

4.3 Width of doors, hatches and corridors included in the means of escape

4.3.1 Corridors and intermediate landings included in means of escape are to be sized in the same manner as stairways.

4.3.2 The clear width of doors and hatches included in means of escape may be smaller than that of the passageways they serve, provided their clear width remains above the minimum clear width required for the associated passageway.

4.4 Evacuation stations

4.4.1 Evacuation stations arrangement

At least one evacuation station is to be provided for each vertical safety zone.

The number of crew and special persons onboard shall be distributed in all the evacuation stations. Each evacuation station shall have sufficient clear deck space to accommodate all the crew and special persons assigned to evacuate from that evacuation station, but at least 0,35 m^2 per person.

4.4.2 The evacuation stations may include spaces such as corridors, landings of stairway enclosures, accommodation and service spaces but an evacuation station is not to include a control station, a machinery space, an ammunition space or a vehicle or ro-ro space. In any case, a space which requires a key for access cannot be included in an evacuation station unless the key is enclosed in a beak-glass type enclosure conspicuously located and indicated near the normally locked access door.

4.5 Evacuation analysis and escape plan

4.5.1 Evacuation analysis

For ships which have a number of persons on board considered large by the Society, the escape routes may be evaluated by an evacuation analysis early in the design process. The analysis, carried out according to the indications of the Society, shall be used to identify and eliminate, as far as practicable, congestion which may develop during an emergency situation.

4.5.2 Means of escape plans

The ships shall be provided with means of escape plans indicating the following:

a) the number of the persons on board in all normal occupied spaces

b) the number of persons expected to escape by stairway, doors, horizontal hatches and corridors

c) primary and secondary means of escape

d) net widths of ladders, stairways, doors, horizontal hatches and corridors

e) evacuation stations arrangement

f) embarkation distribution on the ship.

4.6 Distribution of persons

4.6.1 For the application of the provision of the Fire Safety System Code, Chapter 13 [2.1.2.2.2.1], cases 1 and 2 are to be replaced by:

a) Case 1 (night-time)
   - the total number of the members of crew not operating by watch in its cabins and berthing
   - 2/3 of the members of the crew operating by watch in its cabins and berthing spaces, and
   - 1/3 of the crew operating by watch in its service spaces.

b) Case 2 (daytime)
   - 1/4 of the members of crew not operating by watch in its public spaces
   - 3/4 of the members of crew not operating by watch in its service spaces
   - 1/3 of the crew operating by watch in its cabins and berthing spaces
   - 1/3 of the crew operating by watch in its service spaces, and
   - 1/3 of the crew operating by watch in its public spaces.

Note 1: For the application of the provision of Fire Safety System Code, Chapter 13 [2.1.2.1.4], the number of persons to be distributed in each public space is to be proportional to the deck area of these public spaces, as per the following formula:

$n = N \quad a / A$

where:

N : Total number of persons to be distributed in the public spaces

a : Deck area of the selected public space

A : Total deck area of the public spaces available to the total number of persons to be distributed in the public spaces.

Note 2: Other cases of distribution of persons may be considered in replacement of, or in addition to, cases 1 and 2 above by more effective scenarios given by the Naval Authority.

5 Technical corridors

5.1

5.1.1 Technical corridors or technical galleries not serving as an escape route and not giving access to accommodation spaces, service spaces, control stations, vehicle and ro-ro spaces as mentioned in category (10) of Ch 4, Sec 5, [1.2.3], item b) 1), shall have a minimum net width in order to permit to one person to circulate along this corridor.

Section 9 Fire Control Plans

1 Fire control plans

1.1 Compilation of the fire control plans

1.1.1 General arrangement plans shall be permanently exhibited for the guidance of the crew, showing clearly for each deck the main vertical zones, the horizontal zones, the safety zones, the control stations, the various fire sections enclosed by A class divisions, the sections enclosed by B class divisions together with particulars of the fire detection and fire alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc. and the ventilating system including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section, and the position of fuel oil quick-closing valve remote control and fuel oil pump stops. Alternatively, at the discretion of the Society, the aforementioned details may be set out in a booklet, a copy of which shall be supplied to crew members, and one copy shall at all times be available on board in an accessible position. Plans and booklets shall be kept up to date, any alterations being recorded therein as soon as practicable. Description in such plans and booklets shall be in the official language of the Naval Authority. If the language of the Naval Authority is not English, a translation into such language is to be included.

Note 1: The graphical symbols for the fire control plan are to be in accordance with the following standards: IMO resolution A.952 and ISO 17631:2002.

1.1.2 For ships assigned the additional class notation CBRN, in line with the requirements of Part E, Chapter 8, the following elements are to be shown:

- citadel, sub-citadels and/or shelter
- storage location of personal protective equipment
- CBRN detection system
- pre-wetting and washdown system and associated control valves.

1.2 Location of the fire control plans

1.2.1 In all ships a duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

Section 10 Helicopter Facilities

1 General

1.1 Application

1.1.1 In addition to complying with the requirements of other sections of this Chapter as appropriate, ships equipped with helideck with or without hangar, carrying in total no more than two helicopters, are to comply with the requirements of this section.

1.2 Definitions

1.2.1 Helideck

For the purpose of this section, helideck is a purpose-built helicopter landing area located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters.

1.2.2 Helicopter facilities

Helicopter facilities is a helideck including any refuelling and hangar facilities.

2 Structure

2.1 Construction

2.1.1 The helideck(s) surfaces are to be insulated to A-60 class standard on parts not protected by a thick water system as defined in Pt E, Ch 11, Sec 2, [3.2.2] and located above spaces of category (1), (2), (3) or (4) in accordance with Ch 4, Sec 5, [1.2.3].

2.2 Means of escape

2.2.1 A helideck, is to be provided with both a main and an emergency means of escape and access for fire-fighting and rescue personnel; these are to be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.

3 Fire-fighting appliances

3.1 General

3.1.1 In order to protect the helideck against a helicopter crash, the following fire-fighting appliances are to be provided and so arranged as to permit them to reach any part of the helideck:

Note 1: The fire-fighting appliances are to be capable of simple and rapid operation and, as far as practicable, are to be located outside the helideck and in any case, are to be located outside the landing area.

a) Powder system

1) General

A powder system which can be part of a twin agent system, powder and foam (monotubular or bitubular), is to be provided.

This system is to have at least two self-contained dry chemical powder pressure vessels, with associated controls, pressurizing medium fixed piping and at least two monitors or applicator nozzles fitted with hand hose lines.

The system is to be activated by inert gas stored in pressure vessel adjacent the powder container and is to be capable to deliver dry powder to all parts of the helicopter deck.

The discharge of one of the powder container through one monitor or applicator is not to prevent a second discharge from another monitor or applicator.

2) Monitors

If provided, the capacity of each monitor is to be not less than 10 kg/s.

Powder is to be delivered in less than 20 seconds after the release order.

The quantity of chemical powder to be provided for each monitor is not to be less than the quantity required for 1 minute discharge time.

The fixed monitor capacity is to be function of maximum coverage distance in compliance with type approved tests, as an example, for fixed monitors of capacity of: 10, 25 and 45 kg/s the maximum distance of monitor coverage could be respectively: 10, 30 and 40 m.

The monitor throw in still air conditions is not to be less than the 1.3 times the maximum distance of the monitor from any part of the helideck.

3) Applicators

If provided, the hand hose lines are to be non-kinkable and fitted with a nozzle (applicator) of on/off operation and discharge at rate not less than 100 kg/min.

Powder is to be delivered in less than 20 seconds after the release order.

The quantity of chemical powder to be provided for all applicators is to be not less than the quantity required for 1 minute discharge time.

The length of a hand hose line is not to exceed 33 m.

The hand hose nozzle throw in still air is not to be less than 14 m.

b) Foam system

A foam system, which can be part of a twin agent system, powder and foam (monotubular or bitubular), is to be provided.

Note 2: Refer to the International Civil Aviation Organization Airport Services Manual, part 1, Rescue and Fire-Fighting, chapter 8, Extinguishing Agent Characteristics, paragraph 8.1.5, Foam Specifications table 8-1, level 'B'.

The foam forming liquid is to be of a type approved by the Society.

The foam is to be delivered by at least two monitors or applicator nozzles fitted with hand hose lines.

The supply rate of the foam is to be not less than 200 l/min and the quantity of the foam forming liquid to be provided is not to be less than the quantity required for 10 min discharge time.

Note 3: When it is possible to supply at the required flow rate both of the monitors or applicators subsequently from one foam container, the quantity of the foam forming liquid to be provided need not be greater than the quantity required for 10 min discharge time with one monitor or applicator.

The monitors or applicators are to produce low expansion foam with expansion ratio between 5:1 and 12:1. Other expansion ratios are to be to satisfaction of the Society.

The foam is to be delivered in less than 20 seconds after the release order.

If provided, the applicator throw in still air conditions is not to be less than 15 m.

If provided, the monitor throw in still air conditions is not to be less than 1,3 times the maximum distance of the monitor from any point of the helideck.

The containers of foam forming liquid is to be made of stainless steel or other resistant material.

c) Additional applicators

Two additional applicator nozzles provided with a hand hose line are to be provided. These applicators are to be capable of delivering foam or thick water to any part of the helideck.

The additional foam applicators are to be capable of delivering foam at a rate of not less than 400 l/min during at least 5 minutes or 200 l/min during at least 10 minutes.

The expansion ratio of the foam is to be between 5:1 and 12:1.

The supply rate of the thick water is not to be less than 500 l/min.

The AFFF concentration of the thick water is to be not less than 3%.

The maximum length of the hose lines is to be 30 m.

d) At least two nozzles of an approved dual purpose (jet/ spray) and hoses sufficient to reach any part of the helideck are to be provided. However, when applicators are provided for the purpose of the provisions a) and b) above, two additional hydrants are not necessary.

e) Portable extinguishers

Carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent are to be provided.

f) Fire fighter outfits and rescue equipment

Fire fighter outfits and rescue equipment are to be provided, in number and type, and so arranged as to comply with the requirements of the Naval Authority.

3.1.2 In close proximity to the helideck, the following equipment are to be provided and stored in a manner that permits immediate use and provides protection from the elements:

- adjustable wrench
- blanket, fire resistant
- cutters, bolt 60 cm
- hook, grab or salving
- hacksaw, heavy duty complete with 6 spare blades
- ladder
- lift line 5 mm and 15 m in length
- pliers, side-cutting
- set of assorted screw drivers, and
- harness knife complete with sheath.

3.2 Drainage facilities

3.2.1 Drainage facilities in way of helidecks are to:

- be constructed of steel,
- lead directly overboard, and
- be designed so that drainage does not fall on to any part of the ship.

Where railways are provided for the handling of the helicopter, special consideration is to be given to preventing liquids to enter into the ship through such railways.

Note 1: The drainage system is not required to avoid the spilling on the hull sides of the ship.

3.2.2 Drainage facilities from helidecks are to be independent from any other system. Common scupper pipes between a flight deck or helideck and an aircraft hangar may however be accepted provided that water seals are provided in order to prevent the passage of flammable vapours or liquid from the hangar to the flight deck and reverse.

Where water seals are installed:

- the water seals are to be capable of preventing the passage of vapours and liquids at a pressure corresponding to the maximum expected water column under normal operating conditions
- alarms on the low level of water in the water seal are to be provided at the damage control station.

4 Helicopter refuelling and hangar facilities

4.1 Fuel storage system

4.1.1 Storage area

The fuel oil for refuelling helicopters are to either have a flash point greater than 60°C, or be JP5-NATO (F44). In the present Section, the words "JP5" or "JP5-NATO (F44)" are to be interpreted as "the fuel used for the helicopters".

Such fuel is to be stored in structural tanks as required in Part C, Chapter 1 for ship fuel oil systems.

A designed area is to be provided for the storage of fuel tanks which is to be as remote as possible from the accommodation spaces, service spaces, control stations and escape routes and evacuation stations. The fuel storage area is to be provided with arrangements whereby fuel spillage may be collected and drained to a safe location and isolated from any source of ignition.

The fuel pumping system is to incorporate a device which will prevent over-pressurization of the delivering hose.

Fixed arrangements are to be provided at the refuelling station for filtering and sampling.

4.1.2 Fuel tanks

a) Tanks and associated equipment are to be protected against physical damage and from a fire in an adjacent space or area.

b) The location of JP5 fuel tanks is to be in compliance with the requirements of Pt B, Ch 2, Sec 2. No openings are to be arranged between accommodation or service spaces and a JP5 fuel tank. On a case-by-case basis, gastight openings permanently closed at sea may be accepted between a JP5 tank and a space located directly above.

c) Where portable fuel storage tanks are used, special attention is to be given to:
   - design of the tank for its intended purpose
   - mounting and securing arrangements
   - electric bonding, and
   - inspection procedures.

4.1.3 Fuel pumping

a) Storage tank fuel pumps are to be provided with means which permit shutdown from a safe remote location in the event of fire. Gravity fed fuelling systems are not permitted.

b) The fuel pumping unit is to be connected to one tank at a time. The piping between the tank and the pumping unit is to be of steel or equivalent material, as short as possible, and protected against damage.

c) Electrical fuel pumping units and associated control equipment are to be of a type suitable for the location and potential hazards.

d) Fuel pumping units are to incorporate a device which will prevent over-pressurization of the delivery or filling hose.

4.1.4 Refuelling equipment

All equipment used in refuelling operations is to be electrically bonded. Measures related to the limitation of the production of electrostatic energy in JP5 spaces are to be taken.

In general, JP5 piping is not to pass through accommodation spaces, service spaces and control stations. When this is not possible, specific arrangement are to be submitted to the Society to avoid the flammable vapours in the concerned spaces. Means are to be provided in order to purge the piping after use.

4.2 "No smoking" signs

4.2.1 "No smoking" signs are to be displayed at appropriate locations.

4.3 Hangar, refuelling stations, refuelling and maintenance facilities

4.3.1 In general, refuelling operations are to be carried out on an open deck that is to be arranged and treated for fire protection purposes as a ship fuel filling station. In addition, the connection to the fuel piping is to be located outside of the hangar.

If refuelling is not carried out on an open deck or if the connection to the fuel piping is located inside the hangar, the helicopter hangar as well as the refuelling and maintenance facilities are to be treated as category A machinery spaces with regard to structural fire protection, fixed fire-extinguishing and detection system requirements, and electrical equipment is to comply with [4.3.2].

Note 1: In this Section, the terms "refuelling station", "refuelling installation" and "maintenance facilities" mean the spaces containing the fuel pumps and piping and associated connected equipment and do not include the spaces dedicated to the storage of refuelling equipment such as fuel hoses and nozzles which do not have a permanent connection to the fuel piping.

4.3.2 Electrical equipment and wiring

When the refuelling is intended to be carried out inside the hangar, electrical equipment and wiring inside the hangar are to be of safety type as applicable to ro-ro spaces in compliance with Ch 4, Sec 12, [2.2].

When refuelling is performed on open deck only, notwithstanding the requirements of Ch 4, Sec 12, [2.2] and Ch 4, Sec 12, [2.3], standard marine electrical equipment may be used.

Standard marine electrical equipment may be used in the refuelling station.

4.3.3 Manually operated call points are to be provided close to the exit of the JP5 pump room and helicopter hangar.

4.4 Ventilation

4.4.1 Enclosed hangar facilities or enclosed spaces containing refuelling installation are to be provided with mechanical ventilation as required in Ch 4, Sec 12, [2.1] and according to the definition of Ch 4, Sec 1, [2.30] if the hangar falls under the definition of a "enclosed ro-ro space" and Ch 4, Sec 1, [2.37] if the hangar falls under the definition of a "enclosed vehicle space".

4.4.2 When the refuelling is intended to be carried out inside the hangar, ventilation fans are to be of non sparking type.

5 Operations manual

5.1 General

5.1.1 Each helicopter facility is to have an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements. This manual may be part of the ship's emergency response procedures.

Section 11 Alternative Design and Arrangements

1 General

1.1

1.1.1 The Society may consider designs and arrangements deviating from the prescriptive requirements set out in the present chapter provided they are deemed to provide an equivalent level of fire safety, in line with the equivalence principle given in Pt A, Ch 1, Sec 1, [2.2]. Alternative fire protection, detection and extinction arrangements may be required to be assessed according to IMO Circular MSC.1/Circ.1002 as amended.

Section 12 Protection of Vehicle and Ro-ro Spaces

1 General

1.1 Application

1.1.1 The fuel used by any vehicle using internal combustion engines such as tenders, rescue boats, operational boats, landing barges, road cars, maintenance carts, aircraft and helicopter carts, fire-fighting trucks or aircrafts and helicopters stowed in a vehicle or ro-ro space shall have a flash point greater than 60°C.

1.1.2 In addition to complying with the requirements of this Section, vehicle and ro-ro spaces shall comply also with the requirements of other sections of this Chapter as appropriate.

1.2 Basic principle

1.2.1 The basic principle underlying the provisions of this section is that the normal main vertical zoning required by Ch 4, Sec 5, [1] may not be practicable in vehicle and ro-ro spaces. Therefore, equivalent protection must be obtained in such spaces on the basis of the horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone may include vehicle and ro-ro spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

1.2.2 The requirements of ventilation systems, openings in "A" class divisions and penetrations in "A" class divisions for maintaining the integrity of vertical zones in this Chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal zones from each other and from the remainder of the ship.

2 Precaution against ignition of flammable vapours in closed vehicle and ro-ro spaces

2.1 Ventilation systems

2.1.1 Capacity of ventilation systems

There shall be provided an effective power ventilation system sufficient to give at least the following air changes:

- closed ro-ro spaces: 10 air changes per hour
- closed vehicle spaces: 6 air changes per hour
- during refuelling operations, operation of power cell loading of the batteries of electrical motors, process requiring to start the internal combustion engines of the vehicles inside a closed ro-ro spaces: 15 air changes per hour.

2.1.2 Performance of ventilation systems

a) The power ventilation system required in [2.1.1] for vehicle and ro-ro spaces shall be entirely separated from other ship ventilation systems and shall be in operation at all times when vehicles are in such spaces.

   Ventilation ducts serving such spaces, capable to be sealed, shall be separated for each space. The system shall be capable of being controlled locally from a position outside such spaces and from the continuously manned damage control station.

b) The ventilation system shall be such as to prevent air stratification and the formation of air pockets.

c) Fans are to be of non-sparking type.

2.1.3 Indication of ventilation systems

Means shall be provided to indicate in the continuously manned damage control station any loss of the required ventilating capacity.

2.1.4 Closing appliances and ducts of openings in ventilation systems of vehicle and ro-ro spaces

a) Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system from outside the space in case of fire, taking into account the weather and sea conditions.

b) Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel. Ventilation ducts that pass through other horizontal zones or machinery spaces shall be A-30 class steel ducts constructed in accordance with Ch 4, Sec 5, [6.3.1].

2.2 Electrical equipment and wiring

2.2.1 Electrical equipment and wiring, if installed in vehicle and ro-ro spaces, shall be of a safety type suitable for use in an explosive petrol and air mixture.

2.2.2 In case of vehicle spaces above the bulkhead deck, notwithstanding the provisions in [2.2.1], above a height of 450 mm from the deck and from each platform of vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be permitted as an alternative.

2.3 Electrical equipment and wiring in exhaust ventilation ducts

2.3.1 Electrical equipment and wiring, if installed in ventilation ducts of vehicle and ro-ro spaces shall be of a safety type approved suitable for use in an explosive petrol and air mixture and the outlet from any exhaust duct shall be located in a safe position having regard to other possible sources of ignition.

2.4 Other electrical ignition sources

2.4.1 Other equipment which may constitute a source of ignition of flammable vapours is not permitted. However, power cell loading operations may be permitted in ro-ro spaces for recharging the batteries of electrical motors of maintenance vehicles, provided that the requirements of a battery room, as described in Ch 4, Sec 5, [6.8.3], Ch 2, Sec 3, [10.3] and Ch 2, Sec 11, [6.5], are complied with in the space where such operations are proceeded.

2.5 Scuppers and discharge

2.5.1 Scuppers shall not be led to machinery or other spaces where sources of ignition may be present.

Scuppers shall be made of steel.

3 Fire detection and alarm

3.1 Fixed fire detection and fire alarm systems

3.1.1 There shall be provided a fixed fire detection and fire-alarm system complying with the requirements of Ch 4, Sec 13. The fixed fire detection system shall be capable of rapidly detecting the onset of fire. The type of detectors and their spacing and location shall be to the satisfaction of the Society taking into account the effects of ventilation and other relevant factors. After being installed, the system shall be tested under normal ventilation conditions and shall give an overall response time to the satisfaction of the Society.

3.2 Manually operated call points

3.2.1 Manually operated call points shall be provided as necessary throughout the vehicle and ro-ro spaces so that no part of the space is more than 20 m from a manually operated call point and one shall be placed close to each exit from such spaces.

4 Fire extinction

4.1 Fixed fire-extinguishing systems

4.1.1 Vehicle and ro-ro spaces shall be fitted with a fixed high expansion foam fire-extinguishing system complying with Ch 4, Sec 13, [6.1.2] or a fixed water spraying system complying with Ch 4, Sec 13, [7.1] or a thick water system complying with Ch 4, Sec 13, [7.4].

Where necessary, the non accessible parts of vehicle and ro-ro spaces, such as spaces below gratings or platforms, shall be provided with a low expansion fire-extinguishing system complying with the requirement of Ch 4, Sec 13, [6.1.3].

As an alternative, upon agreement by the Society and upon full scale tests, in conditions simulating a flowing fuel oil fire in vehicle and ro-ro spaces or aircraft hangars, have shown not to be less effective of previous systems, one of the following systems may be fitted:

- an approved fixed clean agent fire-extinguishing system
- an approved water based fire-extinguishing system.

Furthermore, upon agreement by the Society, it may be fitted:

- in vehicle and ro-ro spaces capable of being sealed from a location outside the space, a carbon dioxide system shall be provided for each protected spaces. Its arrangements shall be such as to ensure that at least 2/3 of the gas required for the space is introduced in 10 minutes, to ensure that the quantity of gas available is at least sufficient to give a minimum volume of free gas of 45% of the gross volume of the space and shall comply with the provisions of Ch 4, Sec 13.

4.1.2 When fixed high expansion foam fire-extinguishing systems, pressure water-spraying fire-extinguishing systems, or thick water systems are provided, in view of the serious loss of stability which could arise due to the large water or high expansion foam or thick water quantities accumulating on deck or decks during the operation of the fire-extinguishing system, the following arrangement is to be provided:

a) In the vehicle and ro-ro spaces located above the bulkhead deck, scuppers, complying with IMO Circular MSC.1/Circ.1320, are to be fitted so as to ensure that such water or high expansion foam or thick water is rapidly discharged directly overboard.

Discharge valves for scuppers are to be provided and fitted with positive means of closing operated from above the damage control deck as mentioned in Pt B, Ch 1, Sec 2, [6.5.1] and above the "V" lines as defined in Pt B, Ch 1, Sec 2, [3.2.3] and Pt B, Ch 3, App 4, and are to be kept open while the ship is at sea.

An indication is to be provided in the damage control station and in the bridge to indicate whether those valves are open or closed and an alarm is to provide a visual and audible warning when the fixed fire-extinguishing system is operating and the valves referred above are closed. Any operation of valves referred in the item just above are to be recorded in the log-book.

b) In the spaces below the bulkhead deck, the Society may require pumping and drainage facilities to be provided in addition to the requirement of Ch 1, Sec 10. In such case, the drainage system is to be sized to remove no less than 125% of the combined capacity of both the fixed fire-extinguishing system pumps and the required number of fire hose nozzles, according to IMO Circular MSC.1/Circ.1320. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the fire-extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

4.1.3 Foam monitors may be fitted inside aircraft hangars in addition to the system required by the provisions of [4.1.1].

4.2 Portable fire extinguishers

4.2.1 Portable fire extinguishers shall be provided at each deck level in each hold or compartment where vehicles are carried, spaced not more than 20 m apart on both sides of the space. At least one portable extinguisher shall be located at each access to such a space.

4.2.2 In addition to the provision of [4.2.1], one foam applicator unit complying with the provisions of Ch 4, Sec 13 shall be provided, provided that at least two such units are available in the ship for use in such spaces.

Section 13 Fire Safety Systems

1 General

1.1 Application

1.1.1 This Section applies to fire safety systems as referred to in the Rules.

1.1.2 Piping systems included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 10, unless otherwise specified in the present section.

1.1.3 Pressure vessels included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 3, unless otherwise specified in the present section.

2 International shore connection and Stanag 1169

2.1 Engineering specifications for international shore connection

2.1.1 Standard dimensions

Standard dimensions of flanges for the international shore connection shall be in accordance with Tab 1 (see also Fig 1).

Figure 1 : International shore connection

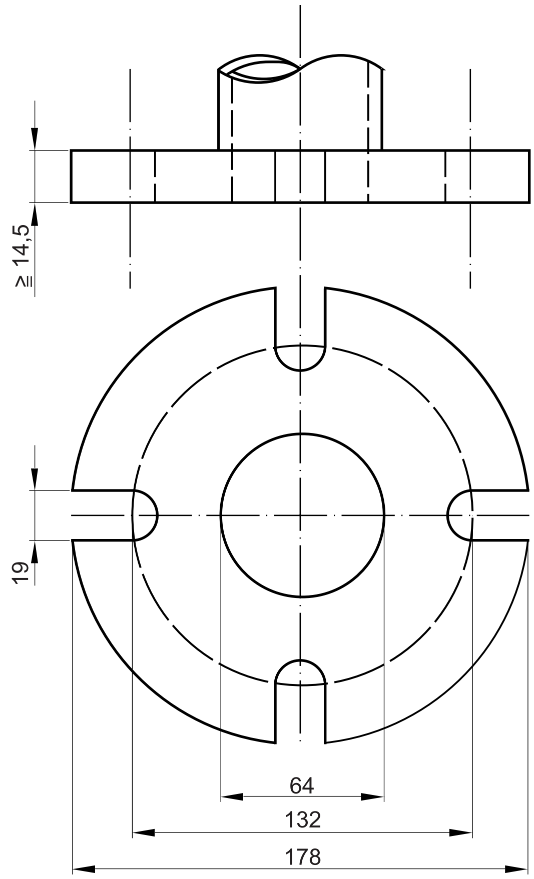


Table 1 : Standard dimensions

Description	Dimension
Outside diameter	178 mm
Inside diameter	64 mm

Description	Dimension
Bolt circle diameter	132 mm
Slots in flange	4 holes 19 mm in diameter spaced equidistantly on a bolt circle of the above diameter, slotted to the flange periphery
Flange thickness	14,5 mm minimum
Bolts and nuts	4, each of 16 mm diameter, 50 mm in length

2.1.2 Materials and accessories

The connection shall be of steel or other suitable material and shall be designed for 1,0 MPa services. The flange shall have a flat face on one side and on the other shall be permanently attached to a coupling that will fit the ship's hydrant and hose. The connection shall be kept aboard the ship together with a gasket of any material suitable for 1,0 MPa services, together with four bolts of 16 mm diameter and 50 mm in length, four nuts of 16 mm diameter, and eight washers.

2.1.3 The ship shall be provided also with a connection complying with standard Stanag 1169.

3 Personnel protection and emergency escape breathing devices

3.1 Engineering specifications

3.1.1 General

The breathing apparatus, axe in the stowage place of firefighter's equipment in each safety zone as well as the protective clothing, boots and gloves, rigid helmet and electric safety lamp of personal equipment, shall be in accordance with the requirement of the standards of the Naval Authority.

In absence of such standards the following [3.1.2] shall be complied with.

3.1.2 Personnel protection and other fittings

A firefighter's outfit shall consist of a set of personal equipment and a breathing apparatus.

a) Personal equipment

   Personal equipment shall consist of the following:

   1) Protective clothing of material to protect the skin, from the heat radiating from the fire and from burns and scalding by steam. The outer surface shall be water-resistant

   2) boots and gloves of rubber or other electrically non-conducting material, suitable for the maximum voltage installed on the ship

   3) rigid helmet providing effective protection against impact

   4) electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours, and

   5) axe with handle provided with high-voltage insulation.

b) Breathing apparatus

   A breathing apparatus of approved type is either a self-contained compressed air-operated, the volume of air contained in its cylinders is at least 1200 l, or another self-contained breathing apparatus capable of functioning for at least 30 minutes. Two complete spare sets shall be provided for each breathing apparatus. In addition, for each safety zone, a refilling station for the bottles of breathing apparatuses shall be provided capable of being put in use within 30 minutes.

c) For each breathing apparatus a fireproof lifeline of at least 30 m in length shall be provided. The lifeline shall successfully pass an approval test by statical load of 3.5 kN for 5 min without failure. The lifeline shall be capable of being attached by means of a snap-hook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the lifeline is operated.

3.1.3 Emergency escape breathing devices (EEBD)

a) The EEBD shall consist of a head covering which completely covers the head, the neck and may cover portions of the shoulders (hood piece).

b) The EEBD shall be supplied with breathable or oxygen air and shall have a service duration of at least 10 minute.

c) The hood piece shall be constructed of flame resistant materials and shall include a clear window for viewing.

d) When inactivated the EEBD shall be capable of being carried hands-free.

4 Portable fire-extinguishing appliances

4.1 Engineering specifications

4.1.1 Fire extinguisher

a) Safety requirements

Fire extinguishers are not permitted if they contain an extinguishing medium which, in the opinion of the Society, either by itself or under the expected conditions of use, gives off toxic gases in such quantities as to endanger persons or which is an ozone depleting substance.

b) Quantity of medium

1) The fire-extinguishing capability of a fire extinguisher shall be at least equivalent to that of a 9 l fluid extinguisher.

Each power or carbon dioxide extinguisher is to have a capacity of at least 5 kg.

2) Other fire extinguishers may be accepted if considered equivalent by the Society.

4.1.2 Portable foam applicators

a) A portable foam applicator unit shall consist of a foam nozzle/branch pipe, either of a self-inducing type or in combination with a separate inductor, capable of being connected to the fire main by a fire hose, together with a portable tank containing at least 20 l of foam concentrate and at least one spare tank of foam concentrate of the same capacity.

b) System performance

1) The nozzle/branch pipe and inductor shall be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution flow rate of at least 200 l/min at the nominal pressure in the fire main.

2) The foam concentrate shall be approved.

3) The values of the foam expansion and drainage time of the foam produced by the portable foam applicator unit shall not differ more than ± 10% of that determined in item 2).

4) The portable foam applicator unit shall be designed to withstand clogging, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on ships

5 Fixed gas fire-extinguishing systems

5.1 Engineering specifications

5.1.1 General

a) Fire-extinguishing medium

1) The use of a fire-extinguishing medium which, in the opinion of the Society or the Naval Authority, either by itself or under the expected condition of use gives off toxic gas in such quantities as to endanger persons is forbidden. In any case when a fixed gas fire-extinguishing system is installed the provisions of this Article shall be complied with.

2) Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space. Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions should be considered as the same space.

3) Where the volume of free air contained in air receivers in any space is such that, if released within that space, it would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium is to be provided.

To this end the volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively, a discharge pipe from the safety valves may be fitted and led directly to the open air.

4) Means shall be provided for the crew to safely check the quantity of medium in the containers. It shall not be necessary to move the containers completely from their fixing position for this purpose. For carbon dioxide systems, hanging bars for a weighing device above each bottle row, or other means shall be provided. For other types of extinguishing media, suitable surface indicators may be used.

5) Containers for the storage of fire-extinguishing medium and associated pressure components shall be designed to pressure codes of practice to the satisfaction of the Society, having regard to their locations and maximum ambient temperatures expected in service.

b) Installation requirements

1) The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained. System flow calculations shall be performed using a calculation technique acceptable to the Society.

In machinery spaces, the discharge nozzles are to be positioned in the upper and lower parts of these spaces.

2) Except as otherwise permitted by the Society, pressure containers required for the storage of fire-extinguishing medium, other than steam, shall be located outside protected spaces in accordance with Ch 4, Sec 6, [3.3].

3) The storage of the fire-extinguishing medium is not permitted within spaces which may contain air/flammable gas mixtures.

4) In piping sections where valve arrangements introduce sections of closed piping, such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to open deck.

5) All discharge piping, fittings and nozzles in the protected spaces shall be constructed of materials having a melting temperature which exceeds 925°C. The piping and associated equipment shall be adequately supported.

Note 1: Gaskets used in discharge piping inside protected spaces need not be constructed of materials having a melting temperature which exceeds 925°C.

6) A fitting shall be installed in the discharge piping to permit the air testing as required in [5.1.3], item g).

c) System control requirements

1) The necessary pipes for conveying fire-extinguishing medium into protected spaces shall be provided with control valves so marked as to indicate clearly the space to which the pipes are led. Suitable provision shall be made to prevent inadvertent release of the medium into the space.

The pipes may pass through accommodation areas provided that they are of substantial thickness and that their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm^2. In addition, pipes passing through accommodation areas shall be joined only by welding and shall not be fitted with drains or other openings within such spaces.

The pipes shall not pass through refrigerated spaces.

Control valves are to be capable of local operation.

The open or closed position of control valves is to be indicated.

Means are to be provided in order to permit the blowing through each branch line of the piping system downstream of the master (control) valves.

2) Means shall be provided for automatically giving visual and audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms should be distinguished from other audible alarms by adjustment of sound pressure or sound patterns.

The pre-discharge alarm shall be automatically activated (e.g. by opening of the release cabinet door). The alarm is to sound for the length of time needed to evacuate the space, but in no case less than 20 seconds before the medium is released.

Where audible alarms are fitted to warn of the release of fire-extinguishing medium into pump rooms, they may be of the pneumatic or electrical type:

- Pneumatically operated alarms

  The alarms may be operated by the fire-extinguishing medium or by clean and dry air.

- Electrically operated alarms

  When electrically operated alarms are used, the arrangements should be such that the electrical actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

  Electrically operated alarms are to be supplied from the main and an emergency source of power. They are to differ from other signals transmitted to the protected space.

3) The means of control of any fixed gas fire-extinguishing system shall be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel.

4) Automatic release of fire-extinguishing medium shall not be permitted, except as allowed by the Society, under request of Naval Authority. In such case, the provision of [5.1.4] are to be complied with.

5.1.2 Carbon dioxide systems - General

a) Quantity of fire-extinguishing medium

1) For machinery spaces the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

- 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lower part of the casing, or

- 35% of the gross volume of the largest machinery space protected, including the casing.

  In the calculation of 35% of the above mentioned volume, the net volume of the funnel shall be considered up to a height equal to the whole casing height if the funnel space is in open connection of closing means.

2) For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m3/kg.

3) For machinery spaces, the fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 minutes.

b) Controls

1) Carbon dioxide systems shall comply with the following requirements:

- two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used for opening the valve of the piping which convey the gas into the protected space and a second control shall be used to discharge the gas from its storage containers. Positive means shall be provided so they can only be operated in that order; and

Note 1: The "positive means", referred to for the correct sequential operation of the controls, is to be achieved by a mechanical and/or electrical interlock that does not depend on any operational procedure to achieve the correct sequence of operation.

- the pre-discharge alarm may be activated before the two separate system release controls are operated (e.g. by a micro-switch that activates the pre-discharge alarm upon opening the release cabinet door as per [5.1.1], item c) 2). Therefore, the two separate controls for releasing carbon dioxide into the protected space (i.e. one control to open the valve of the piping which conveys the gas into the protected space and a second control used to discharge the gas from its storage containers) as per item b) 1) above can be independent of the control for activating the alarm.

  A single control for activation of the alarm is sufficient.

- the two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be located in a break-glass type enclosure conspicuously located adjacent to the box.

5.1.3 High-pressure carbon dioxide systems

a) The system is to be designed for an ambient temperature range of 0°C to 55°C, as a rule.

b) Containers for the storage of the fire-extinguishing medium are to be designed and tested in accordance with the relevant requirements of Part C, Chapter 1.

c) The filling ratio of carbon dioxide bottles is to be normally 0,67 kg/l, or less, of the total internal volume. However, for bottles to be fitted in ships which are to operate solely outside the tropical zone, the filling ratio may be up to 0,75 kg/l.

d) Piping and accessories are to generally satisfy the relevant requirements of Part. C, Chapter 1.

e) For systems where carbon dioxide is stored at ambient temperature, the thickness of steel pipes is not to be less than the values given in Tab 2.

   Slightly smaller thicknesses may be accepted provided they comply with the standards of the Naval Authority.

   The thickness of threaded pipes is to be measured at the bottom of the thread.

f) Pipes are to be appropriately protected against corrosion. Steel pipes are to be, at least, zinc or paint coated, except those fitted in machinery spaces, upon acceptance of the Society.

g) After mounting onboard, and in complement to tests and inspections at the Manufacturer's workshop, as per requirements of Part C, Chapter 1, carbon dioxide pipes and their accessories are to undergo the following tests:

1) pipe lengths between bottles and master valves:

   a hydraulic test, at the workshop or on board, at 128 bar. When the hydraulic test is carried out at the workshop, at least test with inert gas or air, at 7 bar, is to be carried out on board

2) pipe lengths between master valves and nozzles:

   a hydraulic test on board with inert gas or air, at 7 bar

3) master valves:

   a hydraulic test at 128 bar

4) a test of the free air flow in all pipes and nozzles; and

5) a functional test of the alarm equipment

5.1.4 Automatic local carbon dioxide systems for engines inside box and for unmanned rooms for switch boards or electronic or informatic equipment

The carbon dioxide bottles may be positioned inside or outside the box or the room.

The quantity of carbon dioxide inside the bottles shall be sufficient to give a minimum volume of free gas equal to 40 per cent of the gross volume of the box containing the engine(s) or of the room.

For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m^3/kg.

The manual or automatic release of the medium shall activate visual and audible alarms inside and outside the box or the room and in the continuously manned damage control station.

In case of access in the box or in the room the discharge of the system is to be intercept. A notice on the access door is to be fitted for such purpose.

Table 2 : Minimum wall thickness for steel pipes for CO_2 fire-extinguishing systems

External diameter of pipes (mm)	Minimum wall thickness, in mm	
	From bottles to distribution station	From distribution station to nozzles
21,3 - 26,9	3,2	2,6
30,0 - 48,3	4,0	3,2
51,0 - 60,3	4,5	3,6
63,5 - 76,1	5,0	3,6
82,5 - 88,9	5,6	4,0
101,6	6,3	4,0
108,0 - 114,3	7,1	4,5
127,0	8,0	4,5
133,0 - 139,7	8,0	5,0
152,4 - 168,3	8,8	5,6

5.1.5 Semi-fixed carbon dioxyde systems

A semi-fixed carbon dioxyde system is to consist of an applicator nozzle connected by a hose line to carbon dioxyde containers provided for the storage of the fire-extinguishing medium.

The location of any semi-fixed carbon dioxyde system is to be to the satisfaction of the Society. In any case, such systems are not to be fitted in accommodation and service spaces and control rooms.

The length of the hose line is not to exceed 33 m.

The applicator nozzle is to be of an on/off type.

Each container is to be designed and tested in accordance with the relevant requirements of Ch 1, Sec 3, and is to be fitted with a safety valve calibrated at a pressure in accordance with the location and the maximum ambient temperature expected. Furthermore, this safety valve is to be provided with a discharge pipe to the open air in accordance with Ch 4, Sec 6, [3.3.1].

5.2 Equivalent fixed gas extinguishing systems

5.2.1 Fixed gas fire-extinguishing systems equivalent to those specified in [5.1] are to be specially considered by the Society.

Note 1: Refer to IMO MSC/Circ 848 as amended by Circ.1267 for the approval of equivalent fixed gas fire-extinguishing systems.

6 Fixed foam fire-extinguishing systems

6.1 Engineering specifications

6.1.1 General

Fixed foam fire-extinguishing systems shall be capable of generating foam suitable for extinguishing oil fires.

6.1.2 Fixed high expansion foam fire-extinguishing systems

The fixed high expansion foam fire-extinguishing systems are to be designed, installed and tested in accordance with the requirement of Ch 6, §3 of IMO FSS Code, as amended.

6.1.3 Fixed low expansion foam fire-extinguishing systems

a) Quantity and performance of foam concentrates

   1) The foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the Society based on IMO MSC.1/Circ.1312, as amended.

   2) The system shall be capable of discharging through fixed discharge outlets in not more than five minutes a quantity of foam sufficient to cover to a depth of 150 mm the area over which fuel oil is liable to spread. The foam concentrate is to be enough for two discharges required for the protected area. The expansion ratio of the foam shall not exceed 12 to 1.

b) Installation requirements

  1) Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the foam to be effectively directed by fixed sprayers on the main fire hazards in the protected space. The means for effective distribution of the foam are to be proven acceptable to the Society through calculation or by testing.

  2) The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

7 Fixed pressure water-spraying, thick water and water-based fire-extinguishing systems

7.1 Fixed pressure water spraying fire-extinguishing systems

7.1.1 General requirements for all systems

a) The number and arrangement of the nozzles of any required fixed pressure water-spraying fire-extinguishing system in machinery spaces and service spaces shall be to the satisfaction of the Society and shall be such as to ensure an effective average distribution of water of at least 5 $l/m^2/min$ in the spaces to be protected. Where increased application rates are considered necessary, these shall be to the satisfaction of the Society.

b) The number and arrangement of the nozzles of any required fixed pressure water-spraying fire-extinguishing system in vehicle and ro-ro spaces and ammunition spaces are to be such as to ensure an effective average distribution of water

- for ammunition spaces:
  - as per requirements of Ch 4, Sec 6, [6.1]; and
- for vehicle and ro-ro spaces:
  - as per requirement of [7.1.3]

c) Precautions shall be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

d) The nozzles should be manufactured and tested based on the relevant sections of appendix A to circular MSC/Circ.1165, as amended.

e) The pressure water-spraying systems protecting the ammunition spaces are to be fed by the fire main.

7.1.2 Installation requirements for machinery spaces

a) Nozzles shall be fitted above bilges, tank tops and other areas over which fuel oil is liable to spread and also above other specific fire hazards in the machinery spaces.

b) The system may be divided into sections, the distribution valves of which shall be operated from easily accessible positions outside the spaces to be protected and will not be readily cut off by a fire in the protected space.

c) if the water-spraying fire-extinguishing system is not fed by the fire main the following requirements shall be complied with:

- the pump shall be capable of simultaneously supplying at the necessary pressure all sections of the system in any one compartment to be protected.
- the pump may be driven by independent internal combustion machinery but, if it is dependent upon power being supplied from the secondary generator unit fitted in compliance with the provisions of Ch 1, Sec 2, Part C, Chapter 2 as appropriate, that generator shall be so arranged as to start automatically in case of main power failure so that power for the pump is immediately available. The independent internal combustion machinery for driving the pump shall be so situated that a fire in the protected space or spaces will not affect the air supply to the machinery.
- The pump and its controls shall be installed outside the space(s) to be protected. It shall not be possible for a fire in the space(s) protected by the water-spraying system to put the system out of action.

d) The system shall be kept charged at the pressure and the pump supplying the water for the system shall be put automatically into action by a pressure drop in the system.

7.1.3 Installation requirements for vehicle and ro-ro spaces

a) The fixed pressure water-spraying system is to be designed, installed and tested in accordance with MSC.1/Circ.1430, as amended.

b) In any case, the fire main is to be connected to the fire-extinguishing system of the space to be protected by an isolating valve complying with the provisions of Ch 4, Sec 6, [1.2.4].

7.2 Fixed water-based local application fire-fighting systems

7.2.1 Fixed water-based local application fire-fighting systems are to be approved by the Society based on IMO Circular MSC.1/ Circ.1387 as corrected by MSC.1/Circ.1387/Corr.1.

7.3 Equivalent water-based fire-extinguishing systems for machinery spaces and fuel or JP5-NATO (F44) pump rooms

7.3.1 Water-based fire-extinguishing systems for machinery spaces and fuel pump rooms are to be approved by the Society in compliance with the following requirements:

a) The system should be capable of manual release.

b) The system are to be capable of fire extinction, and tested to the satisfaction of the Society in accordance with Appendix B of IMO MSC/Circular1165, as amended.

c) The system shall be available for immediate use and capable of continuously supplying water for at least 30 minutes in order to prevent re-ignition or fire spread within that period of time. Systems which operate at a reduced discharge rate after the initial extinguishing period shall have a second full fire-extinguishing capability available within a 5-minute period of initial activation.

d) The system and its components shall be suitably designated to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in machinery spaces, or fuel or JP5-NATO (F44) pump-rooms, of ships; system components within the protected spaces shall be designed to withstand the elevated temperatures which could occur during a fire.

e) The system and its components shall be designed and installed in accordance with international standards acceptable to the Society and manufactured and tested to the satisfaction of the Society in accordance with appropriate elements of Appendices A and B to IMO MSC/Circular1165.

f) The nozzles location, type of nozzle and nozzle characteristics shall be within the limits tested to provide fire extinction as referred in the previous item b).

g) The electrical components of the pressure source for the system shall have a minimum rating of IP54. The system shall be supplied by at least two of the ship's electrical switchboards which cannot be put out of service in any event at the same time.

h) The system shall be provided with a redundant means of pumping or otherwise supplying the water-based extinguishing medium. The capacity of the redundant means should be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity. Primary pump starting equipment may be manual or automatic. Switch over to redundant means of pumping may be manual or automatic.

   The system shall be fitted with a permanent sea inlet and be capable of continuous operation using seawater.

i) The piping system shall be sized in accordance with an hydraulic calculation technique such as the Hazen-Williams Method with the following values of the friction factor "C" for different pipe types which may be considered should apply:
   - pipes in black or galvanized mild steel: C = 100
   - pipes in copper or in copper alloys: C = 150
   - pipes in stainless steel: C = 150

j) Systems capable of supplying water at the full discharge rate for 30 minutes may be grouped into separate sections within a protected space. The sectioning of the system within such spaces shall be approved by the Society in each case.

k) In all cases the capacity and the design of the system should be based on the complete protection of the space to be protected by the system demanding the greatest volume of water.

l) The system operation controls shall be available at easily accessible positions outside the spaces to be protected and from the continuously manned damage control station and shall not be liable to be cut off by a fire in the protected spaces.

m) Pressure source components of the system shall be located outside the protected spaces.

n) A means for testing the operation of the system for assuring the required pressure and flow shall be provided.

o) Activation of any water distribution valve shall give a visual and audible alarm in the protected spaces at the valves station and in the continuously manned damage control station. An alarm in the continuously manned damage control station shall indicate the specific valve activated.

p) Operating instructions for the system shall be displayed at each operating position. The operating instructions shall be in the official language of the Naval Authority.

q) Additives should not be used for the protection of normally occupied spaces unless they have been approved for fire protection service by an independent authority. The approval should consider possible adverse effects to exposed personnel, including inhalation toxicity.

7.4 Thick water systems

7.4.1 Thick water characteristics

a) The thick water is composed by sea water mixed with an AFFF emulsifier (medium forming a floating film) with 3% concentration. The Society may authorize a lower concentration if the emulsifier medium efficiency and the correct working of the system with lower concentrations are demonstrated.

b) The AFFF emulsifier shall be of a type approved by the Society.

c) This requirement applies in addition to [7.1] for fixed pressure water-spraying fire-extinguishing systems.

7.4.2 Installations requirements

a) A fixed thick water spraying system includes an emulsifier tank and a mixer connected to the sea water main. The spraying is made by open nozzles.

b) The quantity of AFFF is to be such as to ensure at least 5 min of thick water supply.

c) The number and interconnections of the thick water delivery piping, thick water generator, shall allow, at the satisfaction of the Society, an efficient production and distribution of the thick water.

d) The arrangement of the thick water generator delivery ducting shall be such that a fire in the protected space will not affect the thick water generating equipment. When the thick water generators are located near the protected space, delivery ductings shall be installed so that the generators are at a distance of at least 450 mm from the protected space.

e) The thick water generator, its sources of power supply, emulsifier liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

   This means of control is not to be located in high fire risk spaces.

   The thick water generators are to comply with the requirements of Ch 4, Sec 6, [3.3]. The manual means of control is to be located on or above the damage control deck.

   The fixed thick water fire-extinguishing system is to be able to be monitored and controlled from the continuously manned damage control station.

f) Means shall be provided for effective distribution of the thick water through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the thick water to be effectively directed by fixed sprayers on the main fire hazards in the protected space. The means for effective distribution of the thick water are to be proven acceptable to the Society by calculation means or testing.

g) Particular dispositions are to be taken to prevent corrosion of the thick water fire-extinguishing systems at the satisfaction of the Society.

h) Piping shall be able to be flushed out and rinse out with fresh water after use.

i) A gauging system of the emulsifier in the tanks shall be provided. The emulsifier level shall be able to be surveyed from the continuously manned damage control station.

j) A storage and measuring out unit, or any other judged equivalent system, is required when several users are served by a same mixer, and when the flow rates vary within a range of 1 to 7. If not, an atmospheric pressure tank is considered satisfactory.

k) The distance between a fixed or semi-fixed thick water cannon and the farest end of the protected space located in front of this cannon shall not be more than 75% of the cannon range in calm air. This requirement also applies to hose nozzles.

l) The fixed and semi-fixed cannons, hoses shall be installed on port and starboard of the protected space. They shall be located at a height at the satisfaction of the Society.

m) Control valves shall be provided on the thick water main, and also on the sea water main when it is fully belonging to the thick water system, just before each cannon to allow to isolate the damaged parts of these mains.

8 Sprinkler systems

8.1 Type of systems

8.1.1 Sprinkler systems may be:

- manual systems with or without fusible element nozzles according to [8.2] or
- automatic sprinkler for detection and alarm systems according to [8.3].

When the automatic system is adopted, it is to be demonstrated that the vibrations and shock does not induce undue intervention of the system.

8.2 Manual sprinkler systems with or without fusible element nozzles

8.2.1 The sections of sprinkler systems shall be fed by sea water through valves connecting the section main pipes to the fire main which shall be at any time appropriated pressured by sea water.

The sprinkler system shall at least comply with the followings:

a) The connecting valves of system sections to the fire main shall be operated by the continuously manned damage control station. Manual operation of the section valves through the electric feeding system of sprinkler system locally shall be also possible. Such stations shall be located outside the protected area of the concerned section and shall be readily accessible, clearly and permanently marked and protected from unauthorized use.

b) The system and equipment shall be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in ships.

c) The system and its components shall be designed and installed in accordance with international standards acceptable to the Society and manufactured and tested to the satisfaction of the Society.

d) The piping system shall be sized in accordance with an hydraulic calculation technique such as the Hazen-Williams Method with the following values of the friction factor C for different pipe types:
- pipes in black or galvanized mild steel: C = 120
- pipes in copper or in copper alloys: C = 150
- pipes in stainless steel: C = 150
- pipes in plastic: C = 150

e) Sprinklers shall be grouped into separate sections.

If the nozzles of the system are not provided with fusible elements the deck area protected by a section shall not be greater than 80 m^2 or a space if this has a surface greater than 80 m^2.

If the nozzles of the system are provided with fusible elements, any section of the system shall not serve more than two decks of one main vertical zone

f) Sprinkler section piping shall not be used for any other purpose.

g) The section valves of sprinkler system shall be outside category A machinery spaces.

h) The activation of each section valve of the system shall initiate a visual and audible alarms at valve location and in the continuously manned damage control station.

i) A sprinkler control plan shall be displayed in the continuously manned damage control station showing the spaces covered and the location of the ship zone in respect of each section.

j) The nozzles with or without fusible elements shall be approved by the Society.

k) In accommodation and service spaces the fusible elements of nozzles shall have a nominal temperature rating of 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the nominal temperature may be increased by not more than 30°C above the maximum deckhead temperature.

l) If nozzles with fusible elements are installed, supplying water components shall be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than 280 m^2. For application to a small ship with a total protected area of less than 280 m^2, the Society may specify the appropriate area sizing the alternative supply components.

m) The section valves and the alarms shall be fed by ship's electrical switchboards being the ship provided by at least two electrical switchboards which can not be put out of service at the same time by any event.

The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards.

8.3 Automatic sprinkler, fire detection and alarm systems

8.3.1 Engineering specification

a) Type of sprinkler systems

The automatic sprinkler systems shall be of the wet pipe type but small exposed sections may be of the dry pipe type where, in the opinion of the Society, this is a necessary precaution.

b) Equivalent fire-extinguishing automatic sprinkler systems

Fire-extinguishing automatic sprinkler systems equivalent to those specified in [8.3.2] to [8.3.4] are to be approved by the Society based on IMO Resolution A.800(19) as amended.

8.3.2 Sources of power supply

There shall be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where the sources of power for the pump are electrical, these shall be a main generator and a secondary source of power. One supply for the pump shall be taken from the main switchboard, and one from the secondary switchboard by separate feeders reserved solely for that purpose. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards, and shall be run to an automatic changeover switch situated near the sprinkler pump. This switch shall permit the supply of power from the main switchboard so long as a supply is available therefrom, and be so designed that upon failure of that supply it will automatically change over to the supply from the secondary switchboard. The switches on the main switchboard and the secondary switchboard shall be clearly labelled and normally kept closed. No other switch shall be permitted in the feeders concerned. One of the sources of power supply for the alarm and detection system shall be a secondary source. Where one of the sources of power for the pump is an internal combustion engine it shall, in addition to complying with the provisions of item c) of [8.3.4], be so situated that a fire in any protected space will not affect the air supply to the machinery.

8.3.3 Component requirements

a) Sprinklers

The sprinklers shall be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers shall come into operation within the temperature range from 68°C to 79°C. However, in locations where high ambient temperatures might be expected, such as drying rooms, the operating temperature may be increased by not more than 30°C above the maximum deckhead temperature of the considered space.

b) Pressure tanks

1) A pressure tank having a volume equal to at least twice that of the charge of water specified in this item shall be provided. This tank shall contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in item c) 2). Arrangements shall be provided for maintaining an air pressure in the tank such as to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. A glass gauge shall be provided to indicate the correct level of the water in the tank.

2) Means shall be provided to prevent the passage of sea water into the tank.

c) Sprinkler pumps

1) An independent power pump shall be provided solely for the purpose of continuing automatically the discharge of water from the sprinklers. The pump shall be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

2) The pump and the piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of 280 m^2 at the application rate specified in [8.3.5]. When deemed necessary by the Society, the piping hydraulic capacity shall be checked by examination of the hydraulic calculations and testing results of the system.

3) The pump shall have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe shall be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in item b) 1) above.

8.3.4 Installation requirements

a) General

Any parts of the system which may be subjected to temperatures in service equal or below 0°C shall be suitably protected against freezing.

b) Piping arrangements

1) Sprinklers shall be grouped into separate sections, each of which shall contain not more than 200 sprinklers. Any section of sprinklers shall not serve more than two decks and shall not be situated in more than one main vertical zone. However, the Society may permit such a section of sprinklers to serve more than two decks or be situated in more than one main vertical zone, if it is satisfied that the protection of the ship against fire will not thereby be reduced.

2) Each section of sprinklers shall be capable of being isolated by one stop valve only. The stop valves shall be readily accessible, outside their corresponding sections, or inside a box situated in stairway casings. The valves location shall be clearly and permanently indicated. Means shall be provided to prevent the operation of the stop valves by any unauthorized person.

3) A test valve shall be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section shall be situated near the stop valve for that section.

4) The sprinkler system shall have a connection from the ship's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

5) A gauge indicating the pressure in the system shall be provided at each section stop valve and at a central station.

6) The sea inlet to the pump shall, wherever possible, be in the space containing the pump. It shall be so arranged that when the ship is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

c) Location of systems

The sprinkler pump and tank shall be situated in a position reasonably remote from any machinery space of category A and shall not be situated in any space required to be protected by the sprinkler system.

8.3.5 System control requirements

a) Ready availability

1) Any required automatic sprinkler, fire detection and fire alarm system shall be capable of immediate operation at all times and no action by the crew shall be necessary to set it in operation.

2) The automatic sprinkler system shall be kept charged at the necessary pressure and shall have provision for a continuous supply of water as required in this Section.

b) Alarms and indication

1) Each section of sprinklers shall include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems shall be such as to indicate if any fault occurs in the system. Such units shall indicate in which section served by the system fire has occurred and shall be

centralized on the navigating bridge or the damage control station(s). More-over, they shall activate visible and audible alarms placed in a position other than on the above mentioned spaces, so as to ensure that the indication of fire is immediately received by the crew.

2) Switches shall be provided at one of the indicating positions referred to in the previous item 1) which will enable the alarm and the indicators for each section of sprinklers to be tested.

3) Sprinklers shall be placed in an overhead position and spaced in a suitable pattern to maintain an aver-age application rate of not less than 5 l/m^2 per minute over the area covered by the sprinklers. However, the Society may permit the use of sprinklers providing such an alternative amount of water suitably distributed as has been shown, to the satisfaction of the Society, to be no less effective.

4) A list or plan shall be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance shall be available.

c) Testing

Means shall be provided for testing the automatic operation of the pump on reduction of pressure in the system.

9 Fixed fire detection and fire alarm systems

9.1 Engineering specifications

9.1.1 General requirements

a) Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

b) The fire detection system shall not be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel in the continuously manned damage control station.

Note 1: The ventilation fans and the fire dampers serving a machinery room equipped with internal combustion engines taking their combustion air directly inside the room are not to be automatically stopped or closed in case of fire detection, in order to prevent depressurization of the room.

c) The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.

d) Fire detection systems with a zone address identification capability shall be so arranged that:

1) means are provided to ensure that any fault (e.g. power break, short-circuit, earth) occurring in the loop will not render the whole loop ineffective

Note 2: Loop means an electrical circuit linking detectors of various sections in a sequence and connected (input and output) to the indicating unit(s).

2) all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic)

3) the first initiated fire alarm will not prevent any other detector from initiating further fire alarms

4) no loop will pass through a space twice. When this is not practical (e.g. for large public spaces), the part of the loop which by necessity passes through the space for a second time shall be so installed at the maximum possible distance from other parts of the loop.

9.1.2 Sources of power supply

There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fire detection and fire alarm system, one of which shall be an emergency source which may be a second main switchboard where both feeding switchboards can not be put out of service at the same time in any event. Furthermore the feeders shall feed the control panel through buffer battery. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system.

The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

9.1.3 Component requirements

a) Detectors

1) Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Society provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to smoke or heat detectors.

2) Smoke detectors required in all stairways, corridors and escape routes within accommodation spaces shall be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds 2 per cent obscuration per metre. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

3) Heat detectors shall be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

Note 1: For heat detection inside ammunition spaces, different temperatures of operations and sensitivity requirements may be specified by the Naval Authority.

4) At the discretion of the Society, the permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

5) All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

9.1.4 Installation requirements

a) Sections

1) Detectors as well as manually operated call points shall be grouped into separate sections.

Note 1: Section means group of fire detectors or manually operated call points as shown in the indicating unit(s) required in item a)3) of [9.1.5].

2) A section of fire detectors which covers a control station, a service space or an accommodation space shall not include a machinery space of category A or ammunition spaces.

For fire detection systems with remotely and individually identifiable fire detectors the requirement set out in this item 2) is considered to be met when a loop covering an accommodation space, a service space and a control station does not include machinery spaces of category A or ammunition spaces.

3) If the ship is divided in safety zones, there shall be one control panel per safety zone. Associated loops of detectors should not extend outside the safety zone in which its control panel is fitted.

Each control panel is to be provided with an indicating unit in each other damage control stations.

Cable between the fire control panel and the indicating unit is to be either of a fire resistant type or to be duplicated and to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

Note 2: The indicating unit is to ensure that the fire detection and alarm systems from one damage control station are also available in the other damage control station.

Note 3: An indicating unit is a dedicated fire repeater alarm panel.

4) If there is no fire detection system capable of remotely and individually identifying each detector, a section of detectors shall not serve spaces on both sides of the ship nor on more than one deck and neither shall it be situated in more than one main vertical zone except that the Society if it is satisfied that the protection of the ship against fire will not thereby be reduced, may permit such a section of detectors to serve both sides of the ship and more than one deck. In ships fitted with individually identifiable fire detectors, a section may serve spaces on both sides of the ship and on several decks but may not be situated in more than one main vertical zone.

b) Positioning of detectors

1) Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. In general, detectors which are located on the overhead shall be a minimum distance of 0,5 m away from bulkheads.

2) The maximum spacing of detectors shall be in accordance with Tab 3. The Society may require or permit other spacings based upon test data which demonstrate the characteristics of the detectors.

3) Flame detectors shall be positioned at the edge of the room, pointing directly at the center of the area to be protected. If the detector doesn't have the complete area to be protected in its field of vision, one or more additional detectors may be required according to the distance from the anticipated flame and the angle of view of detector. The arrangement of the flame detector shall take into account that the smoke created by fire may render the detection ineffective.

c) Arrangement of electric wiring

1) Electrical wiring which forms part of the system shall be so arranged as to avoid galleys, machinery spaces of category A, and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.

2) A loop of fire detection systems with a zone address identification capability shall be capable to operate even if the loop is damaged in one point by the fire.

9.1.5 System control requirements

a) Visual and audible fire signals

1) The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder system need not be an integral part of the detection system.
2) The control panel shall be located at the continuously manned damage control station.
3) Indicating units shall, as a minimum, denote the section in which a detector is activated or a manually operated call point has operated. At least one unit shall be so located that it is easily accessible to responsible members of the crew at all times. One indicating unit shall be located on the damage control stations.
4) Clear information shall be displayed on or adjacent to each indicating unit about the space covered and the location of the sections.
5) Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

Table 3 : Maximum spacing of detectors

Type of detector	Maximum floor area per detector	Maximum distance apart between centres	Maximum distance away from bulkheads
Heat	37 m^2	9 m	4,5 m
Smoke	60 m^2	10 m	5,0 m
Note 1: For spaces of categories (8) (11) (12) (13) or (14), as defined in Ch 4, Sec 5, [1.2.3] item b), the maximum floor area per smoke detector is not to exceed 24 m^2.			

10 Fire protection system for flight decks

10.1 General

10.1.1 The water capacity, the foam forming liquid capacity and the areas to be protected by the fire protection systems for flight decks given in this article should not restrict the technical solutions for fire-fighting issued by the risk analysis proceeded by the Naval Authority.

10.1.2 The fire protection of flight decks should consist on the other means of fire-fighting as required in [10.2.3] and one of the following fixed fire-extinguishing systems or a combination of them:

- a flight deck thick water system complying with the requirements of [10.2.1] below; and/or
- an arrangement of foam monitors complying with the requirements of [10.2.2] below.

10.2 Flight decks fire-extinguishing systems

10.2.1 Fixed fire-extinguishing thick water system for flight decks

The thick water flow rate of the system shall be at least:

a) 5 l/min/m^2 on the areas of the flight decks identified as high fire risk.

b) 5 l/min/m^2 on the exterior bulkheads of the superstructures facing the flight decks extending up to a height of 5 m above the level of the flight deck.

c) 3 l/min/m^2 on the areas of the flight decks identified as moderate fire risk.

The system shall be capable of remote control from a damage control station and from an aircraft control station.

The thick water nozzles used for the system shall be of a type approved by the Society.

The foam forming liquid shall be of a type approved by the Society.

The mixing ratio of foam forming liquid with sea water shall be at least 3%. Other mixing ratios shall be to the satisfaction of the Society.

10.2.2 Arrangement of foam monitors for flight decks

The foam monitors shall be of a type approved by the Society

The monitors shall be capable of local and remote control from a damage control station and from an aircraft control station.

The foam expansion ratio of the foam delivered by the foam monitors shall be from 5 to 12.

The throw length of the foam monitor in still air conditions shall be at least 1,3 times the maximum distance between the monitor and the area to be protected.

The flow rate of the monitors shall be at least 1200 l/min.

The monitors shall be capable of delivering foam to each part of the flight deck required to be protected by the system. Each of the protected areas shall be covered by the throw emanating from at least two monitors.

The foam forming liquid shall be of a type approved by the Society.

10.2.3 Other means of fire-fighting

Hydrants capable of dual jet/spray purpose and capable of delivering foam at a flow rate of at least 200 l/min and shall be provided throughout the fly decks. Their number and location shall be such as two jets of foam not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the fly decks. The length of the fire hose shall be limited to 20 m but may extend up to 25 m if the maximum breath of the ship exceed 30 m.

A fire-fighter vehicle VLIP capable of delivering foam and powder and having the necessary means for rapidly and safely extracting the pilot from an helicopter or an airplane shall be available on flight decks during the aircraft operations.

NR483

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part D
Service Notations

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3.1 Application

Part D
Service Notations

CHAPTER 1
FRIGATE

Section 1 General

Section 2 Machinery and Systems

Section 3 Electrical Installations

Section 4 Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **frigate**, as defined in Pt A, Ch 1, Sec 2, [4.2].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Part B
Hull	• Part B
Stability	• Part B
Machinery and systems	• Part C • Ch 1, Sec 2
Electrical installations	• Part C • Ch 1, Sec 3
Automation	• Part C
Fire protection, detection and extinction	• Part C • Ch 1, Sec 4

Section 2 Machinery and Systems

1 General

1.1 Application

1.1.1 Ships having the **frigate** notation are to comply with the general requirements of Part C, Chapter 1. In addition they are to comply with the provisions of this Section.

2 Main propulsion

2.1 Availability

2.1.1 According to the mission of this type of ships, a special consideration will be given to the general arrangement of the main propulsion.

Therefore the main propulsion system is to comply at least with the requirements of the additional class notation **AVM-APM** as defined in Pt E, Ch 3, Sec 1.

Section 3 Electrical Installations

1 General

1.1 Applicability

1.1.1 In addition to the requirements given in Part C, Chapter 2 and Part C, Chapter 3, the following requirements are applicable for ships having the **frigate** notation.

For weapons and sensors which are not considered within classification scope as essential services according to [2.1], all the electrical installations (electrical generators, main power sources, cable networks) up to and including the secondary switchboards are concerned by this Chapter. Nevertheless each weapon or sensor is considered as potential source of ignition and then requirements concerning electrical monitoring and safety devices/systems for fire protection are applicable.

1.2 Environmental conditions

1.2.1 Pt C, Ch 2, Sec 1, Tab 4 is to be replaced by Tab 1 of this Section.

Table 1 : Second characteristic numeral

Second characteristic numeral	Brief description of location	Frequency range (Hz)	Displacement amplitude (mm)	Acceleration amplitude g
1	Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 –	– 0,7
2	Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 –	– 2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 –	– 4,0

2 Design of electrical installation

2.1 Essential services

2.1.1 In complement of the requirements of Pt C, Ch 2, Sec 1, [3.4], the following services are to be considered as secondary essential services:

- combat management systems
- weapons and sensors, including signature control and aviation systems, only considered as potential sources of ignition
- command and control systems integrated in the bridge or damage control stations
- internal and external communications systems required in the present Rules
- command and control equipment of locally operated safety systems
- boats launching and crew recovery systems.

2.1.2 Services for habitability are those intended for minimum comfort conditions for people on board, and specially in engine control room, safety room and operation control room.

Examples of equipment for maintaining conditions of habitability:

- lightning (50%)
- galleys (75%)
- mechanical ventilation (50%)
- heating and air conditioning (≥ 50%)
- refrigerated stores (100%)
- hospital (100%)
- drinking water production (100%)
- electric generators and associated power sources supplying the above equipment.

2.2 Specific power supply

2.2.1 Power supply to weapons and sensors, and combat management systems are to be designed so as to comply with the requirements of STANAG 1008.

2.2.2 In addition to the requirements of Pt C, Ch 2, Sec 3, [3.6], high voltage may be used for shore supply.

Section 4 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships having the following service notation:

frigate

1.1.2 The following provisions apply in addition to the requirements of Part C, Chapter 4.

1.2 Documents to be submitted

1.2.1 The interested party is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No	I/A**(1)**	Document **(2)**
1	A	Structural fire protection showing the purpose of the various spaces of the ships, the fire rating of bulkheads and decks, means of closings of openings in A and B class divisions, draught stops, and completed with the indication of material of other bulkhead and of ceilings and lining
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Means of escape and access to spaces
4	A	Automatic fire detection systems and manually operated call points
5	A	Fire pumps and fire main including pumps head and capacity, hydrant and hose locations **(2)**
6	A	Arrangement of fixed fire-extinguishing systems **(2)**
7	A	Arrangement of sprinkler or sprinkler equivalent systems **(2)**
8	A	Fire-fighting equipment and firemen's outfits
9	A	Electrical diagram of the fixed gas fire-extinguishing systems, fixed fire detection systems, fire alarm and emergency lighting
10	A	Electrical diagram of the sprinkler systems
11	A	Electrical diagram of power control and position indication circuits for fire devices
12	I	General arrangement plan
13	I	Safety zone plan
14	A	Fire control plan

(1) A = to be submitted for approval
I = to be submitted for information.

(2) Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as:
- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, sprinkler, foam and powder fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

2 General requirements

2.1 Ship subdivisions

2.1.1 The ship shall be divided in at least two safety zones.

Note 1: If the part of the ship located forward the collision bulkhead forms one main vertical zone, this main vertical zone need not to comply with the requirements of Pt C, Ch 4, Sec 5, [6.3.7] item d) and Pt C, Ch 4, Sec 6, [1.3.2].

2.1.2 The bulkheads forming the boundaries of the safety zones shall be in line with the main vertical zone bulkheads.

2.1.3 When vulnerability zones are specified according to Pt C, Ch 4, Sec 1, [2.38], the bulkheads forming the boundaries of the vulnerability zones are to be in line with the safety zone bulkheads. A vulnerability zone may however include several safety zones.

2.1.4 The bulkheads forming the boundaries of the safety zones shall be at least A-60 fire class divisions or equivalent. Where a category (5), (9) or (10) space defined in item b) of Pt C, Ch 4, Sec 5, [1.2.3] is on one side or where fuel or diesel oil or JP 5 NATO (F44) tanks or water capacity are on both sides of the division, the standard can be reduced to A-0.

2.1.5 One damage control station is to be provided in each safety zone and equipped in such a way that the functionalities of the damage control station are also operable from an other one.

Note 1: The loss of one damage control station need not be considered for application of above requirement.

Part D
Service Notations

CHAPTER 2
AIRCRAFT CARRIER

Section 1	General
Section 2	Hull and Stability
Section 3	Machinery and Systems
Section 4	Electrical Installations
Section 5	Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **aircraft carrier**, as defined in Pt A, Ch 1, Sec 2, [4.3].

1.1.2 Ships dealt with in this Chapter are to comply with:
- Part A
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Part B
Hull	• Part B • Ch 2, Sec 2
Stability	• Part B • Ch 2, Sec 2
Machinery and systems	• Part C • Ch 2, Sec 3
Electrical installations	• Part C • Ch 2, Sec 4
Automation	• Part C • Ch 2, Sec 4
Fire protection, detection and extinction	• Part C • Ch 2, Sec 5

2 Definition

2.1 General

2.1.1 Aircraft

In this Chapter aircraft include airplanes, helicopters or unmanned aerial vehicles (UAV).

2.1.2 Aircraft facilities

Aircraft facilities are systems and equipment which have the purpose of facilitating the launch, recovery, handling, supply, maintenance and repair of the aircraft on board the aircraft carrier.

2.1.3 Flight deck

The flight deck is the uppermost continuous deck used for aircraft operations.

2.1.4 Sponsons

Sponsons are external projections from the basic hull form at the level of or below the flight deck. They are typically used to support overhanging decks, to provide locations for mounting of equipment or to provide access for personnel.

3 Subdivision arrangement

3.1 Doors

3.1.1 Doors in cargo spaces

The doors accessible during the voyage, are to be fitted with a device which prevents unauthorized opening.

Additionally, indicators are required on the safety control station to show automatically when each door is closed and all door fastenings are secured.

3.1.2 Doors or ramps in large cargo spaces

Such doors are to be closed before the voyage commences and are to be kept closed during navigation. Should any of the doors or ramps be accessible during the voyage, they are to be fitted with a device which prevents unauthorized opening.

Section 2 Hull and Stability

1 Stability

1.1 Application

1.1.1 General

Intact stability and damage stability are to be assessed according to Pt B, Ch 3, Sec 2 and Pt B, Ch 3, Sec 3 respectively, taking into consideration the following sub-articles.

1.2 Intact stability

1.2.1 Calculation of the GZ curves

For the purpose of calculating the righting lever (GZ) curve, watertight sponsons and other watertight volumes attached to the sides of the hull may be considered as buoyant spaces provided that their design complies with the scantling requirements for all applicable design loads.

2 Structure design principles

2.1 General information

2.1.1 Aircraft

The types of aircraft for which the aircraft carrier is designed are to be formally given as a list.

In particular, this list must clearly indicate:

- the types of aircraft allowed to land and take-off (for structural design of flight deck)
- the types of aircraft for which maintenance on board is considered (for structural design of aircraft elevators and hangar deck).

For each aircraft, data pertaining to mass distribution per wheel is to be specified as per Pt B, Ch 5, Sec 6, [4] for each operating and non-operating condition. Such conditions may include:

- normal landing, hard landing, emergency landing, catapulting and parked conditions for airplanes and UAVs
- heavy landing, emergency landing and parked conditions for helicopters.

Where helicopters are considered, the requirements of Pt B, Ch 8, Sec 10 are also to be complied with.

2.1.2 Design data for vehicles and wheeled equipment

The types of vehicles and wheeled equipment intended to be used on the flight deck, elevators, hangar deck, in ammunition magazines or in other spaces are to be formally specified as per Pt B, Ch 5, Sec 6, [4].

2.2 Flight deck

2.2.1 Description of zones

The partitioning of the flight deck into various zones considered for design is to be formally documented with respect to their functional use at sea (e.g. parking / launch / recovery / emergency landing). This information is also to include the type, number and arrangement of aircraft that may be present in each zone at any time.

The description of zones is to facilitate the identification of the loads that are applicable in each zone for each functional use. Where one area of the flight deck is concerned by several functional uses, the scantlings are to be checked for all possible loads.

2.2.2 Emergency landing zone

The flight deck emergency landing zone is to be clearly specified. The design criteria to be applied are to be agreed with the Society.

2.2.3 Structure in way of catapults and arresters

The locations of catapults and arresters along with the details of their integration into the flight deck structure are to be indicated on relevant drawings.

2.2.4 Flight deck openings

The various openings in flight deck are to be clearly defined with respect to their location and size (Ammunition elevators, jet blast deflectors, aviation cabins for flight officer, etc.).

Particularly, the transverse and longitudinal extent of the flight deck recesses are to be clearly marked on relevant structure drawings.

2.2.5 Aircraft lashing devices

Lashing devices fitted in the flight deck are to be clearly shown on structural drawings and are to comply with the requirements of Pt B, Ch 8, Sec 10, [7].

2.3 Hangar

2.3.1 General

Information about the design of the hangar is to be submitted, including indication of sea pressure loads, taking into consideration any openings in the sideshell

2.3.2 Description of zones

The various zones of the hangar deck considered during design are to be documented, with respect to their functional use at sea (maintenance of aircraft, cargo area, etc.).

In particular, the design loads on the various structural mezzanines in the hangar are to be specified.

2.3.3 Doors in side shell in way of aircraft elevators

Doors in the side shell in way of aircraft elevators are to be weathertight.

They are to comply with Pt B, Ch 8, Sec 6.

2.3.4 Fire doors partitioning the hangar

As a rule, the fire doors partitioning the hangar, if any, are considered as non-structural items, except if otherwise mentioned.

2.3.5 Hangar deck openings

Openings in the hangar deck are to be clearly defined with respect to their location and size.

In particular, any deck recess in way of hangar fire doors is to be detailed, if relevant.

2.3.6 Aircraft lashing devices

Lashing devices fitted in the hangar deck are to be clearly shown on structural drawings and are to comply with the requirements of Pt B, Ch 8, Sec 10, [7].

2.4 Sponsons

2.4.1 Undersides

The underside of sponsons is the lowest boundary surface, with transverse and longitudinal limits as follows:

- inboard limit: vessel side shell
- outboard limit: lowest hard chine of sponson, if any, or the point where the tangent to the lowest boundary surface makes a 60° angle with respect to the horizontal plane, in case of a rounded transition
- Fore and aft limits: as per outboard limit.

Sponsons of unusual design are to be treated on a case-by-case basis.

2.5 Cranes and other lifting appliances

2.5.1 Permanently fitted cranes and lifting applicances are to be clearly specified, with respect to their operational use and Safe Working Loads. Detailed information concerning the loads transmitted to the ship structure and fixed parts of lifting appliances considered as an integral part of the hull are to be specified and taken into account.

2.6 Aircraft and ammunition elevators

2.6.1 General

The arrangement of aircraft and ammunition elevator systems is to be specified. Detailed information concerning the loads transmitted to the ship structure and fixed parts of lifting appliances considered as an integral part of the hull are to be specified and taken into account.

The possibility of wave loads acting on the underside of deck edge aircraft elevator platforms is to be indicated. The specific loads to be considered are to be agreed with the Society.

3 Design loads

3.1 Local loads on flight deck

3.1.1 General

Loads to be considered on the flight deck are sea pressure and wheeled loads, including those due to aircraft. These loads are to be considered separately.

Table 1 : Airplane and UAV launching and landing loads

Operation	Maximum mass (t)	Main undercarriage load per wheel in z direction			Fore under carriage load per wheel in z direction		
		Maximum vertical force (kN)	Still water force F_S (kN)	Inertial force F_W (kN)	Maximum vertical force (kN)	Still water force F_S (kN)	Inertial force F_W (kN)
Landing - Normal	M_1	F_{MN}	0	F_{MN}	F_{FN}	0	F_{FN}
Landing - Hard	M_1	F_{MH}	0	F_{MH}	F_{FH}	0	F_{FH}
Landing - Exceptional	M_1	F_{ME}	0	F_{ME}	F_{FE}	0	F_{FE}
Launching - Catapulting	M_2	F_{MC}	M.g	F_{MC} – M.g	Not applicable	Not applicable	Not applicable

M_1 : maximum mass for landing, in t
M_2 : maximum mass for launching, in t
M : mass per wheel, in t, to be calculated as follows:
$M = Q_A / n_w$
where Q_A is the axle load, in t, corresponding to mass M_2 and n_w is the number of wheels for the axle considered.
F_{MN}, F_{MH}, F_{ME}: maximum force per wheel of the main undercarriage in the z direction, in kN, for normal, hard and emergency landings respectively, corresponding to mass M_1 and to be specified by the aircraft manufacturer
F_{FN}, F_{FH}, F_{FE}: maximum force per wheel of the fore undercarriage in the z direction, in kN, for normal, hard and emergency landings respectively, corresponding to mass M_1 and to be specified by the aircraft manufacturer
F_{MC} : maximum force per wheel of the main undercarriage in the z direction, in kN, during catapulting, corresponding to mass M_2 and to be specified by the aircraft manufacturer
g : acceleration due to gravity to be taken equal to 9,81 m/s².

3.1.2 Sea pressure

Sea pressure is to be taken according to Pt B, Ch 5, Sec 5, [3].

As a rule, the flight deck is to be considered as the top of the lowest tier.

3.1.3 Wheeled loads

Still water and inertial loads for aircraft and wheeled equipment operating or parked on the flight deck are to be taken according to Pt B, Ch 5, Sec 6, [4].

The still water and inertial loads for launch and recovery of airplanes and UAVs are to be determined as per Tab 1, for each aircraft type.

Helicopter landing and garage loads are to be considered as per Pt B, Ch 8, Sec 10.

3.2 Local loads on hangar deck and mezzanines

3.2.1 Cargo loads

The design cargo loads on the hangar deck and structural mezzanines in the hangar are to be taken in accordance with Pt B, Ch 5, Sec 6, [2] and Pt B, Ch 5, Sec 6, [3].

For mezzanines used only as companionway, the minimum still water pressure p_S may be reduced to 5 kN/m².

3.2.2 Wheeled loads

Still water and inertial loads on the hangar deck are to be considered for aircraft in the parked condition and for other wheeled equipment in the parked and operational conditions as applicable. These loads are to be taken as per Pt B, Ch 5, Sec 6, [4] considering [2.1.1] and [2.1.2].

3.2.3 Sea loads

When sea pressure loads are expected on the hangar deck, the design pressures are to be defined to the satisfaction of the Society.

3.3 Local loads on island and bridge

3.3.1 Loads on front, aft and side bulkheads and on decks of islands and bridges are to be determined according to Pt B, Ch 8, Sec 4.

The lowest tier of islands and bridges is to be considered as the second tier.

3.4 Local loads on sponsons

3.4.1 Side shell of sponsons

Design pressures on the sides of sponsons are to be taken equal to the wave pressures given in Pt B, Ch 5, Sec 5, Tab 3 for upright ship conditions and Pt B, Ch 5, Sec 5, Tab 5 for inclined ship conditions.

For inclined ship conditions, the roll amplitude A_R is to be calculated according to Pt B, Ch 5, Sec 3, without consideration of any ship motion damping system

3.4.2 Front and aft surfaces of sponsons

Design pressures on the front and aft surfaces of sponsons are to be taken equal to the wave pressures given in Pt B, Ch 5, Sec 5, Tab 3 for upright ship conditions and Pt B, Ch 5, Sec 5, Tab 5 for inclined ship conditions.

For inclined ship conditions, the roll amplitude A_R is to be calculated according to Pt B, Ch 5, Sec 3, without consideration of any ship motion damping system.

3.4.3 Underside of sponsons

For transverse sections located longitudinally such than x/L is less than 0,7, the sea pressure to be considered on the underside of sponsons is the normal sea pressure acting on side shell.

For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the sea impact pressure on the underside of sponsons p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = C_S C_Z (0{,}22 + 0{,}15 \tan\alpha)(0{,}4 V \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the impact pressure is considered to be acting:

- $C_S = 1{,}8$ for plating and ordinary stiffeners
- $C_S = 0{,}5$ for primary supporting members

C_Z : Coefficient depending on the distance between the full load waterline and the calculation point:

- for $z \geq 2\,C + T - 11$: $C_Z = C - 0{,}5\,(z - T)$
- for $z < 2\,C + T - 11$: $C_Z = 5{,}5$

C : Wave parameter:

$$C = 10{,}75 - \left(\frac{300 - L}{100}\right)^{1{,}5} \quad \text{for } 90\text{ m} \leq L < 300\text{ m}$$

$$C = 10{,}75 \quad \text{for } 300\text{ m} \leq L \leq 350\text{ m}$$

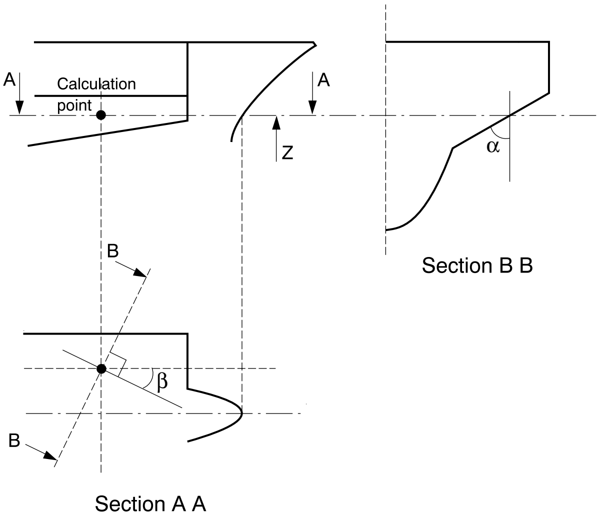
$$C = 10{,}75 - \left(\frac{L - 350}{150}\right)^{1{,}5} \quad \text{for } L > 350\text{ m}$$

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the underside plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1) and not to be taken greater than 80°

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1)

V : Maximum service speed, in knots.

Figure 1 : Definition of angles α and β



4 Hull girder strength

4.1 Strength characteristics of the hull girder transverse sections

4.1.1 Contribution of flight deck

The flight deck is generally to be considered as the strength deck.

The actual contribution of the flight deck in way of sponsons to the hull girder strength is to be confirmed by finite element analysis.

Openings in the flight deck (e.g. elevators, jet blast deflectors, catapult recesses, aviation cabins for flight officers, etc.) are to be taken into consideration in accordance with relevant requirements of Pt B, Ch 4, Sec 6, [6] and Pt B, Ch 6, Sec 1, [2].

4.1.2 Contribution of sponsons

The actual contribution of the flight deck sponsons to the hull girder strength is to be confirmed by finite element analysis.

All other sponsons are to be considered as not contributing to the hull girder strength.

4.1.3 Openings in side shell and sponsons

Openings in side shell and in flight deck sponsons (e.g. hangar doors) are to be taken into consideration in accordance with relevant requirements of Pt B, Ch 6, Sec 1, [2].

4.2 Yielding check

4.2.1 Torque wave bending moment

Wave torque as specified in Pt B, Ch 6, Sec 2 is to be considered.

4.2.2 Structural model for the calculation of shear stresses

Finite element analysis or thin walled beam models representing members which constitute the hull girder transverse sections may be used for calculation of the vertical shear stress distribution.

5 Hull scantlings of flight deck

5.1 General

5.1.1 Structural singularities

The scantlings of flight deck local reinforcement in way of structural singularities (arresters, catapults, deflector hinges etc.) are to be assessed to the satisfaction of the Society.

Design forces (amplitudes, directions) and associated safety coefficients are to be agreed upon on a case-by-case basis.

5.2 Plating

5.2.1 The scantlings of the plating of the flight deck under wheeled loads and sea pressure are to be in compliance with the requirements of Pt B, Ch 7, Sec 1 with partial safety factors taken according to Tab 2.

5.3 Ordinary stiffeners

5.3.1 The scantlings of the ordinary stiffeners of the flight deck under wheeled loads and sea pressure are to be in compliance with the requirements of Pt B, Ch 7, Sec 2, with partial safety factors taken according to Tab 3.

Table 2 : Plating of flight deck - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Sea pressure	Landing Normal	Landing Hard	Landing Emergency	Launching catapulting	Parking
Still water hull girder loads	γ_{S1}	1,00	0	0	0	0	1,00
Wave hull girder loads	γ_{W1}	1,15	0	0	0	0	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20	1,05	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20	1,20	1,20	1,20	1,20	1,20

Table 3 : Stiffeners of flight deck - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Sea pressure	Landing Normal	Landing Hard	Landing Emergency	Launching catapulting	Parking
Still water hull girder loads	γ_{S1}	1,00	0	0	0	0	1,00
Wave hull girder loads	γ_{W1}	1,15	0	0	0	0	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20	1,05	1,20	1,20
Material	γ_m	1,02	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20	1,02	1,02	1,02	1,02	1,02

5.4 Primary supporting structure

5.4.1 The scantlings of the primary structure of the flight deck under wheeled loads and sea pressure are to be in compliance with the requirements of Pt B, Ch 7, Sec 3, with partial safety factors taken according to Tab 3.

6 Sponsons

6.1 Side shell

6.1.1 Plating, ordinary stiffeners and primary structure

The scantlings of the side shell of sponsons are to be in accordance with Part B, Chapter 7, with loads according to [3.4].

For sponsons not contributing to hull girder strength, the scantlings are to checked according to Part B, Chapter 7, with loads according to [3.4] and with longitudinal stress σ_1 equal to 0.

6.2 Front and aft surfaces

6.2.1 Plating, ordinary stiffeners and primary structure

The scantlings of front and aft surfaces of sponsons are to be in accordance with Part B, Chapter 7, with loads according to [3.4], and with longitudinal stress σ_1 equal to 0.

6.3 Underside

6.3.1 Partial safety factors

For transverse sections located longitudinally such than x/L is less than 0,7, the partial safety factors to be considered are given in Pt B, Ch 7, Sec 1, Pt B, Ch 7, Sec 2 or Pt B, Ch 7, Sec 3, as applicable.

For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the partial safety factors to be considered are to be taken as follows:

- Tab 4 for plating and ordinary stiffeners of the underside of sponsons
- Pt B, Ch 7, Sec 3 for primary structure of the underside of sponsons.

Table 4 : Reinforcements of the underside of sponsons Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

6.3.2 Plating and ordinary stiffeners

For transverse sections located longitudinally such than x/L is less than 0,7, the net scantlings of plating and ordinary stiffeners of the underside of sponsons are to be checked according to Pt B, Ch 7, Sec 1 or Pt B, Ch 7, Sec 2, as applicable, for the loads in [3.4.3]. However, the net scantlings of plating and ordinary stiffeners are to be not less than the minimum values given in Tab 5.

For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the net scantlings of plating and ordinary stiffeners of the underside of sponsons are to be not less than the values obtained from the formulae in Tab 5, considering the loads in [3.4.3], and the minimum values in the same Table.

Table 5 : Reinforcements of plating and ordinary stiffeners of the underside of sponsons

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	Net minimum thickness, in mm: $t = (0{,}03\ L + 5{,}5)\ k^{1/2}$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{FI}}{18 c_P R_y} \left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5\ L_2^{1/3}\ k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	
Note 1: c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.		

6.3.3 Intercostal stiffeners

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

6.3.4 Primary supporting members

Primary supporting members are generally to be verified through direct calculations carried out according to Pt B, Ch 7, Sec 3, considering the sea impact pressures defined in [3.4.1].

6.3.5 Strengthening of sponsons in way of workboats / lifeboats

Sponsons are to be adequately strengthened in way of workboat / lifeboat launching appliances. Stiffening of the underside is to be compatible with the boat launching and recovery operations.

7 Other hull scantlings

7.1 Bottom

7.1.1 Bottom plating

The minimum net thickness of bottom plating is to be not less than the values given in Tab 6.

Table 6 : Minimum net thickness of bottom plating

Plating	Minimum net thickness (mm)
Longitudinal framing	$2{,}8 + 0{,}032\ L\ k^{1/2} + 4{,}5\ s$
Transverse framing	$3{,}8 + 0{,}032\ L\ k^{1/2} + 4{,}5\ s$

7.2 Hangar

7.2.1 Hangar deck

The scantlings of the hangar deck structure and the mezzanine decks in the hangar under wheeled loads and cargo loads are to be in compliance with the requirements of Part B, Chapter 7.

7.2.2 Transverse racking effect

The transverse partial bulkheading structure in the hangar is to be checked against transverse racking effect induced by transverse accelerations exerted on deck structure between hangar and flight deck.

The most severe conditions are to be considered for loads and transverse accelerations.

Stress criteria are given in Pt B, Ch 7, Sec 3, [2].

7.3 Island and bridge

7.3.1 The scantlings of island and bridge structure are to be in accordance with Pt B, Ch 8, Sec 4, applicable to deckhouses.

Special consideration is to be given to support of masts on islands and bridges. Strength continuity downwards through several decks may be requested.

8 Hull outfitting

8.1 Anchoring equipment

8.1.1 The anchoring equipment is to be determined according to Pt B, Ch 9, Sec 4.

The equipment number EN is to be obtained according to Pt B, Ch 9, Sec 4, [2.1], where (2 h B) is to be replaced by: (2 h B + A_{CQST} + A_{CQPS}),

with:

A_{CQST} : Frontal area of starboard flight deck sponsons projected on the vertical transverse plane outboard of B/2

A_{CQPS} : Frontal area of portside flight deck sponsons projected on the vertical transverse plane outboard of B/2.

9 Fatigue analysis

9.1 Structural details

9.1.1 The details to be checked against fatigue, according to Pt B, Ch 7, Sec 4, are to be defined jointly with the Designer, at the beginning of the Classification design review process.

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1 Ships having the service notation **aircraft carrier** are to comply with the general requirements of Part C, Chapter 1. In addition they have to comply with the provisions of this Section.

2 Main propulsion

2.1 Availability

2.1.1 When in flight operation and especially in aircraft recovery phase the ordered speed of the ship is to be kept to avoid variation of the relative wind on the flight deck outside of the allowed range and a special consideration will be given to the general arrangement of the main propulsion.

Therefore the main propulsion system is to comply at least with the requirements of the additional class notation **AVM-DPS** for duplicated propulsion and steering systems as defined in Pt E, Ch 3, Sec 2.

3 Steering system

3.1 Availability

3.1.1 When in flight operation and especially in aircraft recovery phase the ordered course of the ship is to be kept to avoid variation of the relative wind on the flight deck so the steering gear is to fulfil the requirements of duplicated propulsion and steering systems **AVM-DPS** as per Pt E, Ch 3, Sec 2.

Where steering gear is used as a component of the stabilization system a special attention is to be paid on the life reduction due to this use.

4 Stabilization system

4.1 General

4.1.1 Where ship movements exceed the maximum allowed for safety of the aircraft operation the ship could be equipped with systems to reduce the movements within the allowed range with the environmental conditions requested by the Naval Authority.

Where system for reducing the movements is installed, this system is to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

4.1.2 Stabilization equipment

Where stabilization system is based on fin type roll stabilizers, these equipment are to comply with the general requirements for steering gear as per Pt C, Ch 1, Sec 12.

5 Heel correction system

5.1 General

5.1.1 Where angle of heel due to ship evolution or to aircraft transfer on flight deck or on hanger deck exceed the maximum allowed angle for safety of the aircraft operation the ship could be equipped with systems to reduce this angle of heel within the allowed range with the environmental conditions requested by the Naval Authority.

Where system for reducing this heel is installed, this system is to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

6 Aircraft launching

6.1 Take off facilities

6.1.1 General

Where catapult launching is needed, take off facilities include:

- catapult installation
- jet deflector
- sling recovery device (if any).

The catapult installation is to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

6.1.2 Catapult

a) A steam catapult for aircraft carrier is composed with:
   - the cylinder
   - the piston
   - the piston arrester
   - the putting back in battery system
   - the inlet regulating steam valve.

   These pieces of equipment are out of the scope of Class.

b) An electromagnetic catapult is composed with:
   - a linear induction motor
   - an energy substorage system
   - a power conversion system
   - a control system.

   These pieces of equipment are out of the scope of Class.

   A particular attention is to be paid to spaces containing electrical equipment that are likely to be affected by electromagnetic interferences.

   A drawing showing the extent of the electromagnetic fields generated by the components of the electromagnetic catapult and outlining the electromagnetic compatibility therewith of equipment located in the impacted areas is to be provided for information.

6.1.3 Catapult steam installation

The steam accumulator and the steam generator are to comply with requirements of Pt C, Ch 1, Sec 3.

A special attention is to be paid to the fatigue thermal cycling of these boilers and pressure vessel and of the associate piping.

The feed water production installation is to be design taking in account the intended consumption of water due to the catapult launching. In particular the increase of salinity of the steam generator is to be avoided.

6.1.4 Jet deflector

Jet deflector screen are installed to protect the flight deck staff from hot gazes blast during launching operation. This equipment is to comply with general requirements of Pt C, Ch 1, Sec 3 and Pt C, Ch 1, Sec 10.

7 Aircraft recovery

7.1 Landing facilities

7.1.1 General

The aircraft landing facilities may include:

- arresting gear installation
- landing path guidance:
  - landing area deck lights
  - optical landing system
- aircraft barricade.

The arresting gear installation, the landing area deck lights and the optical landing system are to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

7.1.2 Arresting gear installation

Arresting gear installation may be using hydraulic energy and alternatively electromagnetic energy coupled with water turbines.

Arresting gear installation are mainly composed of 3 or 4 independent arresting cables with their own pulleys connected to the slowing devices.

When the system includes hydraulic cylinders, these are to comply with general requirement of Pt C, Ch 1, Sec 3 and Pt C, Ch 1, Sec 10.

In case of malfunction of one of these arresting cables, dispositions are to be taken in order to clear the landing area of the defective cable within a delay acceptable by the aircraft recovery operation.

8 Aircraft handling

8.1 Aircraft Elevators

8.1.1 Aircraft elevators are to be considered as a secondary essential service according to Pt C, Ch 2, Sec 1, [3.4.1].

8.1.2 Aircraft elevators are to comply with the requirements of NR526, Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units.

8.2 Aircraft cranes

8.2.1 Permanently fitted cranes for aircraft handling or maintenance are to comply with the requirements of NR526, Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units.

9 Aircraft supplying

9.1 General

9.1.1 The supply of the aircraft needs among others handling, storage or production for:

- fuel
- ammunition
- oxygen for breathing purpose
- special ingredients and fluids for aircraft
- aircraft electric power.

9.1.2 Refuelling system

Refuelling system is to comply with requirements for helicopter platform as per Pt C, Ch 1, Sec 10, [11] and Pt C, Ch 4, Sec 10, [4].

9.1.3 Oxygen production and storage

A special consideration for risk of high concentration of oxygen is to be taken into account for aircraft breathing oxygen storage and production installation. Whenever liquefied oxygen is present on board, special consideration for consequences of leakage is to be taken into account. These consequences are to include fire risk and damage to ship structures.

10 Ammunition handling

10.1 Ammunition elevators

10.1.1 Ammunition elevators are to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

10.1.2 Ammunition elevators are to comply with the requirements of NR526, Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units.

Section 4 Electrical Installations

1 General

1.1 Applicability

1.1.1 In addition to (or instead of) the requirements given in Part C, Chapter 2 and Part C, Chapter 3, the following requirements are applicable for aircraft carriers.

1.2 Documentation to be submitted

1.2.1 In addition to the documents requested in Pt C, Ch 2, Sec 1, the following documents are to be submitted for information:

- harmonic analysis
- study of network stability, in stabilized conditions and at nominal functioning.

2 Design of electrical installation

2.1 Harmonic distortions

2.1.1 Electric systems' harmonic distortions are to comply with the requirements of Pt C, Ch 2, Sec 2, [2.4].

2.2 Essential services

2.2.1 In complement of the requirements of Pt C, Ch 2, Sec 1, [3.4], the following services are to be considered as primary essential services:

- internal safety communication
- external communication
- navigation equipment.

2.2.2 In complement of the requirements of Pt C, Ch 2, Sec 1, [3.4], the following services are to be considered as secondary essential services, involving the operation and preparation of aircrafts, including:

- landing radars
- ammunition elevators
- aircraft elevators
- stabilisation system (includes heel correction system if any)
- davits for rescue boats
- aircraft handling system
- visual landing aids
- landing area deck lights
- arresting gear installation.

2.3 Power supply

2.3.1 Requirement Pt C, Ch 2, Sec 2, [2.1.1] is to be replaced as follows:

All electrical components are to be so designed and manufactured that they are capable of operating satisfactorily under the variations of voltage, frequency and harmonic distortion of the power supply specified from:

- STANAG 1008-10 for components designed with this standard
- [2.2] to [2.4] for the other components.

2.3.2 Power supply to weapons and sensors, and combat management systems are to be designed so as to comply with the requirements of STANAG 1008.

2.3.3 Requirement Pt C, Ch 2, Sec 3, [7.1.1] is to be replaced as follows:

Electrical installations are to be protected against accidental overcurrents including short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure as far as possible:

- continuity of service in the event of a fault, through coordinated and discriminative action of the protective devices, up and included to the level of section boards
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

2.4 Main switchboard

2.4.1 When the main switchboard is constituted of two separate switchboards, connected together with at least one connection bus tie, it is not necessary to divide each main busbars of each switchboard in two parts.

2.5 Emergency switchboard

2.5.1 The requirement for emergency source of electrical power given as a reference in [3.1.1] also applies to emergency switchboards.

2.6 Shore supply

2.6.1 Electrical installations' supply from a source on shore are to be in compliance with Pt C, Ch 2, Sec 3, [3.6].

2.6.2 A second shore supply is to be provided, in order to secure the ship power at quay. This shore supply is to be connected to a different switchboard from the first shore connexion.

2.6.3 Requirement Pt C, Ch 2, Sec 3, [3.6.9] is to be disregarded and replaced as follows:

Necessary arrangements are to be provided to allow coupling of the shore supply with main switchboard, so as to avoid any black out when transferring quay supply to ship supply and vice versa.

2.7 Electrical equipment located in hazardous areas

2.7.1 Cables located in hazardous areas are to be in compliance with Pt C, Ch 2, Sec 3, [10.2].

2.7.2 Electrical equipment located in hazardous areas are to be designed in accordance with IEC 60079 standard.

2.7.3 Electrical equipment located in hazardous areas as defined in Tab 1 are to be of a safe type appropriate for the zone. They are to be explosion group IIa and temperature class T3 minimum.

2.8 Electrical equipment located in special spaces

2.8.1 Following spaces are to be considered as hazardous areas and electrical equipment related to these areas are to comply with the requirements of Pt C, Ch 2, Sec 3, [10.4]:

- paint stores or tanks
- medical product storage rooms
- workshop where solvents are used.

2.8.2 Flour storage spaces are to be considered as hazardous areas and electrical equipment related to these areas are to have a degree of protection IP 65 and maximum surface temperature of 100°C.

2.8.3 Following spaces are to be considered as hazardous areas and electrical equipment related to these areas are to comply with the requirements of Pt C, Ch 2, Sec 3, [10.3]:

- hydrogen distribution dispenser
- battery rooms
- oxygen plant.

2.9 Electrical equipment related to aircrafts services

2.9.1 Landing lights

Landing area lighting.

2.9.2 The requirements of Pt C, Ch 2, Sec 3, [3.11.5] are to be replaced by the following:

A red lighting is to be provided in the following locations:

- alleyways leading to outside spaces, and used for personnel on duty
- all rooms and access leading directly to outside spaces without airlock
- all airlock for external access
- in alleyways leading to landing area, briefing rooms and resting rooms for pilots and aviation personnel on duty
- the lifts leading to platforms
- the spaces for aviation switchboard
- the spaces related to catapult systems, aircraft elevators and associated machinery, and wire break system, having personnel on duty
- the JP5 distribution area.

The level of illumination is to be between 2 and 5 Lux on the floor in passageway and 5 Lux where reading is necessary.

Table 1 : Electrical equipment permitted in hazardous areas

Hazardous areas	Spaces		Electrical equipment
	No.	Description	
Zone 1	1	Areas at less than 450 mm above the deck or platforms for vehicles/aircraft, if fitted, without openings of sufficient size permitting penetration of petrol gases downward	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 0 b) certified intrinsically safe apparatus Ex(ib) c) simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ib” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules, and acceptable to the appropriate authority d) certified flameproof Ex(d) e) certified pressurized Ex(p) f) certified increased safety Ex(e) g) certified encapsulated Ex(m) h) certified sand filled Ex(q) i) certified specially Ex(s) j) cables sheathed with at least one of the following: • a non-metallic impervious sheath in combination with braiding or other metallic covering • copper or stainless steel sheath (for mineral insulated cables only)
Zone 1	2	Exhaust ventilation ducts from hangars	As stated under item 1
Zone 1	3	• aircraft engine test area • loading and unloading area of fuel oil • aircraft spaces (zone around distribution of JP5 and petrol)	As stated under item 1
Zone 2	4	• areas above a height of 450 mm from the deck • areas above a height of 450 mm from each platform for vehicles/ aircraft, if fitted, without openings of sufficient size permitting penetration of petrol gases downward • areas above platforms for vehicles/ aircrafts, if fitted, with openings of sufficient size permitting penetration of petrol gases downward	Electrical equipment complying with one of the following types of protection may be considered: a) any type that may be considered for zone 1 b) tested specially for zone 2 (e.g. type “n” protection) c) pressurized, and acceptable to the appropriate authority d) encapsulated, and acceptable to the appropriate authority e) the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation (minimum class of protection IP55) f) cables sheathed with at least a non-metallic external impervious sheath

3 Emergency source of electrical power and emergency installations

3.1 General

3.1.1 Requirement of Pt C, Ch 2, Sec 3, [2.3.1] on the emergency source of electrical power is to be disregarded for aircraft carrier. The requirements of Pt C, Ch 2, Sec 3, [2.3] are to be replaced with the following provisions [3.1.2] to [3.1.15].

3.1.2 A self-contained emergency source of electrical power shall be provided.

3.1.3 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

The term "exceptionally", whilst the vessel is at sea, is understood to mean conditions such as:

a) blackout situation

b) dead ship situation

c) routine use for testing

d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless instructed otherwise by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of Pt C, Ch 2, Sec 3, [2.4] are complied with.

3.1.4 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

3.1.5 The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in [3.2.3] for the period specified, if they depend upon an electrical source for their operation.

3.1.6 The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services stated in [3.2.6] for the periods specified therein, if they depend upon an electrical source for their operation.

3.1.7 An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in Pt C, Ch 2, Sec 3, [2.3.12] and Pt C, Ch 2, Sec 3, [2.3.13] are being discharged.

3.1.8 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor converters, means are to be provided for supplying such services also in the event of failure of the converter (e.g. providing a bypass feeder or a duplication of converter).

3.1.9 Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 minute time limit given in SOLAS can be interpreted as the time from blackout/dead ship condition defined above to light-off of the first boiler.

3.1.10 Provision shall be made for the periodical testing of the complete emergency system and shall include the testing of automatic starting arrangements.

3.1.11 For starting arrangements of emergency generating sets, see Pt C, Ch 1, Sec 2, [3.1].

3.1.12 The emergency source of electrical power may be either a generator or an accumulator battery, which shall comply with the provisions of [3.1.13] or [3.1.14], respectively.

3.1.13 Where the emergency source of electrical power is a generator, it shall be:

a) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed cup test) of not less than 43°C;

b) started automatically upon failure of the electrical supply to the emergency switchboard from the main source of electrical power and shall be automatically connected to the emergency switchboard; those services referred to in [3.2.6] shall then be transferred automatically to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s; and

c) provided with a transitional source of emergency electrical power according to [3.1.15].

3.1.14 Where the emergency source of electrical power is an accumulator battery, it shall be capable of:

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage;

b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and

c) immediately supplying at least those services specified in [3.2.6].

3.1.15 The transitional source of emergency electrical power required by [3.1.13] shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the services in [3.2.6] if they depend upon an electrical source for their operation.

3.2 Distribution of electrical power

3.2.1 The emergency switch board shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.2.2 In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.

3.2.3 The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 36 hours, emergency lighting:
   1) at every muster and embarkation station and over the sides;
   2) in alleyways, stairways and exits giving access to the muster and embarkation stations;
   3) in all service and accommodation alleyways, stairways and exits, personnel lift cars;
   4) in the machinery spaces and main generating stations including their control positions;
   5) in all control stations, machinery control rooms, and at each main and emergency switchboard;
   6) at all stowage positions for firemen's outfits;
   7) at the steering gear; and
   8) at the fire pump, the sprinkler pump and the emergency bilge pump referred to in (d) below and at the starting position of their motors;

b) for a period of 36 hours:
   1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force; and
   2) on ships constructed on or after 1 February 1995 the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS Consolidated Edition 1992, and, if applicable:
      - the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3;
      - the ship earth station required by Regulation IV/10.1.1; and
      - the MF/HF radio installation required by Regulations IV/10.2.1, IV/10.2.2 and IV/11.1;

c) for a period of 36 hours:
   1) all internal communication equipment required in an emergency (see [3.2.4];
   2) the shipborne navigational equipment as required by Regulation V/12; where such provision is unreasonable or impracticable the Head Office may waive this requirement for ships of less than 5,000 gross tonnage;
   3) the fire detection and fire alarm system, the fire door holding and release system; and
   4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [3.2.5]) that are required in an emergency, unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency;

d) for a period of 36 hours:
   1) one of the fire pumps required by the relevant provisions of Part C, Chapter 4;
   2) the automatic sprinkler pump, if any; and
   3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;
e) for the period of time required in Pt C, Ch 1, Sec 12, [2], the steering gear if required to be so supplied;
f) for a period of half an hour:
   1) any watertight doors required by Regulation II-1/15 to be power operated together with their indicators and warning signals;
   2) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency.

3.2.4 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment
b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled
c) the means of communication which is provided between the officer of the watch and the person responsible for closing any watertight door which is not capable of being closed from a damage control station
d) the public address system or other effective means of communication throughout the accommodation, public and service spaces
e) the means of communication between the navigating bridge and the main fire control station.

3.2.5 Internal signals required in an emergency generally include:

a) general alarm
b) watertight door indication
c) fire door indication.

3.2.6 The transitional source of emergency electrical power required is to supply at least the following services if they depend upon an electrical source for their operation:

a) for half an hour:
   1) the lighting required by item b) [3.2.3] and Pt C, Ch 2, Sec 3, [3.5.6];
   2) all services required by [3.2.3] items c) 1), c) 3) and c) 4) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.
b) It is also to supply power to close the watertight doors as required by Regulation II-1/15.7.3.3, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided. Power to the control, indication and alarm circuits as required by Regulation II-1/15.7.2, for half an hour.

3.3 Low-location lighting

3.3.1 Aircraft carriers are to be provided with a low-location lighting (LLL) system in accordance with Pt C, Ch 4, Sec 8, [2.3.2]. Where LLL is satisfied by electric illumination, it is to comply with the following requirements.

3.3.2 The LLL system is to be connected to the emergency switchboard and is to be capable of being powered either by the main source of electrical power, or by the emergency source of electrical power for a minimum period of 60 minutes after energizing in an emergency.

3.3.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of cables of a fire-resistant type complying with Pt C, Ch 2, Sec 9, [1.1.7], and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.

3.3.4 Single lights and lighting assemblies are to be designed or arranged so that any single fault or failure in a light or lighting assembly, other than a short-circuit, will not result in a break in visible delineation exceeding 1 metre.

3.3.5 Light and lighting assemblies are to be flame-retardant as a minimum, to have an ingress protection of at least IP55 and to meet the type test requirements as specified in Pt C, Ch 3, Sec 6, Tab 1.

3.3.6 The LLL system is to be capable of being manually activated by a single action from the continuously manned damage control station. It may, additionally, be continuously operating or be switched on automatically, e.g. by the presence of smoke within the space(s) being served.

3.3.7 When powered, the systems are to achieve the following minimum luminance:

- for any planar source: 10 cd/m² from the active parts in a continuous line of 15 mm minimum width
- for any point source: 35 mcd in the typical track directions of approach and viewing which is to be considered:
  - for sources which are required to be viewed from a horizontal position, i.e. deck mounted or horizontally bulkhead mounted fittings, within a 60° cone having its centre located 30° from the horizontal mounting surface of the point source and in line with the track direction; see Fig 1
  - for sources which are required to be viewed vertically, i.e. the vertical LLL marking up to the door handles, within a 60° cone having its centre located perpendicular to the mounting service of the point source; see Fig 2.

Spacing between sources is not to exceed 300 mm.

Figure 1 :

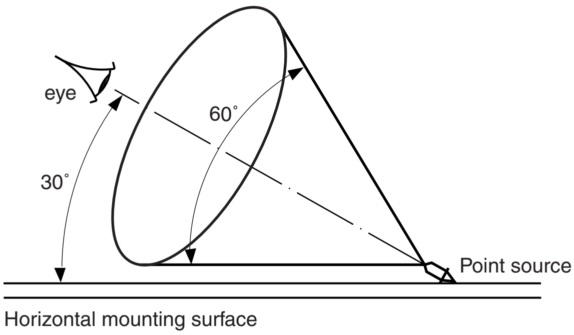
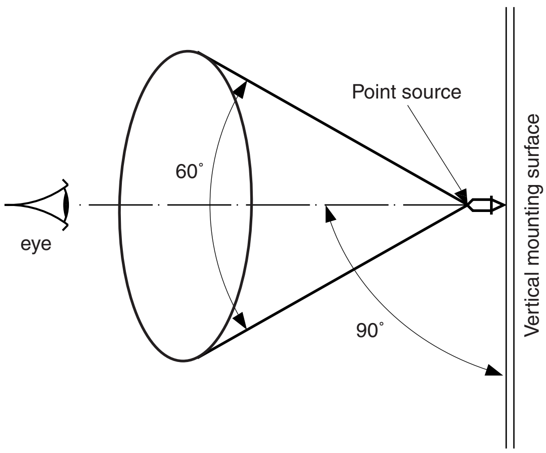


Figure 2 :



3.3.8 The lights or lighting assemblies are to be continuous except as interrupted by constructional constraints, such as corridors or cabin doors etc., are to provide a visible delineation along the escape route and, where applicable, are to lead to the exit door handles. Interruption of the LLL system due to constructional constraints is not to exceed 2 metres.

3.3.9 The lighting is to be provided on at least one side of the corridor or stairway. In corridors and stairways in excess of 2 metres width, lighting is to be provided on both sides.

3.3.10 In corridors the lighting is to be installed either on the bulkhead within 300 mm of the deck or, alternatively, on the deck within 150 mm of the bulkhead.

3.3.11 In stairways the lighting is to be installed within 300 mm above the steps such that each step may be readily identified from either above or below that step. The top and bottom steps are to be further identified to show that there are no further steps.

4 General emergency alarm and public address systems

4.1 General emergency alarm system

4.1.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren for sounding the general emergency alarm signal is to comply with the requirements of Pt C, Ch 2, Sec 3, [3.13] and, in addition, with the requirements of the present sub-article.

4.1.2 The alarm system is to be audible throughout all the accommodation and normal crew working spaces and on all open decks.

4.1.3 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather.

4.1.4 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

4.1.5 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

4.1.6 For cables used for the general emergency alarm system, see Pt C, Ch 2, Sec 3, [9.6]; Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.4].

4.1.7 Electrical cables and apparatus for the general emergency alarm system and their power supply are to be arranged so that the loss of the system in any one area due to localized fire is minimized.

4.1.8 Where the fire alarm to summon the crew operated from the navigating bridge or fire control station is part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm in the public spaces.

4.2 Public address system

4.2.1 The requirements of Pt C, Ch 2, Sec 3, [3.14] are to be replaced with the following provisions [4.2.2] to [4.2.16].

4.2.2 The public address system is to be one complete system consisting of a loudspeaker installation which enables simultaneous broadcast of messages from the navigation bridge, and at least one other location on-board for use when the navigation bridge has been rendered unavailable due to the emergency, to all spaces where crew members are normally present (accommodation and service spaces, control stations and open decks), and to assembly stations (i.e. muster stations).

In spaces such as under deck passageways, bosun's locker, hospital and pump room, the public address system may not be required.

4.2.3 The public address system is to be arranged to operate on the main source of electrical power, the emergency source of electrical power and transitional sources of electrical power as required by Pt C, Ch 2, Sec 3, [2.3] and Pt C, Ch 2, Sec 3, [3.5].

4.2.4 The controls of the system on the navigation bridge are to be capable of interrupting any broadcast on the system from any other location on board.

4.2.5 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

4.2.6 The system is not to require any action by the addressee.

4.2.7 It is to be possible to address crew accommodation and work spaces separately from public spaces.

4.2.8 In addition to any function provided for routine use aboard the ship, the system is to have an emergency function control at each control station which:

a) is clearly indicated as the emergency function

b) is protected against unauthorized use

c) automatically overrides any other input system or program, and

d) automatically overrides all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces.

4.2.9 The system is to be installed with regard to acoustically marginal conditions, so that emergency announcements are clearly audible above ambient noise in all spaces where crew members are normally present (accommodation and service spaces, control stations and open decks), and at assembly stations (i.e. muster stations).

4.2.10 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) in interior spaces 75 dB (A) and at least 20 dB (A) above the speech interference level, and

b) in exterior spaces 80 dB (A) and at least 15 dB (A) above the speech interference level.

Evidence of this level is to be shown with test result in open sea or equivalent quay measurement with appropriate correction factor.

4.2.11 The system is to be arranged to prevent feed-back or other interference.

4.2.12 The system is to be arranged to minimize the effect of a single failure so that the emergency messages are still audible (above ambient noise levels) also in the event of failure of any one circuit or component.

4.2.13 Each loudspeaker is to be individually protected against short-circuits.

4.2.14 For cables used for the public address system, see Pt C, Ch 2, Sec 3, [9.6]; Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.4].

4.2.15 All areas of each fire zone are to be served by at least two dedicated loops of flame-retardant cables which are to be sufficiently separated throughout their length and supplied by two separate and independent amplifiers.

4.2.16 A temperature alarm is to be provided in the public address cabinets in case of forced air cooling.

4.3 Combined general emergency alarm - Public address system

4.3.1 The requirements of Pt C, Ch 2, Sec 3, [3.15] are to be replaced with the following provisions [4.3.2].

4.3.2 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [4.1] and [4.2], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required
- the system is arranged to minimize the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the event of failure of any one circuit or component, by means of the use of more than one device for generating an electronic sound signal.

5 Automation

5.1 Alarms and safeties related to steam generation for catapults

5.1.1 Alarm and safeties related to steam production required for catapult operation, if any, are given in Pt C, Ch 1, Sec 3 and Part E, Chapter 3, where an additional automation notation is granted.

5.2 Data transmission link

5.2.1 The data transmission link are to be designed so as to comply to the rules given in Pt C, Ch 3, Sec 3, [6]. In addition, the hardware and software related to the data transmission link used for essential services are to be found in compliance with IEC 60945 and 61162. Appropriate test report and evidences, in line with these standards, are to be submitted to the Society.

5.3 Wheelhouse arrangement

5.3.1 The visibility from the wheelhouse is to be in accordance with Pt E, Ch 11, Sec 4, [6.2.1]. Where there is blind sectors larger than 5°, due to the asymmetrical location of the wheelhouse, cameras or equivalent vision systems are to be provided in appropriate location so as to cover the blind area.

5.3.2 No blind space of the landing area is to be found from the wheelhouse. If this is not achievable, cameras are to be provided in appropriate location so as to cover the blind area.

5.3.3 A status panel is to be provided in wheelhouse console to indicate the positions of the hangar doors and the positions of the aircraft elevators.

5.3.4 Due to asymmetric location of the wheelhouse, port bridge wing may be omitted.

5.3.5 Microphone and loudspeaker required in Pt E, Ch 11, Sec 4 are to be provided with a dimmer, when aircraft are operated.

Section 5 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships having the following class notation:

aircraft-carrier

1.1.2 Unless otherwise specified, the requirements of this section apply in addition to those of Part C, Chapter 4. Some of the requirements of Part C, Chapter 4 are however replaced by those of this section, as detailed in the concerned requirements.

1.1.3 The installations or equipment used for specific military operations which are not permanently fixed to the hull of the ship, such as mobile containers used to occasionally accommodate a mobile hospital or a mobile headquarters, are not required to comply with the requirements of this section. All other installations and equipment, including portable equipment required in this section, are to comply with the relevant requirements outlined in this section.

1.1.4 Damage control stations

The list of the references for requirements concerning controls and indicators required to be centralized in the damage control stations as defined in Pt C, Ch 4, Sec 1, [2.13.1] is indicated in Tab 1.

Table 1 : Controls and/or indicators required in damage control stations

Requirement reference	Related systems
Pt C, Ch 4, Sec 2, [2.1.1]	Controls and indicators of ventilation systems and fire and smoke damper controls and monitoring
Pt C, Ch 4, Sec 3, [8.2.1]	Fire detection alarms (see also Pt C, Ch 4, Sec 3, [3.2.1]) and monitoring, position of fire doors, control and monitoring of ventilation fans
Pt C, Ch 4, Sec 4, [2.1.3]	Controls for smoke release
[3.2.1], items c), d) and f)	Remote release of fire doors and status of the fire doors as appropriate
Pt C, Ch 4, Sec 5, [5.1.1]	Position of fire doors leading to or from vehicle or ro-ro space
Pt C, Ch 4, Sec 6, [3.2.1]	Controls for closing of ventilation openings and associated monitoring for spaces protected by fixed gas fire-extinguishing systems
Pt C, Ch 4, Sec 6, [4.6.3]	Alarm of activation of any fixed water-based local application fire-extinguishing system
Pt C, Ch 4, Sec 12, [2.1.2]	Controls of power ventilation systems for closed vehicle spaces and ro-ro spaces
Pt C, Ch 4, Sec 12, [2.1.3]	Indication of any loss of capacity of the ventilation systems of close vehicle or ro-ro spaces
Pt C, Ch 4, Sec 12, [4.1.2]	Position of discharge valves for scuppers in vehicle and ro-ro spaces when protected by water-based fire-extinguishing systems. Visual and audible alarm if fire-extinguishing system operating while the valves are closed
Pt C, Ch 4, Sec 13, [5.1.4]	Visual and audible alarm in case of activation of local carbon dioxide systems
Pt C, Ch 4, Sec 13, [6.1.2], items b)4) and b)5)	Controls and alarm for activation of high expansion foam fire-extinguishing system
Pt C, Ch 4, Sec 13, [7.3.1], items l) and o)	Controls and alarms for equivalent water-based fire-extinguishing systems
Pt C, Ch 4, Sec 13, [7.4.2], item e)	Means of control and monitoring of fixed thick water fire-extinguishing systems
Pt C, Ch 4, Sec 13, [7.4.2], item i)	Indication of foam concentrate level for thick water systems
Pt C, Ch 4, Sec 13, [8.2.1], item a)	Means of control of the valves connecting the sprinkler system to the fire main
Pt C, Ch 4, Sec 13, [8.2.1], items h) and i) Pt C, Ch 4, Sec 13, [8.3.5], item b)1)	Visual and audible alarm in case of activation of any manual or automatic sprinkler section valve
Pt C, Ch 4, Sec 13, [9.1.5], item a)2)	Control panel for fire detection and fire alarm system
Pt E, Ch 1, Sec 4, [2.1.2] item b)3) and d), Pt E, Ch 1, Sec 4, [2.3.4], item c), Pt E, Ch 1, Sec 4, [2.4.3]	For ships having the additional class notation **FFS**, position indicator for isolating valves, if provided and overboard discharge valves.
Pt E, Ch 8, Sec 3, [6] and **Tab 3**	For ships to be assigned the additional class notation **CBRN** or **CBRN-AIRBLAST RESISTANCE**, monitoring and control for the CBRN protection systems

1.2 Documents to be submitted

1.2.1 The interested party is to submit to the Society the documents listed in Tab 2.

Table 2 : Documentation to be submitted

No	I/A **(1)**	Document **(2)**
1	A	Structural fire protection showing the purpose of the various spaces of the ships, the fire rating of bulkheads and decks, means of closings of openings in A and B class divisions, draught stops, and completed with the indication of material of other bulkhead and of ceilings and lining
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Means of escape and access to spaces
4	A	Automatic fire detection systems and manually operated call points
5	A	Fire pumps and fire main including pumps head and capacity, hydrant and hose locations **(2)**
6	A	Arrangement of fixed fire-extinguishing systems **(2)**
7	A	Arrangement of sprinkler or sprinkler equivalent systems **(2)**
8	A	Fire-fighting equipment and firemen's outfits
9	A	Electrical diagram of the fixed gas fire-extinguishing systems, fixed fire detection systems, fire alarm and emergency lighting
10	A	Electrical diagram of the sprinkler systems
11	A	Electrical diagram of power control and position indication circuits for fire devices
12	I	General arrangement plan
13	I	Safety zone plan
14	A	Fire control plan

(1) A = to be submitted for approval
I = to be submitted for information.

(2) Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as:
- service pressures
- capacity and head of pumps and compressors, if any
- materials and dimensions of piping and associated fittings
- volumes of protected spaces, for gas and foam fire-extinguishing systems
- surface areas of protected zones for sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems
- capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, sprinkler, foam and powder fire-extinguishing systems
- type, number and location of nozzles of extinguishing media for gas, sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems.

All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.

2 General requirements

2.1 Vertical subdivisions

2.1.1 For ships fitted with a takeoff aircraft catapult equipment, the railway of the catapult is to be excluded from the subdivision into main vertical zones and vertical safety zones.takeoff

2.1.2 The interior of the ship shall be subdivided into vertical safety zones by A-60 class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary they shall also be A-60 class divisions. Where a category (5), (9) or (10) space defined in item b) of Pt C, Ch 4, Sec 5, [1.2.3] is on one side or where fuel or diesel oil or JP 5 NATO (F44) tanks or water capacity are on both sides of the division, the standard can be reduced to A-0.

2.1.3 The subdivisions into main vertical zones and vertical safety zones are to fall into line between each others. That means that a main vertical zone is not to be astride on two vertical safety zones.

2.1.4 When vulnerability zones are specified according to Pt C, Ch 4, Sec 1, [2.38], the bulkheads forming the boundaries of the vulnerability zones are to be in line with the safety zone bulkheads. A vulnerability zone may however include several safety zones.

2.1.5 The length of the vertical safety zones is not to exceed 80 m but may be extended to a maximum of 100 m in order to bring the furthermost ends of the ship such as its bow or corbelled parts of the ship. If the length of the vertical safety zone exceed 80 m, the total area of the vertical safety zone is not to be more than 3400 m² on any deck. The maximum length of a vertical safety zone is the maximum distance between the furthermost points of the bulkheads bounding it.

2.1.6 If the part of the ship located forward of the collision bulkhead forms one vertical safety zone, or if the aircraft hangar forms one horizontal safety zone, this safety zone is to contain only one main vertical zone. This vertical safety zone and main vertical zone need not to comply with [5.2.1] for the assembly and embarkation stations, but the provision of [3.3.1] on ventilation still applies. As for the provisions for the fire pump, the requirements of Pt C, Ch 4, Sec 6, [1.3.2] need not to be applied for these zones.

2.2 Horizontal subdivisions

2.2.1 The ship may accommodate some additional horizontal safety zones to enclose any large ro-ro or vehicles spaces. In this case, the horizontal safety zone may contain only one main horizontal zone.

2.2.2 These horizontal safety zones may extend on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

2.2.3 The requirements of ventilation systems and ducts, openings in A class divisions and penetrations in A class divisions for maintaining the integrity of vertical safety zone in this Chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal safety zones from each other and from the remainder of the ship. That means that the requirements for A-30 class steel ducts and A-30 class divisions of Pt C, Ch 4, Sec 5, [1.2.1] item a) are to be replaced by requirements for A-60 class steel ducts and A-60 class divisions.

2.3 Control stations

2.3.1 One damage control station is to be provided in each safety zone and so equipped in such a way that one damage control station can be replaced by an other one.

2.3.2 Aircraft facilities fire control stations

At least two fire control stations are to be arranged in the aircraft hangars area and at least one fire control station is to be arranged close to the flight deck, at a location allowing fire-fighters to watch over aircraft operations. It is to be possible to park a fire-fighting truck (VLIP) in the vicinity of the flight deck fire control station.

3 Containment of fire

3.1 Fire integrity of bulkheads and decks

3.1.1 The fire integrity of all bulkheads and decks prescribed in Pt C, Ch 4, Sec 5, Tab 1 and Pt C, Ch 4, Sec 5, Tab 2 is to be replaced by the requirements of the following Tab 3 and Tab 4.

3.1.2 Fire integrity of the flight decks

Except when a space of category (5), (9) or (10) is located below the flight decks, the flight decks shall be of A-30 class standard.

Note 1: When accepted by the Naval Authority, the above requested A-30 fire class standard may locally be reduced to A-0.

In addition, the standard is to be A-60 in the following areas:

a) the helideck landing areas, and

b) for ships provided with a catapult equipment, the A-60 fire integrity is required between the catapult space and the other internal parts of the ship and the insulation is to continue on the flight deck for a distance of at least 450 mm.

3.2 Protection of openings in fire-resistant divisions

3.2.1 The requirements of item d) of Pt C, Ch 4, Sec 5, [3.1.1] are to be replaced by the following requirements applicable to fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than watertight doors and those which are normally locked:

a) The doors are to be self-closing and be capable of closing with an angle of inclination of up to 3,5° opening closure.

b) The approximate time of closure for hinged fire doors is to be not more than 40 s and not less than 10 s from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding doors is to be not more than 0,2 m/s and not less than 0,1 m/s with the ship in upright position.

c) The doors, except those for emergency escape trunks, are to be capable of remote release from the continuously manned damage control station, either simultaneously or in groups, and are to be capable of release also individually from a position at both sides of the door. Release switches are to have an on-off function to prevent automatic resetting of the system.

d) Hold-back hooks not subject to remote release from the continuously manned damage control station are prohibited.

e) A door closed remotely from a damage control station is to be capable of being re-opened from both sides of the door by local control. After such local opening, the door is to close again automatically.

f) Indication is to be provided at the fire door indicator panel in the continuously manned damage control station whether each door is closed.

g) The release mechanism is to be so designed that the door is to close automatically in the event of disruption of the control system or central power supply.

h) Local power accumulators for power-operated doors are to be provided in the immediate vicinity of the doors to enable the doors to be operated at least ten times (fully opened and closed) after disruption of the control system or central power supply using the local controls.

i) Disruption of the control system or central power supply at one door is not to impair the safe functioning of the other doors.

j) Remote-release sliding or power-operated doors are to be equipped with an alarm that sounds at least 5 s but not more than 10 s after the door begins to move, and continues sounding until the door is completely closed.

k) A door designed to re-open upon contracting an object in its path is to re-open not more than 1 m from the point of contact.

l) Double-leaf doors equipped with a latch necessary for their fire integrity are to have a latch that is automatically activated by the operation of the doors when released by the system.

m) Doors giving direct access to ro-ro spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in items 3) and j).

n) The components of the local control system are to be accessible for maintenance and adjusting.

o) Power-operated doors are to be provided with a control system of an approved type which is to be able to operate in case of fire and be in accordance with the Fire Test Procedure Code. This system is to satisfy the following requirements:

- the control system is to be able to operate the door at the temperature of at least 200°C for at least 60 min., served by the power supply
- the power supply for all other doors not subject to fire is not to be impaired, and
- at temperatures exceeding 200°C, the control system is to be automatically isolated from the power supply and is to be capable of keeping the door closed up to at least 945°C.

3.2.2 Hose ports

With reference to the provision of Pt C, Ch 4, Sec 5, [3.1.1], as far as practicable, self-closing hose ports are to be provided on all A class doors except watertight doors, weathertight doors (semi-watertight doors), doors leading to the open decks and doors required to be gas-tight.

As far as practicable, where a watertight or weathertight or gas-tight door is fitted in a respective internal watertight or weathertight or gas-tight bulkhead, a respective watertight or weathertight or gas-tight opening capable of being opened from both sides of the bulkhead is to be provided on this bulkhead close to the door for permitting the passage of a fire hose through this bulkhead when the door is closed. Suitable measures are to be taken to ensure that this opening is closed at sea.

3.2.3 Stairway enclosures

a) With reference to the provision of Pt C, Ch 4, Sec 5, [1.2.4], stairways not enclosed within enclosures formed of A class divisions in compliance with Tab 3 and Tab 4 are not to be permitted.

b) Nevertheless, stairways which are fitted in accordance with [5.1.4] may not be enclosed within A class divisions, provided that the stairway penetrates a single deck and is protected, at a minimum, at one level by at least B class divisions and self-closing doors.

3.2.4 Openings in B class divisions

Notwithstanding the provisions of Pt C, Ch 4, Sec 5, [3.1.2], item a), ventilation openings in B class divisions with an area of more than 0,05m^2 may be permitted within accommodation areas provided they are fitted in the lower part of the division and are provided with a grill made of non-combustible material which is fitted with a means of closing, operable from the passageway.

Such arrangement is to be to the satisfaction of the Society.

3.3 Ventilation systems

3.3.1 For the application of this Chapter, the requirement of Pt C, Ch 4, Sec 5, [6.3.7] is to be replaced by:

“The ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zones.

The air conditioning units shall not serve more than one main vertical zone. However the air inlets and outlets of the ventilation system serving one main vertical zone may be located outside the main vertical zone provided that they are located inside the same vertical safety zone. In this case, the requirement of Pt C, Ch 4, Sec 5, [6.3.9] will apply for the dedicated ventilation duct passing through the main vertical zone boundary.

If the part of the ship located forward the collision bulkhead forms one vertical safety zone containing one single main vertical zone, the dedicated air conditioning units serving this main vertical zone can be located outside this main vertical zone provided that they are located inside the immediately adjacent aftward main vertical zone. In the same way, the air inlets and outlets of the ventilation system serving this vertical safety zone can be located outside this vertical safety zone provided that they are located inside the immediately adjacent aftward safety zone. In these two cases, the requirement of Pt C, Ch 4, Sec 5, [6.3.9] will apply for the dedicated duct passing through the main vertical zone boundary or vertical safety zone boundary.

Except for the particular cases mentionned above, a ventilation duct is to pass neither through a main vertical zone boundary nor through a vertical safety zone boundary.”

4 Fire-extinguishing

4.1 Fire pump capacity

4.1.1 The capacity of each large capacity fire pump required by Pt C, Ch 4, Sec 6, [1.3.2] is to be not less than 100 m^3/h.

4.2 Sprinkler installation

4.2.1 A sprinkler system of an approved type and complying with the requirements of Pt C, Ch 4, Sec 13 is to be fitted in all control stations, accommodation and service spaces.

Alternatively, control stations, where water may cause damage to essential equipment, may be fitted with an approved fixed fire-extinguishing system of another type.

Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with a sprinkler system

4.3 Flight decks

4.3.1 The flight decks are to be protected by a fire protection system for flight decks complying with the provisions of Pt C, Ch 4, Sec 13, [10].

5 Evacuation

5.1 General

5.1.1 The requirements of Pt C, Ch 4, Sec 8 are to be replaced by the applicable requirements of SOLAS, Chapter II-2, Part D, Regulations 12 and 13 as applicable, for passenger ships carrying more than 36 passengers, and the applicable requirements of the Fire Safety System Code, Chapter 13, and other relevant IMO Resolutions, Circulars, Guidelines and other standards referred therein, except that:

a) regulations 13.3.2.1, 13.3.2.2 and 13.3.2.4.1 are replaced by the following [5.1.2] to [5.1.5]

b) regulation 13.3.2.3 is replaced by the following [5.1.6]

c) regulation 13.3.4 is replaced by Pt C, Ch 4, Sec 8, [3]

d) requirement 2.1.1 of FSS Code, Ch 13, is replaced by the following [5.1.9]

e) requirement 2.2.3 of FSS Code, Ch 13, is replaced by the following [5.1.10]

f) requirement 2.3.1 of FSS Code, Ch 13, is replaced by the following [5.1.11].

5.1.2 Escape from spaces below damage control deck

a) Below the damage control deck, two means of escape are to be provided from each watertight compartment or similarly restricted space or group of spaces.

b) The Society may dispense with one of the means of escape for service or machinery spaces which are entered only occasionally and for service and machinery spaces where the maximum travel distance to the door is 11m or less.

c) At least one of the means of escape required in item a) above is to consist of a readily accessible enclosed stairway (Category [2]), which is to provide continuous fire shelter from the level of its origin to the appropriate embarkation decks.

d) When external escape routes are provided, they are to be provided with emergency lighting in accordance with SOLAS Ch III regulation 11 and slip-free surfaces underfoot. Boundaries facing external open stairways and passage-ways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck are to have fire integrity, including insulation values, in accordance with Tab 3 and Tab 4, as appropriate, for category [4] spaces.

e) The stairway arrangement required by the preceding item b) for below damage control deck compartments of one main vertical zone can be arranged by:

   1) one enclosed stairway which provides a continuous fire shelter from the level of its origin to the embarkation deck in one watertight compartment, and

   2) each of the other watertight compartments of the main vertical zone has an enclosed stairway which provides a continuous fire shelter from the level of its origin to the damage control deck, and

   3) the continuous fire shelter is also provided on the damage control deck through a route protected as a category [2] space (horizontal stairway).

Table 3 : Bulkheads not bounding neither vertical zones nor horizontal zones nor safety zones

SPACES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces (1)	A-0 [a] [g]	A-0	A-0	A-0	A-0	A-60 A-15 [f]	A-60 A-30 [f]	A-60 A-30 [f]	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Stairways (2)		A-0 [a]	A-0	A-0	A-0	A-0	A-15 A-0[f]	A-15 A-0[f]	A-0	A-0	A-15	A-30	A-15	A-30	A-30
Corridors (3)			B-15 C [f]	A-60	A-0	B-15 B-0[f]	B-15 B-0[f]	B-15 B-0[f]	B-15 B-0[f]	A-0	A-15	A-30	A-0	A-30	A-30
Evacuation stations and external escape routes (4)				*	A-0	A-60 [b] [d]	A-60 [b] [d]	A-60 [b] [d]	A-0 [d]	A-0	A-60 [b]	A-60 [b]	A-60 [b]	A-60 [b]	A-30
Open deck spaces (5)					*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [e]
Accommodation spaces of minor fire risk (6)						B-0 C[f]	B-0 C[f]	B-0 C[f]	C	A-0	A-0	A-30	A-0	A-30 A-15 [f]	A-30
Service spaces and accommodation spaces of moderate fire risk (7)							B-0 C[f]	B-0 C[f]	C	A-0	A-15	A-60	A-15	A-60 A-30 [f]	A-30
Accommodation spaces of greater fire risk (8)								B-0 C[f]	C	A-0	A-30	A-60	A-15	A-60	A-30
Sanitary and similar spaces (9)									C	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, voids and auxiliary machinery spaces having little or no fire risk (10)										A-0 [a]	A-0	A-0	A-0	A-0	A-30 [e]
Auxiliary machinery spaces and other similar spaces of moderate fire risk (11)											A-0 [a]	A-30 [h]	A-0	A-15 A-0 [f]	A-30
Machinery spaces of category A and equivalent spaces of high fire risk (12)												A-30	A-0	A-60	A-60
Service spaces of high fire risk (13)													A-0	A-0	A-30
Special purpose spaces (14)														A-30 [a]	A-30
Ammunition spaces and other equivalent spaces (15)															A-30

Note 1: (to be applied to Tab 3 and Tab 4, as appropriate)

[a] : Where adjacent spaces are in the same numerical category and letter [a] appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose. For example, in category (13) a bulkhead need not be required between a galley and its annexed pantries provided the pantry bulkheads and decks maintain the integrity of the galley boundaries. A bulkhead is, however, required between a galley and a workshop even though both spaces are in category (13).

[b] : The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to liferafts and evacuation slides may be reduced to A-30.

[c] : Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of B class integrity.

[d] : Where spaces of category (6), (7), (8) and (9) are located completely within the perimeter of the evacuation station, the bulkheads of these spaces are allowed to be of B-0 class integrity. Control positions for audio, video and light installations may be considered as part of the evacuation station.

[e] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only “A-0” fire class standard is required.

[f] : Where the spaces on both sides of the bulkhead are protected by an automatic sprinkler system or equivalent, the fire integrity can be the lower class standard. Where, on one side of the bulkhead, the space is protected by an automatic sprinkler system or equivalent and, on the other side, the space is of category (9) and not protected by the sprinkler system, the fire integrity can also be the lower class standard. Where the space below the deck is protected by an automatic sprinkler system or equivalent, the fire integrity of the deck can be the lower class standard.

[g] : Bulkheads separating the wheelhouse, chartroom and radio room from each other can have only a B-0 rating.

[h] : If the adjacent space of category (11) is a fuel oil or JP5 NATO (F44) tank, the standard can be reduced to A-0.

[i] : Where the ammunition space is fitted above a water tank, the deck can have only A-0 rating.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of A class standard. However, where a deck, except an open deck, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

Table 4 : Decks not forming steps in main vertical zones nor bounding horizontal zones nor safety zones

SPACE below		SPACE above														
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces	(1)	A-30 A-0[f]	A-30 A-0[f]	A-15 A-0[f]	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-60 A-30 [f]	A-30
Stairways	(2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30 A-0[f]	A-30
Corridors	(3)	A-15 A-0[f]	A-0	A-0 [a]	A-60	A-0	A-0	A-15 A-0[f]	A-15 A-0[f]	A-0	A-0	A-0	A-30	A-0	A-30 A-0[f]	A-30
Evacuation stations and external escape routes	(4)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Open deck spaces	(5)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [e]
Accommodation spaces of minor fire risk	(6)	A-60 A-0[f]	A-15 A-0[f]	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Service spaces and accommodation spaces of moderate fire risk	(7)	A-60 A-30 [f]	A-15 A-0[f]	A-15 A-0[f]	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Accommodation spaces of greater fire risk	(8)	A-60 A-30 [f]	A-15	A-15 A-0[f]	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Sanitary and similar spaces	(9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, voids and auxiliary machinery spaces having little or no fire risk	(10)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [a]	A-0	A-0	A-0	A-0	A-30 [i], [e]
Auxiliary machinery spa-ces and other similar spa-ces of moderate fire risk	(11)	A-60	A-60 A-15 [f]	A-60 A-15 [f]	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [a]	A-30 [h]	A-0	A-30 A-0 [f]	A-30
Machinery spaces of category A and equivalent spaces of high fire risk	(12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30 [h]	A-30	A-0	A-60	A-60
Service spaces of high fire risk	(13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0 [a]	A-0	A-30
Special purpose spaces	(14)	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Ammunition spaces and other equivalent spaces	(15)	A-30	A-30	A-30	A-30	A-30 [e]	A-30	A-30	A-30	A-30	A-30 [e]	A-30	A-60	A-30	A-30	A-30
Note 1: The notes of Tab 3 apply to Tab 4, as appropriate.																

5.1.3 Escape from spaces above the damage control deck: fire scenario

Above the damage control deck there is to be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape providing continuous fire shelter to the embarkation deck.

5.1.4 Escape from spaces between damage control deck and bulkhead deck: flooding scenario

a) Between damage control deck and bulkhead deck, at least one means of escape independent from watertight doors and giving access to embarkation deck is to be provided at each deck level from each watertight compartment or similarly restricted space or group of spaces.

b) The means of escape required in item a) above are to be, as far as practicable, a stairway, but where the purpose and forms of the ship make it impracticable, the means of escape may be a ladder or ladders (depending on the number of persons to be evacuated), to the satisfaction of the Society.

5.1.5 Additional requirements

a) When it is not possible to cross from one side to the other of the ship, the requirements [5.1.2] to [5.1.4] are applicable to each side of the ship.

b) The stairways referred to in [5.1.2] and [5.1.3] (fire scenario - continuous fire shelter) are to be sized considering that the total number of persons to be evacuated use those stairways. Other stairways which may be added for compliance with requirement [5.1.4] but do not comply with [5.1.2] are not to be considered as main escape routes for fire scenario evacuation analysis.

5.1.6 Direct access to stairway enclosures

Stairway enclosures in accommodation and service spaces are to have direct access from the corridors and be of a sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency.

Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment and open information counters are permitted. Only public spaces, accommodation spaces of minor fire risk as defined in Pt C, Ch 4, Sec 5, [1.2.3], item b), corridors, lifts, public toilets, pantries containing no cooking appliances, ro-ro and vehicle spaces, other escape stairways required by regulation 13.3.2.4.1 or escape stairways from machinery spaces other that category A machinery spaces and external areas are permitted to have direct access to these stairway enclosures. Small corridors or “lobbies” used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of 4,5 m^2, a width of not less than 900 mm and contain a fire hose station.

5.1.7 Evacuation analysis

Escape routes are to be evaluated by an evacuation analysis early in the design process.

The analysis is to be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of crew along escape routes. In addition, the analysis is to be used to demonstrate that escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty.

Note 1: For the application of the IMO Circular MSC.1/Circ.1533, the scenarios and given values such as Response duration (R), Total travel duration (T), Embarkation and launching duration (E+L), counterflow factor, walking speed, etc. may be replaced by more effective scenarios and values given by the Naval Authority.

5.1.8 Around the flight decks, corridors on open deck, giving access to a safe route to the assembly stations, are to be provided. The persons evacuating by these external corridors are to be protected from the liquids falling from the flight decks by a suitable gutter arrangement.

5.1.9 Basic requirements for stairway widths

a) Stairways are not to be less than 700 mm in net width.

b) The width of the stairways is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13, [2.1.2], considering the distribution of persons given in [5.3] hereafter.

5.1.10 Vertical rise and inclination of stairways

Stairways are not to exceed 4 m in vertical rise without the provision of a landing and are to have an angle of inclination not greater than 62°. In machinery spaces however, stairways with an angle of inclination up to 70° may be permitted.

Where the hospital and the flight deck are not on the same deck, the stairway intended for medical evacuation is to have an angle of inclination not exceeding 45°.

5.1.11 Width of doors, hatches and corridors included in the means of escape

a) Corridors and intermediate landings included in means of escape are to be sized in the same manner as stairways.

b) The clear width of doors and hatches included in means of escape may be smaller than that of the passageways they serve, provided their clear width remains above the minimum clear width required for the associated passageway.

5.2 Dispensation and application

5.2.1 When it is not practical to apply one requirement of the mentioned rules above, the arrangement is to be at the satisfaction of the Society with the agreement of the Naval Authority.

The explicit requirements referring to passengers may not be applied: all the persons onboard are to be assimilated to the crew.

At least one assembly station and one embarkation station is to be provided for each vertical safety zone. The assembly stations shall have sufficient clear deck space to accommodate all persons assigned to muster at that station but at least 0,35 m^2 per person.

Note 1: The assembly stations and embarkation stations may include spaces such as corridors, landings of stairway enclosures, accommodation and service spaces but a an assembly station is not to include a control station, a machinery space, an ammunition space or a vehicle or ro-ro space. In any case, a space which requires a key for access can not be included in an assembly station or an embarkation station unless the key is enclosed in a beak-glass type enclosure conspicuously located an indicated near the normally locked access door.

5.3 Distribution of persons

5.3.1 For the application of the provision of the Fire Safety System Code, Chapter 13 [2.1.2.2.2.1], cases 1 and 2 are to be replaced by:

a) Case 1 (night-time)
   - All crew not operating by watch in their cabins and berthing spaces
   - 3/4 of the crew operating by watch in their cabins and berthing spaces, and
   - Accommodation, service spaces and control stations occupied by 1/4 of the crew operating by watch, according to their operating position.

b) Case 2 (daytime)
- Public spaces occupied by 1/4 of the crew not operating by watch and 1/2 of the crew operating by watch
- 3/4 of the crew not operating by watch and 1/4 of the crew operating by watch distributed in accommodation, service spaces and control stations according to their operating positions.

Note 1: For the application of the provision of Fire Safety System Code, Chapter 13 [2.1.2.1.4], the number of persons to be distributed in each public space is to be proportional to the deck area of these public spaces, as per the following formula:

$n = N \cdot a / A$

where:

N : Total number of persons to be distributed in the public spaces

a : Deck area of the selected public space

A : Total deck area of the public spaces available to the total number of persons to be distributed in the public spaces.

Note 2: Other cases of distribution of persons may be considered in replacement of, or in addition to, cases 1 and 2 above by more effective scenarios given by the Naval Authority.

6 Aircraft hangars

6.1 General

6.1.1 General definition

An aircraft hangar is a closed manned space in which aircrafts can be loaded. Maintenance and other necessary services such as refuelling, defuelling, ammunition loading, oxygen loading can be handed on the aircrafts inside the aircraft hangar.

6.1.2 Application

a) The requirements and the general provisions for a ro-ro space as defined in Pt C, Ch 4, Sec 1, [2.30.1] are also applicable to an aircraft hangar except for the single requirement of Pt C, Ch 4, Sec 12, [2.1.1] for which the aircraft hangar can be considered as a closed vehicle space and therefore be provided with a ventilation system sufficient to give at least 6 air changes per hour.

b) Permanent openings in the side plating, the ends or deckhead of the space are to be so situated that a fire in the aircraft hangar does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the aircraft hangar.

6.1.3 Protection of aircraft hangar access doors

Suitable means of fire-protection such as local water spraying systems are to be provided to the doors giving access to aircraft hangars from the open decks in order to withstand any projection of fired fuel oil from the flight decks.

6.1.4 Subdivided aircraft hangars

Where an aircraft hangar is internally divided into several sub-aircraft hangars by means of internal subdividing bulkheads extending across the full breadth of the aircraft hangar, the doors fitted in the subdividing bulkheads need not have A class integrity nor be made of steel and the use of combustible materials may be accepted if agreed by the Society. However, when such a door does not have A class integrity or is not of steel construction or is made of combustible materials, a water curtain capable of delivering at least 5 l/min/m² of water is to be provided on both sides of the door.

6.1.5 Drainage facilities

Drainage from aircraft hangars directly to the sea is to be avoided as far as possible. In addition to the requirements of Pt C, Ch 1, Sec 10, [8.10.7], drainage facilities from aircraft hangars are to comply with the requirements of Pt C, Ch 4, Sec 10, [3.2.2].

6.1.6 Aircraft refuelling facilities

In addition to the requirements of Pt C, Ch 1, Sec 10, [11], aircraft refuelling facilities are to comply with the requirements of Pt C, Ch 4, Sec 10, [4.1], Pt C, Ch 4, Sec 10, [4.2] and Pt C, Ch 4, Sec 10, [4.4.1], as applicable, to helicopter facilities.

6.2 Operational

6.2.1 Vehicles

Where vehicles such as cars, fire-fighting trucks (VLIP), maintenance trucks using internal combustion engine for their own propulsion are running or stored inside the aircraft hangar, their fuel is not to have a flash point below 60°C. At any time of operation, the total number of such vehicles in the aircraft hangar is to be such that the total power output of these vehicles does not exceed 0,02 kW/m³.

6.2.2 Battery charging

When some vehicle using electrical engines or other batteries are located in the aircraft hangar, the charging of such batteries will not be permitted in the aircraft hangar. The charging of such batteries is to be done in a dedicated spaces considered as a battery room.

6.2.3 Aircraft refuelling

The aircraft refuelling may be permitted inside the aircraft hangar if suitable safety devices are provided and safety procedures are ensured.

In case of aircraft refuelling operation inside the hangar, the dedicated area is to be fitted with a mechanical ventilation system providing at least 10 air changes per hour during the refuelling operations.

Ventilation fans are to be of non-sparking type.

6.3 Fire protection

6.3.1 Fire-fighting system

With regards to the risk analysis proceeded by the Naval Authority, the fire-fighting system required by Pt C, Ch 4, Sec 12, [4.1] may be replaced by a more suitable technical solution on the agreement of the Society.

6.4 Rooms for testing the airplane reactors

6.4.1 Rooms in which the airplane reactors are tested, are to have a sufficient opening to the exterior of the ship. This opening is to be arranged such that the fired gases can be exhausted outside without reaching any other part of the ship.

6.4.2 Rooms in which the airplane reactors are tested, are to be considered as a machinery space of category A in way of fire integrity of their boundaries, ventilation, fire detection and fire-fighting.

6.4.3 Access to the airplane reactor testing room is to be provided through a self-closing and reasonably gastight fire door provided with a self-closing hose port. Arrangements are to be provided in order to ensure that the door will remain closed while airplane reactors are under operation.

6.4.4 Airplane reactor testing control room

The airplane reactor testing control room may be included in the airplane reactor testing room for fire protection purposes provided the airplane reactor testing control room is provided with a means of escape independent from the rest of the airplane reactor testing room. In this case, all fire protection requirements applying to the airplane reactor testing room also apply to the airplane reactor testing control room, especially the fixed fire-extinguishing system required by [6.4.6] is also to cover the airplane reactor testing control room. Section valves may be provided in order to avoid unwanted water release in the airplane reactor testing control room.

Alternatively, the airplane reactor testing control room may be considered as fully separate from the airplane reactor testing room for fire-protection purposes. In this case, any door or window intended to be provided between both spaces is to fulfil the applicable fire-integrity requirements in addition to any mechanical qualification required otherwise.

6.4.5 One flame detector is to be provided in the room in which the airplane reactors are tested and this detector is to be capable of being stopped during operation of the airplane reactors. Arrangements are to be provided in order to ensure that this flame detector will be activated at all other times.

6.4.6 A fixed high expansion foam fire-extinguishing system, a fixed pressure water spraying, a thick water spraying system complying with the requirements of Pt C, Ch 4, Sec 13 or an other fixed fire-extinguishing system deemed equivalent by the Society is to be provided in the room in which the airplane reactors are tested.

6.4.7 For the system required by the provisions of [6.4.6] above, some nozzles are to be fitted at the air supply point of the tested airplane reactor.

6.4.8 A semi-fixed carbon dioxide fire-extinguishing system complying with the provision of Pt C, Ch 4, Sec 13, [5.1.5] is to be available at the access point of the room in which the airplane reactors are tested.

6.4.9 The fuel oil used for the reactors such as JP5 is to be stowed outside the room in which the airplane reactors are tested.

7 Flight deck

7.1 Drainage facilities

7.1.1 In addition to the requirements of Pt C, Ch 1, Sec 10, [8.10.7], drainage facilities of flight decks are to comply with the requirements of Pt C, Ch 4, Sec 10, [3.2], as applicable to helidecks.

8 Oxygen production

8.1 Oxygen production and storage installation

8.1.1 Where oxygen for aircraft breathing is produced aboard the ship, special consideration is to be given to the oxygen production and storage installation, with regard to fire prevention, containment of fire, ventilation, fire detection and fire fighting.

Where fitted, such installation is to be to the satisfaction of the Society.

Part D
Service Notations

CHAPTER 3
CORVETTE

Section 1	General
Section 2	Hull
Section 3	Machinery and Systems
Section 4	Electrical Installations
Section 5	Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **corvette**, as defined in Pt A, Ch 1, Sec 2, [4.4].

1.1.2 Ships dealt with in this Chapter are to comply with:

- Part A
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Part B
Hull	• Part B • Ch 3, Sec 2
Stability	• Part B
Machinery and systems	• Part C • Ch 3, Sec 3
Electrical installations	• Part C • Ch 3, Sec 4
Automation	• Part C • Ch 3, Sec 4
Fire protection, detection and extinction	• Part C • Ch 3, Sec 5

Section 2 Hull

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

V : Maximum ahead service speed, in knots

α_d : For hull that does not have a clearly identified deodorise angle, α_d is the angle between the horizontal and a straight line joining the keel and the chine. For hull that does not have a clearly identified chine, the chine is the hull point at which the tangent to the hull is inclined 50° to the horizontal.

1 General

1.1 Application

1.1.1 Naval ships having the service notation **corvette** are to comply with the applicable requirements of Part B.

The maximum speed, in knots, to be used in Part B, Chapter 5 is to be not greater than $7,16\ \Delta^{1/6}$.

1.1.2 In addition, naval ships having the service notation **corvette** and having a maximum ahead service speed V, in knots, such that:

$V \geq 7,16\ \Delta^{1/6}$

are to comply with the following requirements.

1.1.3 For naval ships with the service notation **corvette** and a maximum ahead service speed V lower than specified in [1.1.2], the following requirements can be disregarded and the sole compliance with Part B is required.

1.1.4 Following requirements are applicable for ships constructed in steel and/or aluminium alloys.

Ships constructed in composite or with parts constructed in composite will be considered by the Society on a case by case basis.

1.2 Gross scantling approach

1.2.1 All scantling and dimensions referred to in this Section are net, i.e. they don't include the margins for corrosion.

The gross scantling are to be calculated from the net scantling by adding the corrosion margins specified in Pt B, Ch 4, Sec 2.

1.3 Corrosion protection - Heterogeneous steel/aluminium alloy assembly

1.3.1 Connections between aluminium alloy parts, and between aluminium alloy and steel parts, if any, are to be protected against corrosion by means of coatings applied by suitable procedures agreed by the Society.

1.3.2 In any case, any direct contact between steel and aluminium alloy is to be avoided (e.g. by means of zinc or cadmium plating of the steel parts and application of a suitable coating on the corresponding light alloy parts).

1.3.3 Any heterogeneous jointing system is subject to the Society's agreement.

1.3.4 The use of transition joints made of aluminium/steel-cladded plates or profiles is subject to the Society's agreement.

1.3.5 Transition joints are to be type-approved.

1.3.6 Qualifications tests for welding procedures are to be carried out for each joint configuration.

1.3.7 A welding booklet giving preparations and various welding parameters for each type of assembly is to be submitted for review.

2 Structure design principles

2.1 Vertical acceleration at LCG

2.1.1 The vertical acceleration at LCG considered for the design, a_{CG}, in g, is the average of the one per cent highest accelerations in the most severe conditions expected within the "limit operating conditions", in addition to the gravity acceleration.

2.1.2 The vertical acceleration is the responsibility of the designer and is to be submitted to the Society.

However, at a preliminary stage where vertical acceleration at LCG is not known, a_{CG}, can be taken as follows:

$$a_{CG} = \frac{2}{3} Soc \frac{V}{\sqrt{L}}$$

Table 1 : Soc values

Sea area	Open sea	Restricted open sea	Moderate environment	Smooth sea
Soc	C_F **(1)**	0,30	0,23	0,14
(1) $C_F = 0,2 + \dfrac{0,6}{V/\sqrt{L}} \geq 0,32$				

2.1.3 The sea areas referred to in Tab 1 are defined with reference to significant wave heights H_s which are exceeded for an average of not more than 10 percent of the year:

- Open-sea service: $H_s \geq 4,0$ m
- Restricted open-sea service: 2,5 m $\leq H_s <$ 4,0 m
- Moderate environment service: 0,5 m $< H_s <$ 2,5 m
- Smooth sea service: $H_s \leq 0,5$ m.

2.1.4 The longitudinal distribution of vertical acceleration along the hull is given by:

$a_v = k_v \, a_{CG}$

where:

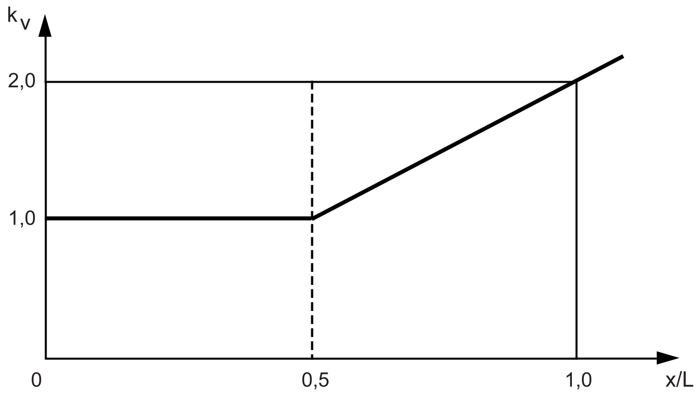
k_v : Longitudinal distribution factor, not to be less than (see Fig 1):

$k_v = 1$ for $x/L \leq 0,5$

$k_v = 2\,x/L$ for $x/L > 0,5$

Higher values may be requested based on pitch consideration.

Figure 1 : k_v factor



2.2 Transverse acceleration

2.2.1 The transverse acceleration, a_T, is the average of the one per cent highest accelerations in the most severe conditions expected within the “limit operating conditions”.

2.2.2 The transversal acceleration is the responsibility of the designer and is to be submitted to the Society.

However, at a preliminary stage where the transversal acceleration is not known, a_T, at a given calculation point, can be taken equal to:

$$a_T = 2,5\frac{H_{sl}}{L}\left(1 + \frac{5r}{L}\left(1 + \frac{V}{6\sqrt{L}}\right)^2\right)$$

where:

H_{sl} : Permissible significant wave height at maximum service speed V

r : Distance of the considered calculation point to 0,5 D.

2.3 Operating conditions

2.3.1 Assessment of limit operating conditions

a) "Limit operating conditions" in this paragraph are to be taken to mean sea states (characterized only by their significant wave heights) compatible with the structural design parameters of the ship, i.e. the sea states in which the ship may operate depending on its actual speed.

b) Limit operating conditions are derived from the restrictions presented in [2.3.2] and [2.3.3].

c) It is the designer's responsibility to specify the format and the values of the limit operating conditions. Their format may be for example a relationship between speed and significant wave height which ascertains actual loads less than the one used for structural design.

d) Other specific design parameters influenced by sea state and speed could be also considered at the discretion of the Society.

e) The limit operating conditions are defined, at the discretion of the Society, on the basis of results of model tests and full-scale measurements or by numerical simulations.

f) The limit operating conditions, taken as a basis for classification, are indicated in the Classification Certificate.

These limit operating conditions must be put at the disposal of the crews operating the crew boat (display at the weelhouse is recommended).

2.3.2 Limitation imposed by bottom impact pressure and deck loads

a) Bottom impact pressure, given in [4.3], and deck loads, given in [4.6], depend explicitly or implicitly upon the vertical acceleration at the LCG. Therefore, the design values of these loads taken as the basis for the classification directly impose a limitation on the permissible vertical acceleration at the LCG.

b) It is the designer's responsibility to provide for a relation between the speed and the significant wave height that provides a maximum vertical acceleration less than the design value.

c) Model tests if any are to be carried out in irregular sea conditions with a significant wave height corresponding to the operating conditions of the craft and a clearly specified sea spectrum. The scale effect is to be accounted for with an appropriate margin of safety. The characteristic value of acceleration and global loads to be assumed corresponds to the average of the 1 per cent highest values obtained during tests. The duration of the test is, as far as practicable, to be sufficient to guarantee that results are stationary.

d) Where model test results or full-scale measurements are not available, the formula given in e) may be used to define maximum speeds compatible with design acceleration, depending on sea states having a significant height H_s .

e) The significant wave height is related to the ship's geometric and motion characteristics and to the vertical acceleration a_{CG} by the following formula:

$$a_{CG} = \frac{(50-\alpha_{dCG})\left(\frac{\tau}{16}+0,75\right)}{3555C_B}\left(\frac{H_S}{T}+(0,084)\frac{B_{WS}}{T}\right)K_{FR}K_{HS}$$

- for units for which $V/L^{0,5} \geq 3$ and $\Delta/(0,01L)^3 \geq 3500$:

$$K_{FR} = \left(\frac{V_X}{\sqrt{L}}\right)^2$$

$$K_{HS} = 1$$

- for units for which $V/L^{0,5} < 3$ or $\Delta/(0,01L)^3 < 3500$:

$$K_{FR} = 0,8+(1,6)\frac{V_X}{\sqrt{L}}$$

$$K_{HS} = \frac{H_S}{T}$$

where:

H_s : Significant wave height, in m

α_{dCG} : Deadrise angle, in degrees, at LCG, to be taken between 10° and 30°

τ : Trim angle during navigation, in degrees, to be taken not less than 4°

V : Maximum service speed, in knots

V_x : Actual ship speed, in knots.

If V_x is replaced by the maximum service speed V of the ship, the previous formula yields the significant height of the limit sea state, H_{sl}. This formula may also be used to specify the permissible speed in a sea state characterized by a significant wave height equal to or greater than H_{sl} .

f) On the basis of the formula indicated in e), the limit sea state may be defined (characterized by its significant wave height H_{sl}), i.e. the sea state in which the craft may operate at its maximum service speed. During its voyage, whenever the ship encounters waves having a significant height greater than H_{sl}, it has to reduce its speed.

g) The reduction of vertical acceleration a_{CG} induced by stabilization system if any is to be disregarded for the purpose of limit operating conditions imposed by bottom impact loads.

2.3.3 Limitation imposed by global loads

The longitudinal bending moment and shear forces as given in [3.1] depend explicitly or implicitly upon the vertical acceleration along the ship. Therefore, the design values of these loads taken as the basis for classification directly impose a limitation on the permissible vertical acceleration at the LCG. The requirements of [2.3.2], items b) to g) apply.

The reduction of vertical acceleration along the ship induced by the stabilization system, if any, is to be disregarded for the purpose of specifying the limiting operating conditions imposed by global loads.

2.3.4 Hull monitoring

The Society may require a hull monitoring system to be fitted on board in case of:

- ship with unusual hull lines
- ship for which the vertical acceleration at LCG, a_{CG}, has not been duly justified either by experience or by direct calculations.

The hull monitoring system is to display in real time the vertical acceleration and any other sensitive parameter with respect to the strength.

The information is to be available at the wheelhouse and displayed in a clear format allowing to compare with design values.

When a hull monitoring system is requested, its specification is to be submitted for review.

3 Hull girder strength

3.1 Hull girder loads

3.1.1 Still water bending moments

The still water bending moments in hogging and sagging conditions, $M_{SWM,H}$ and $M_{SWM,S}$ are to be submitted by the designer and calculated according to Pt B, Ch 5, Sec 2, [2].

3.1.2 Total bending moments

The values of the longitudinal bending moment are given, in first approximation, by the formulae in items a) and b).

The total bending moments M_{TH}, in hogging conditions, and M_{TS}, in sagging conditions, in kN.m, are to be taken as the greatest of those given by the formulae in items a) and b).

The longitudinal distribution of the total bending moments M_{TH} and M_{TS} is given in [3.1.3]

a) Bending moments due to still water loads, wave induced loads and impact loads (case with impact considered):

$$M_{TH} = -M_{TS} = 0{,}55\ \Delta\ L\ (C_B + 0{,}7)\ (1 + a_{CG})$$

where a_{CG} is the vertical acceleration at the LCG, defined in [2.1].

b) Bending moments due to still water loads and wave induced loads (case with no impact considered):

$$M_{TH} = M_{SWM,H} + 0{,}60\ Soc\ C\ L^2\ B\ C_B$$

$$M_{TS} = M_{SWM,S} - 0{,}35\ Soc\ C\ L^2\ B\ (C_B + 0{,}7)$$

where:

$M_{SWM,H}$: Hogging still water bending moment, in kN/m

$M_{SWM,S}$: Sagging still water bending moment, considered as negative, in kN/m

C : Coefficient to be taken equal to: $C = 6 + 0{,}02\ L$

For the purpose of this calculation, C_B may not be taken less than 0,6.

If the actual distribution of weights along the craft is known, a more accurate calculation may be carried out according to the procedure in [3.1.4]. The Society reserves the right to require calculation to be carried out according to [3.1.4] whenever it deems necessary.

3.1.3 Longitudinal distribution of total bending moment

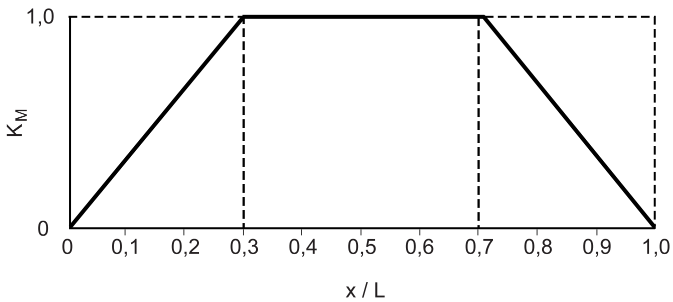
The longitudinal distribution of the total bending moments is given by:

- in hogging condition: $K_M \cdot M_{TH}$
- in sagging condition: $K_M \cdot M_{TS}$

where:

K_M : Longitudinal distribution factor as shown on Fig 2.

Figure 2 : Factor K_M



3.1.4 Bending moment and shear force taking into account the actual distribution of weights

The distribution of quasi-static bending moment and shear force, due to still water loads and wave induced loads, is to be determined from the difference in weight and buoyancy distributions in hogging and sagging for each loading or ballast condition envisaged.

For the calculation purpose, the following values are to be taken for the design wave:

- wave length, in m:

  $\lambda = L$

- wave height, in m:

$$h = \frac{L}{15 + \frac{L}{20}}$$

- wave form: sinusoidal.

In addition, the increase in bending moment and shear force, due to impact loads in the forebody area, for the sagging condition only, is to be determined as specified below. For the purpose of this calculation, the hull is considered longitudinally subdivided into a number of intervals, to be taken, in general, equal to 20. For smaller craft, this number may be reduced to 10 if justified, at the Society's discretion, on the basis of the weight distribution, the hull forms and value of the design acceleration a_{CG}.

The total impact force, in kN, is:

$$F_{SL} = \sum q_{SLi} \cdot \Delta x_i$$

where:

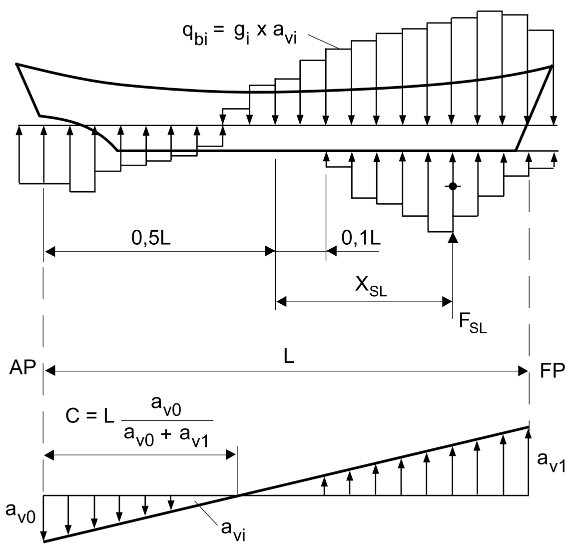
$\Delta\xi_i$: Length of interval, in m

q_{SLi} : Additional load per unit length, in kN/m, for $x/L \geq 0,6$ (see also Fig 3), given by:

$$q_{SLi} = p_0 \cdot B_i \cdot \sin\left[2 \cdot \pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right]$$

x_i : Distance, in m, from the aft perpendicular, to be measured at the centre of interval i

Figure 3 : Load due to impact on fore body



B_i : Craft breadth, in m, at the uppermost continuous deck (i.e. generally B_i is to be evaluated at the bulkhead deck), to be measured at the centre of interval i

p_0 : Maximum hydrodynamic pressure, in kN/m², equal to:

$$p_0 = \frac{a_{v1} \cdot G \cdot (r_0^2 - x_W^2)}{f_{SL} \cdot [r_0^2 + 0,5 \cdot L \cdot (x_{SL} - x_W) - x_{SL} \cdot x_W]}$$

a_{v1} : Vertical design acceleration at the forward perpendicular, as defined in [2.1.4]

G : Weight force, in kN, equal to:

$$G = \sum g_i \cdot \Delta x_i$$

g_i : Weight per unit length, in kN/m, of interval i

x_W : Distance, in m, of LCG from the midship perpendicular, equal to:

$$x_W = \frac{\sum (g_i \cdot \Delta x_i \cdot x_i)}{\sum (g_i \cdot \Delta x_i)} - 0,5 \cdot L$$

r_0 : Radius of gyration, in m, of weight distribution, equal to:

$$r_0 = \left(\frac{\sum g_i \cdot \Delta x_i \cdot (x_i - 0,5L)^2}{\sum g_i \cdot \Delta x_i}\right)^{0,5}$$

Normally: $0,2\ L < r_0 < 0,25\ L$ (guidance value)

x_{SL} : Distance, in m, of centre of surface F_{SL} from the midship perpendicular, given by:

$$x_{SL} = \frac{1}{f_{SL}} \sum \Delta x_i \cdot x_i \cdot B_i \cdot \sin\left[2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right] - 0,5L$$

f_{SL} : Surface, in m², equal to:

$$f_{SL} = \sum \Delta x_i \cdot B_i \cdot \sin\left[2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right]$$

with $x_i / L \geq 0,6$

The resulting load distribution q_{si}, in kN/m, for the calculation of the impact induced sagging bending moment and shear force is:

- For $x/L < 0,6$:

  $q_{si} = q_{bi} = g_i \cdot a_{vi}$

  where:

  a_{vi} : Total dimensionless vertical acceleration at interval i, equal to:

  $a_{vi} = a_h + a_p\ (x_i - 0,5\ L)$

  a_h : Acceleration due to heaving motion, equal to:

  $$a_h = \frac{F_{SL}}{G} \cdot \left(\frac{r_0^2 - x_{SL} \cdot x_W}{r_0^2 - x_W^2}\right)$$

  a_p : Acceleration due to pitching motion, in m⁻¹, equal to:

  $$a_p = \frac{F_{SL}}{G} \cdot \left(\frac{x_{SL} - x_W}{r_0^2 - x_W^2}\right)$$

  a_h and a_p are relative to g

- For $x/L \geq 0,6$:

  $q_{si} = q_{bi} - q_{SLi}$

  The impact induced sagging bending moment and shear force are obtained by integration of the load distribution q_{si} along the hull. They are to be added to the respective values calculated according to design wave in order to obtain the total bending moment M_T and shear force Q_T due to still water loads, wave induced loads and impact loads.

3.1.5 Total shear force

The total shear force, in kN, is to be taken equal to:

$$Q_T = \frac{3,2 M_T}{L}$$

where:

M_T : Greatest bending moment between M_{TH} and M_{TS} in absolute value calculated according to [3.1.2].

3.2 Yielding check

3.2.1 Section modulus

The net section modulus Z_A , in cm^3, at any point of a hull transverse section is to be calculated as specified in Pt B, Ch 6, Sec 1.

3.2.2 Hull girder stress

The normal stresses, in N/mm^2, induced by the vertical bending moments are obtained at any point of the hull transverse section from the following formula:

$$\sigma_{X1} = \frac{M_T}{Z_A} 10^3$$

3.2.3 Checking criteria

It is to be checked that the normal stress σ_{X1} and the shear stress τ induced by the vertical bending moments are not greater than:

$$\sigma_{X1} \le \frac{165}{k}$$

$$\tau \le \frac{100}{k}$$

4 Local loads

4.1 Introduction

4.1.1 Design loads defined in this Article are to be used for the resistance checks provided for in [5] to obtain scantlings of structural elements of hull and deckhouses.

4.1.2 Such loads may be integrated or modified on the basis of the results of model tests or full-scale measurements. Model tests are to be carried out in irregular sea conditions with significant wave heights corresponding to the operating conditions of the ship. The scale effect is to be accounted for by an appropriate margin of safety.

4.1.3 The characteristic value to be assumed is defined as the average of the 1 per cent highest values obtained during testing. The length of the test is, as far as practicable, to be sufficient to guarantee that statistical results are stationary.

4.2 Loads

4.2.1 General

The following loads are to be considered in determining scantlings of hull structures:

- impact pressures due to slamming, if expected to occur
- sea pressures due to hydrostatic heads and wave loads
- internal loads.

External pressure generally determines scantlings of side and bottom structures; internal loads generally determine scantlings of deck structures.

Where internal loads are caused by concentrated masses of significant magnitude (e.g. tanks, machinery), the capacity of the side and bottom structures to withstand such loads is to be verified according to criteria stipulated by the Society. In such cases, the inertial effects due to acceleration of the ship are to be taken into account.

Such verification is to disregard the simultaneous presence of any external wave loads acting in the opposite direction to internal loads.

4.2.2 Load points

Pressure on panels and strength members may be considered uniform and equal to the pressure at the following load points:

- for panels:
  - lower edge of the plate, for pressure due to hydrostatic head and wave load
  - geometrical centre of the panel, for impact pressure
- for strength members:
  - centre of the area supported by the element.

Where the pressure diagram shows cusps or discontinuities along the span of a strength member, a uniform value is to be taken on the basis of the weighted mean value of pressure calculated along the length.

4.3 Impact pressure on the bottom

4.3.1 Except otherwise justified by the designer, it is generally considered that slamming is expected to occur on bottom. The impact pressure, in kN/m², considered as acting on the bottom is not less than:

$$p_{sl} = 70\frac{\Delta}{S_r}K_1K_2K_3a_{CG}$$

where:

Δ : Moulded full load displacement, end of life, in tonnes

S_r : Reference area, in m², equal to:

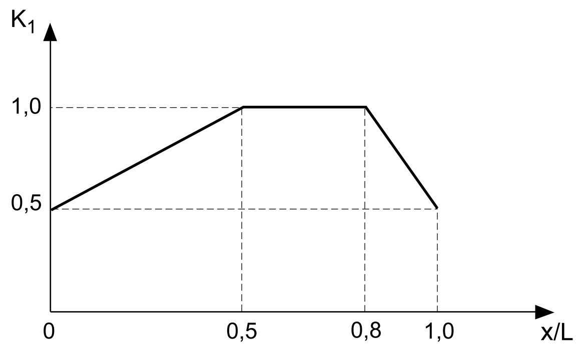
$$S_r = 0,7\frac{\Delta}{T}$$

K_1 : Longitudinal bottom impact pressure distribution factor (see Fig 4):

- for $x/L < 0,5$: $K_1 = 0,5 + x/L$
- for $0,5 \leq x/L \leq 0,8$: $K_1 = 1,0$
- for $x/L > 0,8$: $K_1 = 3,0 - 2,5 \cdot x/L$

where x is the distance, in m, from the aft end to the load point

Figure 4 : Impact area factor K_1



K_2 : Factor accounting for impact area, equal to:

$$K_2 = 0,455 - 0,35\frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

with:

- $K_2 \geq 0,50$ for plating
- $K_2 \geq 0,45$ for stiffeners
- $K_2 \geq 0,35$ for girders and floors

$$u = 100\frac{s}{S_r}$$

where s is the area, in m², supported by the element (plating, stiffener, floor or girder). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

K_3 : Factor accounting for shape and deadrise of the hull, equal to:

$K_3 = (70 - \alpha_d) / (70 - \alpha_{dCG})$

where:

α_{dCG} : Deadrise angle, in degrees, measured at LCG

α_d : Deadrise angle, in degrees, between horizontal line and straight line joining the edges of respective area measured at the longitudinal position of the load point

values of α_d and α_{dCG} are to be taken between 10° and 30°

a_{CG} : Design vertical acceleration at LCG, defined in [2.1].

4.4 Sea pressures

4.4.1 Sea pressure on bottom and side shell

a) The sea pressure, in kN/m², considered as acting on the bottom and side shell is not less than p_{smin}, defined in Tab 2, nor less than:

- for $z \le T$:

$$p_s = 10\left[T + 0,75S - \left(1 - 0,25\frac{S}{T}\right)z\right]$$

- for $z > T$:

$p_s = 10\ (T + S - z)$

where:

z : Vertical distance, in m, from the moulded base line to load point. z is to be taken positively upwards

S : As given, in m, in Tab 2 with C_B taken not greater than 0,5.

b) Between midship area and fore end ($0,5 < x/L < 0,9$), p_s varies in a linear way as follows:

$p_s = p_{sFP} - (2,25 - 2,5\ x/L)\ (p_{sFP} - p_{sM})$

where p_{sFP} is the sea pressure at fore end and p_{sM} the sea pressure in midship area.

Table 2 : Values of S and p_{smin}

x/L	S	p_{smin}
$x/L \ge 0,9$	$T \le 0,36a_{CG}\frac{\sqrt{L}}{C_B} \le 3,5T$	$20 \le \frac{L+75}{5} \le 35$
$x/L \le 0,5$	$T \le 0,60a_{CG}\sqrt{L} \le 2,5T$	$10 \le \frac{L+75}{10} \le 20$

4.5 Sea pressures on deckhouses

4.5.1 The pressure, kN/m², considered as acting on walls of deckhouses is not less than:

$$p_{su} = K_{su}\left[1 + \frac{x_1}{2L(C_B + 0,1)}\right](1 + 0,045L - 0,38z_1)$$

where:

K_{su} : Coefficient equal to:

- for front walls of a deckhouse located directly on the main watertight deck not at the fore end:
  $K_{su} = 6,0$
- for unprotected front walls of the second tier, not located at the fore end:
  $K_{su} = 5,0$
- for sides of deckhouses, b being the breadth, in m, of the considered deckhouse:
  $K_{su} = 1,5 + 3,5\ b/B$ (with $3 \le K < 5$)
- for the other walls:
  $K_{su} = 3,0$

x_1 : Distance, in m, from front walls or from wall elements to the midship perpendicular (for front walls or side walls aft of the midship perpendicular, x_1 is equal to 0)

z_1 : Distance, in m, from load point to waterline at draught T.

4.5.2 The minimum values of p_{su}, in kN/m², to be considered are:

- for the front wall of the lower tier:
  $p_{su} = 6,5 + 0,06\ L$
- for the sides and aft walls of the lower tier:
  $p_{su} = 4,0$
- for the other walls or sides:
  $p_{su} = 3,0$

4.5.3 For unprotected front walls located at the fore end, the pressure p_{su} will be individually considered by the Society.

4.6 Deck loads

4.6.1 General

The pressure, in kN/m^2, considered as acting on decks is given by the formula:

$p_d = p\ (1 + 0{,}4\ a_v)$

where:

p : Uniform pressure due to the load carried, in kN/m^2. Minimum values are given in [4.6.2] and [4.6.3]

a_v : Design vertical acceleration, defined in [2.1.4].

Where decks are intended to carry masses of significant magnitude, including vehicles, the concentrated loads transmitted to structures are given by the formula:

$F_d = F\ (1 + 0{,}4\ a_v)$

where:

F : Static force due to the load carried, in kN. Minimum values are given in [4.6.2]

a_v : Design vertical acceleration, defined in [2.1.4].

4.6.2 Exposed decks

a) For exposed decks without deck cargo:

- if $z_d \leq 2$:

  $p = 6{,}0$ kN/m^2

- if $2 < z_d < 3$:

  $p = (12 - 3\ z_d)$ kN/m^2

- if $z_d \geq 3$:

  $p = 3{,}0$ kN/m^2

where z_d is the vertical distance, in m, from deck to waterline at draught T.

p can be reduced by 20% for primary supporting members and pillars under decks located at least 4 m above the waterline at draught T, excluding embarkation areas.

b) For exposed decks with deck cargo:

- if $z_d \leq 2$:

  $p = (p_c + 2)$ kN/m^2, with $p_c \geq 4{,}0$ kN/m^2

- if $2 < z_d < 3$:

  $p = (p_c + 4 - z_d)$ kN/m^2, with $p_c \geq (8{,}0 - 2\ z_d)$ kN/m^2

- if $z_d \geq 3$:

  $p = (p_c + 1)$ kN/m^2, with $p_c \geq 2{,}0$ kN/m^2

where:

z_d : Distance defined in item a) above

p_c : Uniform pressure due to deck cargo load, in kN/m^2, to be defined by the designer with the limitations indicated above.

4.6.3 Protected decks

They are decks which are protected by enclosed accommodation, and which are therefore not exposed to green-seas effect.

a) For protected deck supporting uniform pressure, the value of still water pressure p is to be taken equal to the value of p_s defined in Pt B, Ch 5, Sec 6, Tab 3, Pt B, Ch 5, Sec 6, Tab 7 and Pt B, Ch 5, Sec 6, Tab 8.

b) For protected deck supporting dry unit cargo, the value of still water force F is to be taken equal to the value of F_s defined in Pt B, Ch 5, Sec 6, Tab 4 and Pt B, Ch 5, Sec 6, Tab 5.

c) For protected deck supporting vehicles and helicopters, the value of still water force P is to be taken as defined in [5.1.3].

4.7 Pressures on tank structures

4.7.1 The pressure, in kN/m^2, considered as acting on structures which constitute boundaries of compartments intended to carry liquids is to be taken not less than:

$p_{t1} = 9{,}81\ h_1\ \rho\ (1 + 0{,}4\ a_v) + 100\ p_v$

where:

h_1 : Distance, in m, from load point to tank top

ρ : Liquid density, in t/m^3 (1,0 t/m^3 for water)

p_v : Setting pressure, in bars, of pressure relief valve, when fitted.

5 Hull scantlings

5.1 Plating

5.1.1 General

The requirements of this sub-article apply for the strength check of plating subjected to lateral pressure, wheeled loads and hull girder normal stress.

The static and inertial pressures induced by the sea and the various type of cargoes and loads are to be considered depending on the location of the plating under consideration.

5.1.2 Plating subjected to lateral pressure

The net thickness of plate panels subjected to lateral pressure, in mm, is to be not less than the value obtained from the following formula:

$$t = 22,4\mu s\sqrt{\frac{p}{f\sigma_{am}}}$$

where:

μ : Aspect ratio of the plate panel equal to:

$$\mu = \sqrt{1,1-0,5\left(\frac{s}{\ell}\right)^2}$$

to be taken not greater than 1

s : Length, in m, of the shorter side of the plate panel

ℓ : Length, in m, of the longer side of the plate panel

p : Lateral pressure, in kN/m², to be evaluated from the requirements in [4]

f : Coefficient equal to:

- 1,00 for steel structure
- 2,35 for aluminium alloy structures

σ_{am} : Admissible stress values, in N/mm², given in Tab 3 for the various hull components.

Table 3 : Admissible stress values, in N/mm²

	Steel	Aluminium alloy
Bottom and bilge under impact loads	235 / k	95 / k
Bottom and bilge under sea loads	200 / k	85 / k
Other hull components	200 / k	85 / k

5.1.3 Plating subjected to wheeled loads

The thickness of plate panels subjected to wheeled loads is not to be less than the value given by formulae defined in Pt B, Ch 7, Sec 1, [4.3.1], provided that the wheeled force, P_0, is taken equal to:

$P_0 = P\,(1 + 0,4\,a_v)$

where:

Π : Static load, in kN, on one tyre print

α_V : Vertical acceleration defined in [2.1.4].

5.1.4 Buckling

For plate panel subjected to compression and bending on one side, the critical buckling stress is to comply with the following criteria:

$|\sigma_{X1} + \sigma_{X2}| \le \sigma_c$

where:

σ_{X1} : Hull girder compression normal stress, in N/mm², to be calculated as specified in Tab 4

σ_{X2} : Compressive normal stress, in N/mm², induced by the local bending of the primary supporting members

σ_c : Critical buckling stress, in N/mm², to be calculated as specified in Pt B, Ch 7, Sec 1, [5.3.1].

When the buckling criteria is exceeded, the scantlings may still be considered as acceptable, provided that the stiffeners located on the plate panel satisfy the buckling and the ultimate strength checks as specified in Pt B, Ch 7, Sec 2, [4] and Pt B, Ch 7, Sec 2, [5].

Table 4 : σ_{x1} for buckling

Condition	σ_{x1} in N/mm²
$z \geq N$	$\sigma_{X1} = \dfrac{M_{ts}(z-N)10^{-3}}{I_Y}$
$z < N$	$\sigma_{X1} = \dfrac{M_{th}(z-N)10^{-3}}{I_Y}$
Note 1: N is defined in Part B, Chapter 7	

5.2 Ordinary stiffeners

5.2.1 General

The requirements of this sub-article apply for the strength check of ordinary stiffeners subjected to lateral pressure, wheeled loads and hull girder normal stress.

The static and inertial pressure induced by the sea and the various type of cargoes and loads are to be considered depending on the location of the stiffener under consideration.

5.2.2 The section modulus Z, in cm³, and the shear area A_t, in cm², required for the purpose of supporting the design pressure transmitted by the plating, are given by the following formulae:

- case of uniform pressure

$$Z = 1000\frac{\ell^2 sp}{mfC\sigma_{am}}$$

$$A_t = 5\frac{\ell sp}{f\tau_{am}}$$

- case of wheeled loads

$$Z = 1000\frac{\ell P_0}{6fC\sigma_{am}}$$

$$A_t = 10\frac{P_0}{f\tau_{am}}$$

where:

s, ℓ ≺ ≻: As defined in [5.1.2]

P_0 : As defined in [5.1.3]

m : Coefficient specified in Tab 5 and depending on the stiffener type and on whether there are rule brackets at the end of each individual span

C : Coefficient equal to:

- for steel stiffeners:

  $$C = C_S = 1,4 - \frac{k\sigma_{X1}}{165f}$$

- for aluminium alloy stiffeners:

  $$C = C_A = 1,3 - \frac{k\sigma_{X1}}{165f}$$

- for steel or aluminium stiffeners under impact pressure:

  C = 1

- for steel or aluminium stiffeners not contributing to hull girder strength:

  C = 1

without being taken greater than 1

σ_{am} : Maximum normal stress, in N/mm², to be taken equal to:

- 165 / k for steel stiffeners
- 70 / k for aluminium alloy stiffeners

τ_{am} : Maximum shear stress, in N/mm², to be taken equal to:

- 100 / k for steel stiffeners
- 45 / k for aluminium alloy stiffeners.

Table 5 : Coefficient m

Type of stiffener	m
Continuous longitudinal stiffeners without rule brackets at the ends of span	12
Longitudinal and transverse stiffeners with rule brackets at the ends of span	19
Longitudinal and transverse stiffeners with rule brackets at one end of span	15
Non-continuous longitudinal stiffeners and transverse stiffeners without rule brackets at the ends of span	8
Note 1: A rule bracket is to have a arm equal to $\ell/8$, where ℓ is the greater span of the connected stiffeners.	

5.2.3 Buckling

For ordinary stiffeners subjected to compression and bending on one side, the critical buckling stress is to comply with the following criteria:

$$|\sigma_{X1} + \sigma_{X2}| \leq \frac{\sigma_C}{S_F}$$

where:

σ_{X1} : Hull girder compression normal stress, in N/mm², to be calculated as specified in Tab 4

σ_{X2} : Compressive normal stress, in N/mm², induced by the local bending of the primary supporting members

σ_c : Critical buckling stress, in N/mm², to be calculated as specified in Pt B, Ch 7, Sec 2, [4.3]

S_F : Safety factor to be taken equal to 1,33 for stiffeners contributing to the longitudinal strength and to 1,00 otherwise.

5.3 Primary members

5.3.1 General

As a general rule, primary members of a corvette are to be analyzed through direct calculation in accordance with the criteria defined in [5.4].

However, primary members not interacting with the surrounding structure can be analyzed through isolated beam model. In such case, the modulus and the section of the primary members is not to be less than specified in [5.2.2] provided that:

- m is taken equal to 12 for side stringer and equal to 10 for floors, bottom girders, side frames, deck beam, deck girder and vertical web of superstructures
- the maximum normal stress σ_{am} for side and front walls is to be taken equal to:

$$\sigma_{am} = \frac{165}{fk} - \sigma_a$$

where:

f : Coefficient equal to:
- 1,00 for steel structure
- 2,35 for aluminium alloy structures

σ_a : Stress induced by the normal force in side transverse due to deck loads transmitted by deck beam.

5.4 Direct calculation

5.4.1 General

As a rule, the primary members of a corvette are to be analyzed through direct calculation based on a three-dimensional analysis.

5.4.2 impact loads

The impact pressure is to be calculated as stipulated in [4.3]. For each floor, the K_2-factor which appears in the formula for the impact pressure is to be calculated as a function of the area supported by the floor itself.

In the case of three-dimensional analyses, the longitudinal distribution of impact pressure is to be considered individually, in the opinion of the Society. In general, the impact pressure is to be considered as acting separately on each transverse section of the model, the remaining sections being subject to the hydrostatic pressure.

5.4.3 Load cases

As a rule the following loading conditions are to be considered for the direct calculation of the primary members:

a) Loading condition in still water
- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft
- outer hydrostatic load in still water.

b) Combined loading condition 1

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction.

c) Combined loading condition 2

- forces caused by weights which are expected to be carried in the full load condition, distributed according to the weight booklet of the craft
- forces of inertia due to the vertical acceleration a_v of the craft, considered in a downward direction
- impact pressure acting on the bottom of the craft (2 cases):
  - case 1: symmetrically and according to [4.3]
  - case 2: asymmetrically and acting on one side of a complete compartment between transverse bulkheads, the other side being subject to hydrostatic load in still water.

5.4.4 Structural model

Primary structures of a corvette may usually be modelled with beam elements. When, however, grounds for the admissibility of this model are lacking, or when the geometry of the structures gives reason to suspect the presence of high stress concentrations, finite element analyses are necessary.

The extent of the model is to be such as to allow analysis of the behaviour of the main structural elements and their mutual effects.

The requirements defined in Pt B, Ch 7, App 1 are applicable to establish the three dimensional model of the primary structure.

5.4.5 Checking criteria

The stresses given by the above calculations are to be not greater than the following allowable values, in N/mm^2:

- bending stress:

$$\sigma_{am} = \frac{165}{k \cdot f_s}$$

- shear stress:

$$\tau_{am} = \frac{100}{k \cdot f_s}$$

- Von Mises equivalent bending stress:

$$\sigma_{eq,\,am} = \frac{210}{k \cdot f_s}$$

where:

k : Material factor defined in Pt B, Ch 4, Sec 1

f_s : Safety coefficient, to be assumed equal to:

- 1,00 for combined loading conditions
- 1,25 for loading condition in still water.

6 Hull outfitting

6.1 Anchoring equipment

6.1.1 Anchoring equipment of a corvette are to be designed in accordance with the applicable requirements of Pt B, Ch 9, Sec 4.

However, for corvettes, one of the two anchors required by above requirements may be not retractable. Which means that the anchor is designed to be lowered just once and released from the ship after a single operation.

In such a case the non retractable anchoring line needs not to be associated to a windlass and a chain stopper. In addition, the mooring force exerted by the chain cable on its connection to the ships will be considered on a case by case basis.

6.2 Rudders

6.2.1 Rudders are to comply with applicable requirements of Pt B, Ch 9, Sec 1, considering a maximum speed V_{max}, in knots, not greater than 7,16 $\Delta^{1/6}$.

In addition the designer is to justify that the operational conditions of the rudder at high speed will not induce loads on the rudder higher than specified in Pt B, Ch 9, Sec 1.

6.3 Waterjets

6.3.1 The supporting structures of waterjets are to be able to withstand the loads thereby generated in the following conditions:

- maximum ahead thrust
- maximum thrust at maximum lateral inclination
- maximum reversed thrust (going astern).

Information on the above loads is to be given by the waterjet manufacturer and supported by documents.

6.3.2 For each waterjet, following loading cases are to be investigated:

LDC 1 : Internal hydrodynamic pressure p_h in the built-in nozzle

LDC 2 : Horizontal longitudinal force F_{x1} in normal service (ahead)

LDC 3 : Horizontal transverse force F_y and associated moment M_z during steering operation

LDC 4 : Horizontal longitudinal force F_{x2} , vertical force F_z and overturning moment M_y in crash-stop situation.

6.3.3 The actual location of the thrust bearing is to be adequately considered (either located aft of the stem in the stator bowl or inside the waterjet compartment).

6.3.4 The scantlings are to be checked by direct calculations.

6.3.5 Tab 6 indicates the loading cases to be considered for the various components of the waterjet system. Other loading cases could be considered for specific or new design.

6.3.6 The stress criteria for static analysis may be taken as the following one, in N/mm^2:

- bending stress:

$$\sigma_{am} = \frac{165}{k}$$

- shear stress:

$$\tau_{am} = \frac{100}{k}$$

- Von Mises equivalent bending stress:

$$\sigma_{eq, am} = \frac{210}{k}$$

where:

k : Material factor defined in Pt B, Ch 4, Sec 1.

6.3.7 The stress criteria for fatigue analysis are to be specified by the designer.

6.3.8 The shell thickness in way of nozzles as well as the shell thickness of the tunnel are to be individually considered. In general, such thicknesses are to be not less than 1,5 times the thickness of the adjacent bottom plating.

Table 6 : Load cases

Component	LDC 1	LDC 2	LDC 3	LDC 4
Built-in nozzle:				
- plating	X **(1)**	X **(2)**		
- bending behaviour				X **(3)**
Ship stem		X **(2)**	X	X **(4)**
Bolting on stem			X **(5)**	X **(5)**

(1) To be checked under lateral pressure and against fatigue behaviour
(2) Buckling to be checked (100% of F_x transferred by built-in nozzle in case of thrust bearing aft of the stem)
(3) Ratio of M_y directly sustained by the built-in nozzle to be estimated on basis of relative stiffnesses
(4) Ratio of M_y directly sustained by the transom structure to be estimated on basis of relative stiffnesses
(5) Bolting calculation taking account of the actual pre-tension in bolts.

6.3.9 General principles to be followed for such structures subject to cyclic loadings are listed hereafter:

- continuous welding
- shear connections between stiffeners and transverse frames
- soft toe brackets
- no sniped ends
- no termination on plate fields
- no scallops in critical areas
- no start and stop of welding in corners or at ends of stiffeners and brackets
- possibly grinding of toes of critical welds.

Note 1: As a guidance, the following criteria may be considered:

The bending natural frequency of plates and strength members of the hull in the area of waterjets should not be less than 2,3 times the blade frequency for structures below the design waterline and between transom and aft engine room bulkhead. Structural components (such as the casing of waterjet and accessory parts and the immersed shell area) which may transfer pressure fluctuations into the ship structure have to fulfill the requirements of the waterjet manufacturer. Especially with regard the grids installed in the inlet duct, the hydrodynamic design should assure an unproblematic operation with respect to cavitation phenomenon.

This checking is left to the manufacturers.

6.4 Hull appendages - Propeller shaft brackets

6.4.1 Propeller shaft bracket are to be designed in accordance with applicable requirements of Pt B, Ch 9, Sec 3, where RPM is taken equal to the revolution per minute of the propeller for the maximum speed V, in Kn, of the ship.

7 Fatigue

7.1

7.1.1 The fatigue strength of structural details is to be checked, when deemed necessary by the Society. In this case, the criteria defined in Pt B, Ch 7, Sec 4 are to be applied.

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1 Ships having the service notation **corvette** are to comply with the general requirements of Part C, Chapter 1. In addition they are to comply with the provisions of this Section.

2 Gearing

2.1 General

2.1.1 The general requirements of Pt C, Ch 1, Sec 6 apply with the following changes of the safety factors.

2.1.2 Safety factors for contact stress

The safety factors for contact stress as per Pt C, Ch 1, Sec 6, Tab 18 are to be replaced by the values given in Tab 1.

Table 1 : Safety factor S_H for contact stress

Type of installation		S_H
Main gears (propulsion)	single machinery	1,25
	duplicate machinery	1,20
Auxiliary gears		1,15

2.1.3 Safety factors for bending stress

The safety factors for tooth root bending stress as per Pt C, Ch 1, Sec 6, Tab 24 are to be replaced by the values given in Tab 2.

Table 2 : Values of safety factor S_F for tooth root bending stress

Type of installation		S_F
Main gears (propulsion)	single machinery	1,60
	duplicate machinery	1,55
Auxiliary gears	single machinery	1,45
	duplicate machinery	1,40

Section 4 Electrical Installations

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to ships granted with the service notation **corvette**. These requirements are additional to those of Part C, Chapter 2.

1.1.2 The text "at every muster station" in Pt C, Ch 2, Sec 3, [3.5.3], item a) is to be replaced by "at main and emergency evacuation stations, as defined in Ch 3, Sec 5, [1.2.1] and Ch 3, Sec 5, [1.2.2]".

Section 5 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships having the service notation **corvette**.

1.1.2 Applicable Rules

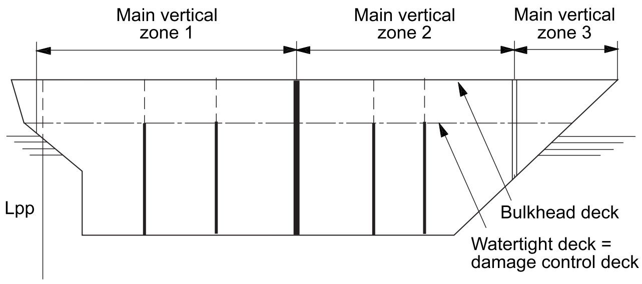
Unless otherwise specified in this Section, requirements of Part C, Chapter 4 shall apply.

Non-applicable requirements of Part C, Chapter 4 are summarized in Tab 1.

1.1.3 Ship arrangement

The ship arrangement represented by Pt C, Ch 4, Sec 1, Fig 1 is replaced by Fig 1.

Figure 1 : Ship's vertical subdivision arrangement



1.2 Definitions

1.2.1 Main evacuation stations

The main evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

Note 1: The evacuation stations may include spaces such as corridors, landings of stairway enclosures, accommodation and service spaces but an evacuation station is not to include a control station, a machinery space, an ammunition space or a vehicle or ro-ro space. In any case, a space which requires a key for access can not be included in an evacuation station unless the key is enclosed in a beak-glass type enclosure conspicuously located an indicated near the normally locked access door.

1.2.2 Emergency evacuation stations

The emergency evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when main evacuation stations are unusable.

Table 1 : Summary of requirements of Part C, Chapter 4 to be replaced by requirements of Pt D, Ch 3, Sec 5

Concerned Sections of Part C, Chapter 4	Applicable requirements for service notation **corvette**
Pt C, Ch 4, Sec 1	Pt C, Ch 4, Sec 1, [1.1.2] replaced by [1.1.3]
Pt C, Ch 4, Sec 5	Pt C, Ch 4, Sec 5, [1.2.1] item a) replaced by [2.2.2]
	Pt C, Ch 4, Sec 5, [1.2.3] item b) corrected by [2.2.3]
	Pt C, Ch 4, Sec 5, [6.3.8] replaced by [2.3.1]
	Pt C, Ch 4, Sec 5, [6.4.1] corrected by [2.3.2]
Pt C, Ch 4, Sec 6	Pt C, Ch 4, Sec 6, [1.2.4] item a) replaced by [3.1.1]
	Pt C, Ch 4, Sec 6, [1.3.2] replaced by [3.1.2]
	Pt C, Ch 4, Sec 6, [1.3.3] replaced by [3.1.3]
	Pt C, Ch 4, Sec 6, [8.2] replaced by [3.2.1]
Pt C, Ch 4, Sec 8	Pt C, Ch 4, Sec 8, [2.1.1] replaced by [4.1.1]
	Pt C, Ch 4, Sec 8, [2.3.2] replaced by [4.1.2]
	Pt C, Ch 4, Sec 8, [4.4] replaced by [4.2.2] and [4.2.3]
	Pt C, Ch 4, Sec 8, [4.2.1] and Pt C, Ch 4, Sec 8, [4.2.2] replaced by [4.3.2] and [4.3.3]
Pt C, Ch 4, Sec 12	Pt C, Ch 4, Sec 12, [2.1.4] item b) replaced by [5.1.1]

2 Suppression of fire and explosion: Containment of fire

2.1 Damage control stations

2.1.1 Two damage control stations as defined in Pt C, Ch 4, Sec 1, [2.13] are to be provided and equipped in such a way that the functionalities of each damage control station are also operable from the other station.

Note 1: The loss of one damage control station need not be considered for application of above requirement.

2.1.2 Those damage control stations may be located in the same main vertical zone provided direct access to the damage control station which is not permanently manned at sea is provided from the other main vertical zone.

Note 1: Access to this damage control station by a single corridor may be accepted, to the satisfaction of the Society.

Note 2: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need not have direct access to the damage control stations and should not be taken into account for the purpose of this requirement.

2.2 Ship subdivision

2.2.1 Safety zone

For the provisions of this Section and applicable requirements of Part C, Chapter 4, the entire ship is to be considered as one safety zone.

2.2.2 Main vertical zones

The requirements of Pt C, Ch 4, Sec 5, [1.2.1] item a) are to be replaced by:

a) The interior of the hull, superstructure and deckhouses shall be divided (see Fig 1) into at least two main vertical zones by A-60 class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary, they shall have the fire integrity of the vertical limits of the main vertical zones. Where a category (5), (9) or (10) space defined in item b) of Pt C, Ch 4, Sec 5, [1.2.3] is on one side or where fuel or diesel oil or JP 5 NATO (F44) tanks or water capacities are on both sides of the division, the standard can be reduced to A-0.

Note 1: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need not to comply with the requirements of [3.2.1], [4.2.3] Pt C, Ch 4, Sec 4, [4.3.1] item a)1) and Pt C, Ch 4, Sec 5, [6.3.7].

2.2.3 Fire integrity of bulkheads and decks

a) The definition of category (4) of Pt C, Ch 4, Sec 5, [1.2.3], item b) 2) is to be replaced by:

- (4) Evacuation stations and external escape routes

  Survival craft stowage area.

  Open deck spaces and passageways forming lifeboat and liferaft embarkation and lowering stations.

  External stairs and open decks used for escape routes.

  The ship's side to the waterline in the lightest condition including superstructures and deckhouse sides situated below the evacuation areas.

  Internal and external main evacuation stations.

  Note 3 and Note 4 of category (5) of Pt C, Ch 4, Sec 5, [1.2.3] item b) 2) are also applicable for this category (4).

2.3 Ventilation systems

2.3.1 Stairway enclosure ventilation system

The requirements of Pt C, Ch 4, Sec 5, [6.3.8] are to be replaced by:

"Ventilation systems serving stairway enclosures which penetrate more than a single deck shall be so arranged as to reduce the likelihood of smoke and hot gases passing from one 'tween deck space to another through the system."

Note 1: A ventilation system fitted at each penetration of the stairway enclosure with a fire or smoke damper is considered to meet this requirement. See also Pt C, Ch 4, Sec 5, [6.4.2] Pt C, Ch 4, Sec 5, [6.4.3].

2.3.2 Main vertical zone boundary penetration

The last paragraph of Pt C, Ch 4, Sec 5, [6.3.9] is to be replaced by:

"The duct is to be insulated to "A-60" class standard throughout the main vertical zone which is not served by the ventilation duct."

3 Suppression of fire and explosion: Fire-fighting

3.1 Fire pumps

3.1.1 Isolating valves and relief valve

The requirements of Pt C, Ch 4, Sec 6, [1.2.4] item a) 2) are to be replaced by:

"At least one isolating valve is to be fitted at each main vertical zone bulkhead penetrated. It shall be possible to operate the isolating valve from both sides of the main vertical zone bulkhead unless isolating valves are fitted on both sides of the division."

Note 1: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need not to comply with item a) 3) of Pt C, Ch 4, Sec 6, [1.2.4].

3.1.2 Number of fire pumps

The requirements of Pt C, Ch 4, Sec 6, [1.3.2] are to be replaced by:

"The ship is to be equipped with at least two independently driven fire pumps.

The arrangement of the fire pumps shall be such that, in the event of a fire in any one compartment, the remaining fire pumps are capable of supplying the quantity of water required in [3.1.3]."

3.1.3 Capacity of fire pumps

The requirements of Pt C, Ch 4, Sec 6, [1.3.3] are to be replaced by:

"The fire pumps required by [3.1.2] shall be capable of supplying, at the pressure stated in Pt C, Ch 4, Sec 6, [1.2.6], four hydrants and the ship most demanding fire-fighting system using the fire main as the main supply of sea water, including bilge pumping if bilge ejectors are used as mentioned in Pt C, Ch 1, Sec 10, [6].

Note 1: The expression "the ship most demanding systems" means the most demanding room associated with its adjacent ammunition stores.

The fire-fighting system plan shall indicate the water systems to be in operation at the same time and the relevant water demand."

3.2 Firefighter's outfits

3.2.1 Number of firefighter's outfits

The requirements of Pt C, Ch 4, Sec 6, [8.2] are to be replaced by the following requirement [3.2.2].

3.2.2 Each main vertical zone is to be provided with at least 4 firefighter's outfits.

Note 1: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need not to comply with this requirement.

4 Escape and circulation

4.1 Means of escape

4.1.1 Purpose

The requirement Pt C, Ch 4, Sec 8, [2.1.1] is to be replaced by:

"The purpose of the following requirements of this section is to provide means of escape so that persons on board can safely and swiftly escape to the evacuation stations or adjacent main vertical zone. For this purpose, the following functional requirements shall be met:

- escape routes shall be maintained in a safe condition, clear of obstacles, and
- additional aids for escape shall be provided as necessary to ensure accessibility, clear marking and adequate design for emergency situations.

Note 1: Means of escape are all the available means to exit from any space continuously or occasionally manned at sea.

Note 2: Evacuation routes or escape routes are all the main and secondary ways to escape from any space to evacuation stations or to adjacent main vertical zones."

4.1.2 Means of escape from accommodation spaces, service spaces and control station

The requirements of Pt C, Ch 4, Sec 8, [2.3.2] item a) are to be replaced by:

a) General

   Stairways and ladders shall be so arranged as to provide ready means of escape to the main and emergency evacuation stations as defined in [1.2.1] and [1.2.2] from all the accommodation and service spaces and control stations in which the crew is normally employed.

4.2 Evacuation stations

4.2.1 Application

The requirements of Pt C, Ch 4, Sec 8, [4.4] are to be replaced by the following requirements [4.2.2] and [4.2.3].

4.2.2 Main evacuation stations arrangement

At least one main evacuation station as defined in [1.2.1] is to be provided for the ship.

The main evacuation station(s) shall be arranged in compliance with the prescriptions of items a) to c) below:

a) Access to liferaft launched at sea from the evacuation station shall be possible from each side of the ship

b) If a main vertical zone is not provided with a main evacuation station, access to the main evacuation station from this main vertical zone is to be provided through a main passageway as defined in [1.2.1], which have fire integrity and insulation values for stairway enclosures as determined by Pt C, Ch 4, Sec 5, Tab 1 and Pt C, Ch 4, Sec 5, Tab 2.

Note 1: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need not to comply with this requirement.

c) The number of crew and special persons onboard shall be distributed in the main evacuation stations. Each main evacuation station shall have sufficient clear deck area to accommodate all the crew and special persons assigned to evacuate from that evacuation station, but at least 0,35 m^2 per person.

4.2.3 Emergency evacuation station

a) At least one emergency evacuation station as defined in [1.2.2] is to be provided for the ship, which shall allow the persons to be evacuated to reach the liferaft when launched at sea, in case it is not possible to use the main evacuation station.

Note 1: Access to the emergency evacuation station may be provided through adjacent spaces such as the helicopter hangar provided passage is maintained clear of obstacles at all times, with appropriate marking.

b) This evacuation station should be located as far as possible from the main evacuation station and in another main vertical zone. In no case shall this emergency evacuation station be contiguous to the main evacuation station.

c) This emergency evacuation station is not needed when one main evacuation station is provided for each main vertical zone or when the main evacuation station is provided on the open deck.

Note 2: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone is not to be considered for the application of item c).

4.3 Width of escape routes

4.3.1 Application

The requirements of Pt C, Ch 4, Sec 8, [4.2.1] and Pt C, Ch 4, Sec 8, [4.2.2] are to be replaced by the following [4.3.2] and [4.3.3].

4.3.2 The Main passageways and doors within, including exit door leading to the evacuation station, shall not be less than 800mm net width. In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per Pt C, Ch 4, Sec 8, [4.5].

4.3.3 Other passageways used as escape route and doors within, shall not be less than 600 mm net width. In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per Pt C, Ch 4, Sec 8, [4.5].

Doors, stairways and hatches along these passageways are to be sized in a same manner as the passageways.

5 Protection of vehicle and ro-ro spaces

5.1 Precaution against ignition of flammable vapours in closed vehicle and ro-ro spaces

5.1.1 Closing appliances and ducts in ventilation systems of vehicle and ro-ro spaces

The requirements of Pt C, Ch 4, Sec 12, [2.1.4] item b) are to be replaced by:

b) Ventilation ducts, including dampers, within a common

horizontal zone shall be made of steel. Ventilation ducts that pass through other horizontal zones or machinery spaces shall be “A” class steel ducts constructed in accordance with Pt C, Ch 4, Sec 5, [6.3.1].

Part D
Service Notations

CHAPTER 4
AUXILIARY NAVAL VESSEL

Section 1	General
Section 2	Ship Arrangement
Section 3	Hull and Stability
Section 4	Machinery and Systems
Section 5	Electrical Installations
Section 6	Fire Protection
Section 7	Escape
Section 8	Replenishment at Sea
Section 9	Carriage of Limited Quantities of Flammable Products with Flashpoint $\leq$ 60°C

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **auxiliary naval vessel**, as defined in Pt A, Ch 1, Sec 2, [4.5].

1.1.2 The requirements of this Chapter apply to ships intended for the carriage and underway replenishment of oil products:

- having a flash point above 60°C, and
- at a temperature below and not within 15°C of their flash point.

Limited quantities of flammable products with flashpoint ≤ 60°C may be carried subject to the requirements of Ch 4, Sec 9.

The auxiliary naval vessels may also be intended to carry and transfer at sea ammunition and dry stores.

1.1.3 Number of persons on board

The requirements of this Chapter apply to ships carrying not more than 240 persons on board.

Note 1: Ships carrying more than 240 persons on board are subject to special examination of the Society.

1.1.4 Ships dealt with in this Chapter are to comply with:

- Part A
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Ch 4, Sec 2
Hull	• NR467, Part B • NR467, Pt D, Ch 7, Sec 3, [3] to [13] as applicable for **oil tanker** • Ch 4, Sec 3
Stability	• NR467, Part B, Chapter 3 • Ch 4, Sec 3
Machinery and systems	• NR467, Part C, Chapter 1 • NR467, Pt D, Ch 11, Sec 4 • Ch 4, Sec 4
Electrical installations	• NR467, Part C, Chapter 2 • NR467, Pt D, Ch 11, Sec 5 • Ch 4, Sec 5
Automation	• NR467, Part C, Chapter 3
Fire protection, detection and extinction	• NR467, Part C, Chapter 4 as applicable for passenger ships carrying less than 36 passengers **(1)** • Ch 4, Sec 6 and Ch 4, Sec 7
Replenishment at sea	• Ch 4, Sec 8
Carriage of limited quantities of flammable products with flashpoint < 60°C	• Ch 4, Sec 9
(1) Except that Helicopter Facilities are to comply with the requirements of Pt C, Ch 4, Sec 10.	

1.2 Definitions

1.2.1 Accommodation spaces

Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, secretariats, meeting rooms, pantries containing no cooking appliances and similar spaces.

Pantries (including isolated pantries) containing no cooking appliances may contain:

- coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances, each with a maximum power of 5 kW
- electrically heated cooking plates and hot plates for keeping food warm, each with a maximum power of 2 kW and a surface temperature not greater than 150°C.

A dining room containing such appliances is not regarded as a pantry.

1.2.2 Cargo area

The cargo area is that part of the ship that contains cargo tanks, slop tanks, cargo pump rooms as well as deck areas throughout the entire length and breadth of the part of the ship above these spaces.

1.2.3 Cargo pump room

Cargo pump room is a space containing pumps and their accessories for the handling of products covered by the service notation granted to the ship.

1.2.4 Cargo service spaces

Cargo service spaces are spaces within the cargo area used for workshops, lockers and storerooms of more than 2 m^2 in area, intended for cargo handling equipment.

1.2.5 Cofferdam

For the purpose of Ch 4, Sec 2, a cofferdam is an isolating space between two adjacent steel bulkheads or decks. It is to meet the following criteria:

a) The minimum distance between the two bulkheads or decks is to be sufficient for safe access and inspection

b) In order to meet the single failure principle, in the particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner.

1.2.6 Hold space

Hold space is the space enclosed by the ship's structure in which an independent cargo tank is fitted.

1.2.7 Fuel oil

Fuel oil means any oil used as fuel in connection with the propulsion and auxiliary machinery of the ship on which such oil is carried.

1.2.8 Machinery spaces

Machinery spaces are all machinery spaces of category A and all other spaces containing propulsion machinery, boilers, fuel cells systems, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

1.2.9 Non-sparking fan

A fan is considered as non-sparking if in either normal or abnormal conditions it is unlikely to produce sparks. For this purpose, the following criteria are to be met:

a) Design criteria

   1) The air gap between the impeller and the casing is to be not less than 1/10 of the shaft diameter in way of the impeller bearing and in any case not less than 2 mm, but need not exceed 13 mm.

   2) Protective screens with square mesh of not more than 13 mm are to be fitted to the inlet and outlet of ventilation ducts to prevent objects entering the fan housing.

b) Materials

   1) Except as indicated in the fourth bullet of item b) 3) below, the impeller and the housing in way of the impeller are to be made of spark-proof materials which are recognised as such by means of an appropriate test to the satisfaction of the Society.

   2) Electrostatic charges, both in the rotating body and the casing, are to be prevented by the use of antistatic materials. Furthermore, the installation on board of ventilation units is to be such as to ensure their safe bonding to the hull.

3) Tests may not be required for fans having the following material combinations:
   - impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
   - impellers and housings of non-ferrous materials
   - impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous material is fitted in way of the impeller
   - any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

1.2.10 Segregated ballast

Segregated ballast means the ballast water introduced into a tank which is completely separated from the cargo oil and fuel oil system and which is permanently allocated to the carriage of ballast

1.2.11 Service spaces

Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, laundries, waste compactors, ironing rooms, laboratories, oven, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

a) Main pantries and pantries containing cooking appliances may contain:
   1) coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances, each with a power of more than 5 kW
   2) electrically heated cooking plates and hot plates for keeping food warm, each with a maximum power of 5 kW.

b) Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 4, Sec 6, as galleys.

1.2.12 Slop tank

Slop tank means a tank specifically designated for the collection of tank draining, tank washings and other oily mixtures.

1.2.13 Ammunition spaces

Ammunition spaces are the spaces (integral magazines, independent magazines, small magazines, magazines lockers, magazines boxes and pyrotechnics lockers) used for the storage of ammunition (missiles, shells, mines, demolition stores, etc. charged with explosives, propellant, pyrotechnics, initiating compositions or nuclear, biological or chemical material) for use in conjunction with offensive, defensive, training or non operating purposes, including those parts of the weapons systems containing explosives. Lifting spaces for ammunition are to be considered as ammunition spaces for the purpose of this Chapter.

1.2.14 Open superstructure

An open superstructure is a superstructure which is:

- open at both ends, or
- open at one end and provided with adequate natural ventilation effective over the entire length through permanent openings to outside of at least 10% of the total area of the space sides, or
- provided with adequate natural ventilation effective over the entire length though permanent openings to outside of at least 30% of the total area of the space sides.

Note 1: the total area of the space sides excludes the deck area of the space.

1.2.15 Breadth (B)

Breadth (B) means the maximum breadth of the ship, measured amidships to the moulded line of the frame. The breadth shall be measured in metres.

Section 2 Ship Arrangement

1 General

1.1 Documents to be submitted

1.1.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document
1	General arrangement drawing with indication of: • access and openings • capacity and size of the cargo tanks, slop tanks and ballast tanks • dry stores and ammunition transfer routes
2	Diagram of the mechanical and natural ventilation with indication of the ventilation inlets and outlets

2 Definitions

2.1 Deadweight

2.1.1 For the application of this Section and of Ch 4, Sec 4, "Deadweight" is to be understood as the mass, in tons, of the maximum cargo oil capacity of the ship, corresponding to the highest cargo density.

3 Ship arrangement

3.1 Double bottom arrangement outside of cargo area

3.1.1 *Except for the cargo area where requirements of [5] apply, a double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.*

3.1.2 *Where a double bottom is required to be fitted, the inner bottom is to be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection is to be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h measured from the keel line, as calculated by the formula: h = B/20*

However, in no case is the value of h to be less than 760 mm, and need not to be taken as more than 2 m.

3.1.3 *Small wells constructed in the double bottom, in connection with the drainage arrangements of holds, are not to extend downward more than necessary. A well extending to the outer bottom, is, however, permitted at the after end of the shaft tunnel of the ship. Other wells may be permitted by the Society if it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with [3.1]. In no case, the vertical distance from the bottom of such a well to a plane coinciding with the keel line is to be less than 500 mm.*

3.1.4 *A double bottom need not be fitted in way of watertight tanks, including dry tanks of moderate size, provided the safety of the ship is not impaired in the event of bottom or side damage as defined in Ch 4, Sec 3, [1.2].*

3.1.5 *In the case of unusual bottom arrangements, it is to be demonstrated that the ship is capable of withstanding bottom damages, as specified in Ch 4, Sec 3, [1.2]*

3.2 Openings in watertight bulkheads below the bulkhead deck

3.2.1 *The number of openings in watertight bulkheads shall be reduced to the minimum compatible with the design and proper working of the ship; satisfactory means shall be provided for closing these openings.*

3.2.2

a) *Where pipes, scuppers, electric cables, etc.;, are carried through watertight bulkheads, arrangements shall be made to ensure the watertight integrity of the bulkheads.*

b) *Valves not forming part of a piping system shall not be permitted in watertight bulkheads.*

c) *Heat sensitive materials shall not be used in systems which penetrate watertight bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkheads.*

3.2.3 Openings in machinery spaces

Not more than one door apart from the doors to shaft tunnels may be fitted in each watertight bulkhead within spaces containing the main and auxiliary propulsion machinery including boilers serving the needs of propulsion. Where two or more shafts are fitted the tunnels are to be connected by an inter-communicating passage. Only one door is to be provided between the machinery space and the tunnel spaces where two shafts are fitted and only two doors where there are more than two shafts. All these doors are to be of the sliding type and are to be so located as to have their sills as high as practicable. The hand gear for operating these doors from above the bulkhead deck is to be situated outside the spaces containing the machinery.

Portable plates on bulkheads are not permitted except in machinery spaces. The Society may permit not more than one power-operated sliding watertight door in each watertight bulkhead larger than 1,20 m to be substituted for these portable plates, provided these doors are intended to remain closed during navigation except in the case of urgent necessity at the discretion of the Master. These doors need not meet the requirements of complete closure by hand-operated gear in 90 seconds (see [3.2.7] e).

3.2.4 Openings in cargo spaces

Watertight doors complying with the requirements of [3.2.7] may be fitted in watertight bulkheads dividing cargo between deck spaces. Such doors may be hinged, rolling or sliding doors but are not to be remotely controlled. They are to be fitted at the highest level and as far from the shell plating as practicable, but in no case are the outboard vertical edges to be situated at a distance from the shell plating which is less than one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line.

The doors accessible during the voyage are to be fitted with a device which prevents unauthorised opening. When it is proposed to fit such doors, the number and arrangements are to receive the special consideration of the Society.

3.2.5 Trunks and tunnels

Where trunkways or tunnels for access from crew accommodation to the stokehold, for piping, or for any other purpose are carried through watertight bulkheads, they are to be watertight and in accordance with the requirements of NR467, Pt B, Ch 4, Sec 7, [1.3]. The access to at least one end of each such tunnel or trunkway, if used as a passage at sea, is to be through a trunk extending watertight to a height sufficient to permit access above the bulkhead deck. The access to the other end of the trunkway or tunnel may be through a watertight door of the type required by its location in the ship. Such trunkways or tunnels are not to extend through the first subdivision bulkhead abaft the collision bulkhead.

Where trunkways in connection with refrigerated cargo and ventilation or forced draught trunks are carried through more than one watertight bulkhead, the means of closure at such openings are to be operated by power and be capable of being closed from a central position situated above the bulkhead deck.

3.2.6 Requirements for doors

The requirements relevant to the degree of tightness, as well as the operating systems, for doors complying with the prescriptions in [3.2.7] are specified in Tab 2.

3.2.7 Doors in watertight bulkheads below the bulkhead deck

a) *Watertight doors, except as provided in [3.2.4] paragraph 1, are to be capable of being closed simultaneously from the central operating console at the navigation bridge in not more than 60 s with the ship in the upright position.*

b) *The means of operation whether by power or by hand of any power-operated sliding watertight door are to be capable of closing the door with the ship listed to 15° either way. Consideration is to also be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.*

c) *Watertight door controls, including hydraulic piping and electrical cables, are to be kept as close as practicable to the bulkhead in which the doors are fitted, in order to minimise the likelihood of them being involved in any damage which the ship may sustain. The positioning of watertight doors and their controls are to be such that if the ship sustains damage within one fifth of the breadth of the ship, such distance being measured at right angles to the centreline at the level of the deepest subdivision load line, the operation of the watertight doors clear of the damaged portion of the ship is not impaired.*

d) *All power-operated sliding watertight doors are to be provided with means of indication which show at all remote operating positions whether the doors are open or closed. Remote operating positions are only to be located at the navigating bridge and at the location where hand operation above the bulkhead deck is required by e).*

e) *Each power-operated sliding watertight door:*
- *is to move vertically or horizontally;*
- *is to be normally limited to a maximum clear opening width of 1,20 m. The Society may permit larger doors only to the extent considered necessary for the effective operation of the ship provided that other safety measures, including the following, are taken into consideration:*
  - *special consideration is to be given to the strength of the door and its closing appliances in order to prevent leakages;*
  - *the door is to be located outside the damage zone B/5.*
- *is to be fitted with the necessary equipment to open and close the door using electrical power, hydraulic power, or any other form of power that is acceptable to the Society;*
- *is to be provided with an individual hand-operated mechanism. It is to be possible to open and close the door by hand at the door itself from either side and, in addition, close the door from an accessible position above the bulkhead deck with an all round crank motion or some other movement providing the same degree of safety acceptable to the Society. Direction of rotation or other movement is to be clearly indicated at all operating positions. The time necessary for the complete closure of the door, when operating by hand gear, may not exceed 90 s with the ship in the upright position;*
- *is to be provided with controls for opening and closing the door by power from both sides of the door and also for closing the door by power from the central operating console at the navigation bridge;*
- *is to be provided with an audible alarm, distinct from any other alarm in the area, which is to sound whenever the door is closed remotely by power and which is to sound for at least 5 s but no more than 10 s before the door begins to move and is to continue sounding until the door is completely closed. In the case of remote hand operation it is sufficient for the audible alarm to sound only when the door is moving. Additionally, in passenger areas and areas of high ambient noise, the Society may require the audible alarm to be supplemented by an intermittent visual signal at the door;*
- *is to have an approximately uniform rate of closure under power. The closure time, from the time the door begins to move to the time it reaches the completely closed position, is to in no case be less than 20 s or more than 40 s with the ship in the upright position.*

f) *The electrical power required for power-operated sliding watertight doors is to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and be capable of being automatically supplied by a transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power.*

The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to control, indication and alarm circuits at least for half an hour.

g) *Power-operated sliding watertight doors are to have either:*
- *a centralised hydraulic system with two independent power sources each consisting of a motor and pump capable of simultaneously closing all doors. In addition, there are to be for the whole installation hydraulic accumulators of sufficient capacity to operate all the doors at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. The power operating system is to be designed to minimise the possibility of having a single failure in the hydraulic piping adversely affect the operation of more than one door. The hydraulic system is to be provided with a low-level alarm for hydraulic fluid reservoirs serving the power-operated system and a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators. These alarms are to be audible and visual and are to be situated on the central operating console at the navigating bridge; or*
- *an independent hydraulic system for each door with each power source consisting of a motor or pump capable of opening and closing the door. In addition, there is to be a hydraulic accumulator of sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°. This operating cycle is to be capable of being carried out when the accumulator is at the pump cut-in pressure. The fluid used is to be chosen considering the temperatures liable to be encountered by the installation during its service. A low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators is to be provided at the central operating console on the navigation bridge. Loss of stored energy indication at each local operating position is to also be provided; or*
- *an independent electrical system and motor for each door with each power source consisting of a motor capable of opening and closing the door. The power source is to be capable of being automatically supplied by the transitional source of emergency electrical power in the event of failure of either the main or emergency source of electrical power and with sufficient capacity to operate the door at least three times, i.e. closed-open-closed, against an adverse list of 15°.*

  The transitional source of emergency electrical power is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be of sufficient capacity and so arranged as to supply power automatically, in the event of failure of either the main or emergency source of electrical power, to watertight doors, but not necessarily all of them simultaneously, unless an independent source of stored energy is provided.

For the systems specified above, provision is to be made as follows:

Power systems for power-operated watertight sliding doors are to be separate from any other power system. A single failure in the electrical or hydraulic power-operated systems excluding the hydraulic actuator is not to prevent the hand operation of any door.

h) *Control handles are to be provided at each side of the bulkhead at a minimum height of 1,6 m above the floor and are to be so arranged as to enable persons passing through the doorway to hold both handles in the open position without being able to set the power closing mechanism in operation accidentally. The direction of movement of the handles in opening and closing the door is to be in the direction of door movement and is to be clearly indicated.*

i) *As far as practicable, electrical equipment and components for watertight doors are to be situated above the bulkhead deck and outside hazardous areas and spaces.*

j) *The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water.*

k) *Electric power, control, indication and alarm circuits are to be protected against faults in such a way that a failure in one door circuit is not to cause a failure in any other door circuit. Short-circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of that door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck is not to cause the door to open.*

l) *A single electrical failure in the power operating or control system of a power-operated sliding watertight door is not to result in a closed door opening. Availability of the power supply is to be continuously monitored at a point in the electric circuit as near as practicable to each of the motors required in g). Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigation bridge.*

m) *The central operating console at the navigation bridge is to have a "master mode" switch with two modes of control:*

- *a "local control" mode which is to allow any door to be locally opened and locally closed after use without automatic closure, and*
- *a "doors closed" mode which is to automatically close any door that is open. The "doors closed" mode is to permit doors to be opened locally and is to automatically reclose the doors upon release of the local control mechanism.*

The "master mode" switch is to normally be in the "local control" mode. The "doors closed" mode is to only be used in an emergency or for testing purposes. Special consideration is to be given to the reliability of the "master mode" switch.

n) *The central operating console at the navigation bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light is to indicate a door is fully closed. When the door is closed remotely the red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.*

o) *It is not to be possible to remotely open any door from the central operating console.*

Table 2 : Doors

			Sliding type			Hinged type			Rolling type (cargo between deck spaces)
			Remote operation indication on the bridge	Indicator on the bridge	Local operation only	Remote operation indication on the bridge	Indicator on the bridge	Local operation only	
Watertight	below the bulkhead deck	open at sea	X						
		normally closed**(4)**	X						
		remain closed **(4)**					X **(1)**		X **(1)** **(3)**
Weathertight / semi-watertight **(2)**	above the bulkhead deck	open at sea	X			X			
		normally closed**(4)**		X			X		
		remain closed **(4)**						X	

(1) The door is to be closed before the voyage commences.
(2) Semi-watertight doors are required when they are located below the waterline at the equilibrium of the intermediate stages of flooding.
(3) If the door is accessible during the voyage, a device which prevents unauthorised opening is to be fitted.
(4) Notice to be affixed on both sides of the door: "to be kept closed at sea".

4 General arrangement of the ship with regard to fire prevention and crew safety

4.1 Location and separation of spaces

4.1.1 Tanks containing cargo or cargo residues are to be segregated from accommodation, service and machinery spaces, tanks containing drinking water and stores for human consumption by means of a cofferdam or similar space.

4.1.2 Double bottom tanks adjacent to cargo tanks are not to be used as fuel oil tanks.

4.1.3 Protection of accommodations

Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation, is to be constructed of steel and insulated to A-60 standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m is to be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation is to be carried up to the underside of the deck of the navigation bridge.

Note 1: For the portions which face the cargo area, the A-60 standard insulation should be provided up to the underside of the deck of the navigation bridge.

4.2 Access and openings

4.2.1 Access and openings to accommodation spaces, service spaces, control stations and machinery spaces

Access doors, air inlets and openings to accommodation spaces, service spaces and control stations are not to face the cargo area.

4.2.2 Access to spaces in the cargo area

a) *Safe access to cofferdams, ballast tanks, cargo tanks and other compartments in the cargo area is to be direct from the open deck and such as to ensure their complete inspection. Safe access to double bottom compartments or to forward ballast tanks may be from a pump-room, deep cofferdam, pipe tunnel, double hull compartment or similar compartment not intended for the carriage of oil or hazardous cargoes.*

Note 1: Unless other additional arrangements provided to facilitate their access are considered satisfactory by the Society, the double bottom tanks are to be provided with at least two separate means of access complying with a) above.

b) *For access through horizontal openings, hatches or manholes, the dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment to ascend or descend any ladder without obstruction and also provide a clear opening to facilitate the hoisting of an injured person from the bottom of the compartment. The minimum clear opening is to be not less than 600 mm x 600 mm.*

c) *For access through vertical openings, or manholes, in swash bulkheads, floors, girders and web frames providing passage through the length and breadth of the compartment, the minimum opening is to be not less than 600 mm x 800 mm at a height of not more than 600 mm from the bottom shell plating unless gratings or other foot holds are provided.*

d) *Access ladders of cargo tanks are to be fitted with handrails and to be securely attached to the tank structure. They are not to be fitted vertically, unless justified by the size of the tanks. Rest platforms are to be provided at suitable intervals of not more than 10 m.*

4.2.3 Access to the pipe tunnels

a) *The pipe tunnels in the double bottom are to comply with the following requirements:*
   1) *they are not to communicate with the engine room,*
   2) *provision is to be made for at least two exits to the open deck arranged at a maximum distance from each other. One of these exits fitted with a watertight closure may lead to the cargo pump room.*

b) *Where there is permanent access from a pipe tunnel to the main pump room, a watertight door is to be fitted complying with the requirements of NR467, Pt B, Ch 2, Sec 1, [5] and in addition with the following:*
   1) *in addition to the bridge operation, the watertight door is to be capable of being manually closed from outside the main pump room entrance,*
   2) *the watertight door is to be kept closed during normal operations of the ship except when access to the pipe tunnel is required.*

Note 1: A notice is to be affixed to the door to the effect that it may not be left open.

4.3 Ventilation

4.3.1 General

Spaces located within the cargo area are to be efficiently ventilated. Portable means of ventilation are permitted.

4.3.2 Ventilation of cargo pump rooms

The ventilation of the cargo pump room is to comply with requirements of Ch 4, Sec 4, [4.5.1].

5 General arrangement of the ship with regard to pollution prevention

5.1 Protection of the cargo tank length in the event of grounding or collision

5.1.1 General

a) *The design and construction of auxiliary naval vessels is to pay due regard to the general safety aspects including the need for maintenance and inspections of wing and double bottom tanks or spaces.*

b) *Oil is not to be carried in any space extending forward of a collision bulkhead located in accordance with NR467, Pt B, Ch 2, Sec 1, [2]. An oil tanker that is not required to have a collision bulkhead in accordance with that regulation is not to carry oil in any space extending forward of the transverse plane perpendicular to the centreline that is located as if it were a collision bulkhead located in accordance with that regulation.*

5.1.2 Case of ships of 5000 tons deadweight and above

On auxiliary naval vessels of 5000 tons deadweight and above, the entire cargo tank length is to be protected by ballast tanks or spaces other than cargo and fuel oil tanks as follows:

a) *Wing tanks or spaces*

Wing tanks or spaces are to extend either for the full depth of the ship's side or from the top of the double bottom to the uppermost deck, disregarding a rounded gunwale where fitted. They are to be arranged such that the cargo tanks are located inboard of the moulded line of the side shell plating, nowhere less than the distance w which, as shown in Fig 1 is measured at any cross-section at right angles to the side shell, as specified below:

$$w = 0,5 + \frac{DW}{20000}(m)$$

or w = 2,0 m, whichever is the lesser.

The minimum value of w = 1,0 m.

b) *Double bottom tanks or spaces*

At any cross-section, the depth of each double bottom tank or compartment is to be such that the distance h between the bottom of the cargo tanks and the moulded line of the bottom shell plating measured at right angles to the bottom shell plating, as shown in Fig 1 is not less than specified below:

- *B/15 (m), or*
- *2,0 m, whichever is the lesser.*

The minimum value of h = 1,0 m.

Note 1: Double bottom tanks or spaces as required by the above paragraph may be dispensed with, provided that the design of the tanker is such that the cargo and vapour pressure exerted on the bottom shell plating forming a single boundary between the cargo and the sea does not exceed the external hydrostatic water pressure, as expressed by the following formula:

$$f \times h_c \times \rho_c \times g + 100\Delta_p \le d_n \times \rho_s \times g$$

where:

h_c : *Height of cargo in contact with the bottom shell plating, in metres*

ρ_c : *Maximum cargo density, in t/m³*

d_n : *Minimum operating draught under any expected loading conditions, in metres*

ρ_s : *Density of seawater, in t/m³*

Δ_p : *Maximum set pressure of pressure/vacuum valve provided for the cargo tanks, in bars*

f : *Safety factor = 1,1*

g : *Standard acceleration of gravity (9,81 m/s²).*

Any horizontal partition necessary to fulfil the above requirements are to be located at a height of not less than B/6 or 6 m, whichever is the lesser, but not more than 0,6D, above the baseline where D is the moulded depth amidships.

The location of wing tanks or spaces is to be as defined in item a) above except that, below a level 1,5 h above the baseline where h is as defined above, the cargo tank boundary line may be vertical down to the bottom plating, as shown in Fig 2.

Figure 1 : Cargo tank boundary lines

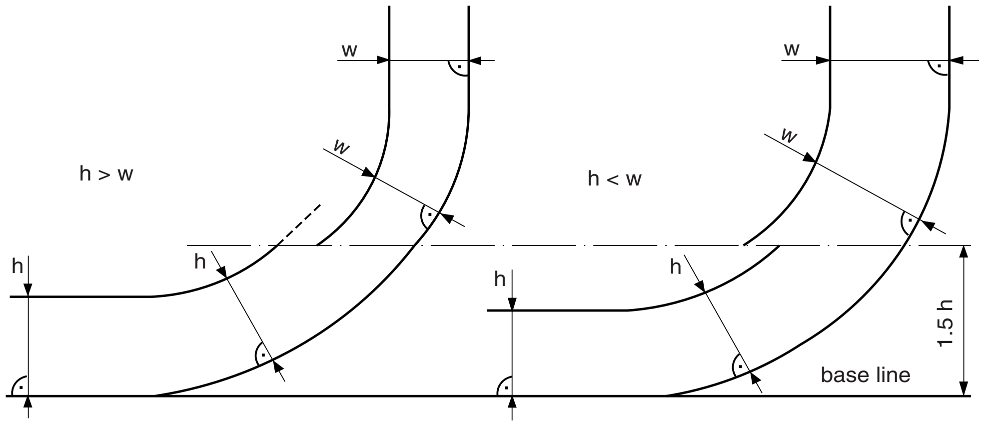
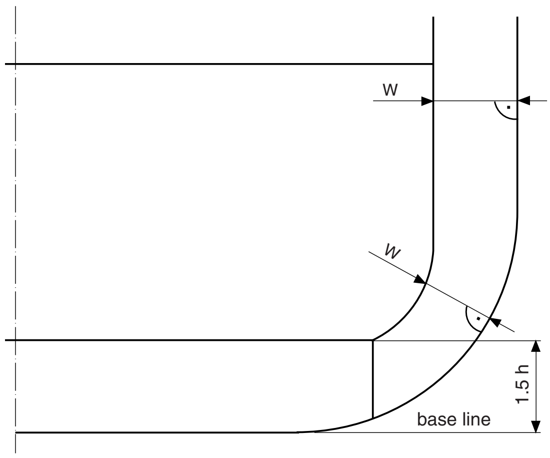


Figure 2 : Cargo tank boundary lines



c) *Turn of the bilge area or at locations without a clearly defined turn of the bilge*

Where the distance h and w are different, the distance w is to have preference at levels exceeding 1,5 h above baseline as shown in Fig 1.

d) *Suction wells in cargo tanks may protube into the double bottom below the boundary line defined by the distance h provided that such wells are as small as practicable and the distance between the well bottom and bottom shell plating is not less than 0,5 h.*

e) *Ballast and cargo piping is to comply with the provisions of Ch 4, Sec 4, [3.3.1] and Ch 4, Sec 4, [4.4.1].*

Note 2: Other methods of design and construction of auxiliary naval vessels may also be accepted as alternatives to the requirements prescribed in items a) to e), provided that such methods ensure at least the same level of protection against oil pollution in the event of collision or stranding and are approved in principle by the Society.

The Society will accept the methods of design and construction described in IMO Resolution MEPC.110(49) and its corrigenda.

5.1.3 Case of ships of less than 5000 tons deadweight

Auxiliary naval vessels of less than 5000 tons deadweight are to:

a) *at least be fitted with double bottom tanks or spaces having such a depth that the distance h specified in [5.1.2] b) complies with the following:*

$h = B/15$ (m)

with a minimum value of h = 0,76 m;

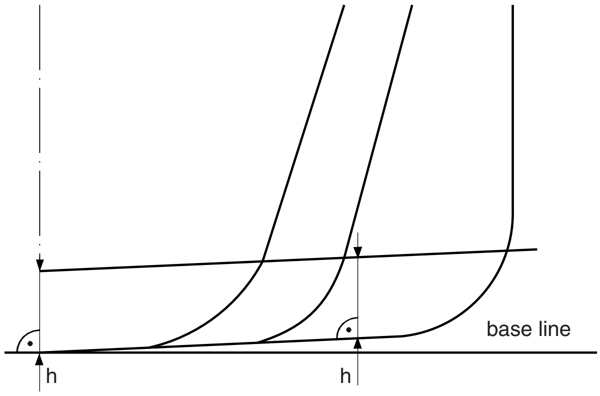
in the turn of the bilge area and at locations without a clearly defined turn of bilge, the cargo tank boundary line is to run parallel to the line of the midship flat bottom as shown in Fig 3; and

b) *be provided with cargo tanks so arranged that the capacity of each cargo tank does not exceed 700 m³ unless wing tanks or spaces are arranged in accordance with [5.1.2] a) complying with the following:*

$$w = 0,4 + \frac{2,4DW}{20000}(m)$$

with a minimum value of w = 0,76 m.

Figure 3 : Cargo tank boundary lines



5.2 Segregation of oil and water ballast

5.2.1 No ballast water is to be carried in any oil fuel tank.

5.3 Accidental oil outflow performance

5.3.1 Auxiliary naval vessels are to comply with the requirements of the Regulation 23 of Annex I to Marpol Convention, as amended.

5.4 Retention of oil on board - Slop tanks

5.4.1 General

a) *Auxiliary naval vessels shall be provided with slop tank arrangements in accordance with items a) and b) below, [5.4.2] and [5.4.3].*

b) *Adequate means are to be provided for transferring the dirty ballast residue and tank washings from the cargo tanks into a slop tank approved by the Society.*

c) *Arrangements are to be provided to transfer the oily waste into a slop tank or combination of slop tanks.*

5.4.2 Capacity of slop tanks

The arrangement of the slop tank or combination of slop tanks is to have a capacity necessary to retain the slop generated by tank washings, oil residues and dirty ballast residues. The total capacity of the slop tank or tanks is not to be less than 3% of the oil carrying capacity of the ship, except that the Society may accept:

a) *2% for auxiliary naval vessels where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without the introduction of additional water into the system*

b) *2% where segregated ballast tanks are provided in accordance with [5.2]. This capacity may be further reduced to 1,5% where the tank washing arrangements are such that once the slop tank or tanks are charged with washing water, this water is sufficient for tank washing and, where applicable, for providing the driving fluid for eductors, without introduction of additional water into the system.*

Auxiliary naval vessels of 70 000 tons deadweight and above are to be fitted with at least two slop tanks.

5.4.3 Design of slop tanks

Slop tanks are to be so designed particularly in respect of the position of inlets, outlets, baffles or weirs where fitted, so as to avoid excessive turbulence and entrainment of oil or emulsion with the water.

5.5 Deck spills

5.5.1

a) *Means are to be provided to keep deck spills away from accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a height of at least 300 mm, extending from side to side. Special consideration shall be given to the arrangements associated with stern loading.*

Note 1: The provisions of paragraph a) above also apply to bow and stern cargo loading stations.

b) *Where gutter bars are installed on the weather decks of oil tankers in way of cargo manifolds and are extended aft as far as the aft bulkhead of superstructures for the purpose of containing cargo spills on deck during loading and discharge operations, the free surface effects caused by containment of a cargo spill during liquid transfer operations or of boarding seas while underway are to be considered with respect to the vessel's available margin of positive initial stability (GMo).*

c) *Where the gutter bars installed are higher than 300 mm, they are to be treated as bulwarks with freeing ports arranged in accordance with NR467, Pt B, Ch 9, Sec 9, [5] and provided with effective closures for use during loading and discharge operations. Attached closures are to be arranged in such a way that jamming is prevented while at sea, enabling the freeing ports to remain effective.*

d) *On ships without deck camber, or where the height of the installed gutter bars exceeds the camber, and for oil tankers having cargo tanks exceeding 60% of the vessel's maximum beam amidships regardless of gutter bar height, gutter bars may not be accepted without an assessment of the initial stability (GMo) for compliance with the relevant intact stability requirements taking into account the free surface effect caused by liquids contained by the gutter bars.*

5.6 Pump-room bottom protection

5.6.1 General

This Article is applicable to auxiliary naval vessels of 5000 tons deadweight and above.

5.6.2 *The pump-room is to be provided with a double bottom such that at any cross-section the depth of each double bottom tank or space is to be such that the distance h between the bottom of the pump-room and the ship's base line measured at right angles to the ship's base line is to be not less than the lesser of:*

- *h= B/15 m*
- *h=2m*

without being taken less than 1 m.

5.6.3 *In case of pump rooms whose bottom plate is located above the base line by at least the minimum height required in [5.6.2] (e.g. gondola stern designs), there is no need for a double bottom construction in way of the pump-room.*

5.6.4 *Ballast pumps are to be provided with suitable arrangements to ensure efficient suction from double bottom tanks.*

5.6.5 *Notwithstanding the provisions of [5.6.2] and [5.6.3], where the flooding of the pump-room would not render the ballast or cargo pumping system inoperative, a double bottom need not be fitted.*

Section 3 Hull and Stability

Symbols

L_{LL} : Load line length, in m, defined in NR467, Pt B, Ch 1, Sec 2, [3.2]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to 235/k N/mm^2, unless otherwise specified

k : Material factor for steel, defined in NR467, Pt B, Ch 4, Sec 1, [2.3]

E : Young's modulus, in N/mm^2, to be taken equal to:

- $E = 2{,}06 \cdot 10^5$ N/mm^2 for steels in general
- $E = 1{,}95 \cdot 10^5$ N/mm^2 for stainless steels.

1 Stability

1.1 Intact stability

1.1.1 General

The stability of the ship for the loading conditions specified in NR467, Pt B, Ch 3, App 2, [1.2.6] is to be in compliance with the requirements of NR467, Pt B, Ch 3, Sec 2. In addition, the requirements in [1.1.2] are to be complied with.

1.1.2 Liquid transfer operations

Ships with certain internal subdivision may be subjected to lolling during liquid transfer operations such as loading, unloading or ballasting. In order to prevent the effect of lolling, the design of ships having the service notation ***auxiliary naval vessel*** *is to be such that the following criteria are complied with:*

a) *The intact stability criteria reported in b) is to be complied with for the worst possible condition of loading and ballasting as defined in c), consistent with good operational practice, including the intermediate stages of liquid transfer operations. Under all conditions the ballast tanks are to be assumed slack.*

b) *The initial metacentric height GMo, in m, corrected for free surface measured at 0° heel, is to be not less than 0,15. For the purpose of calculating GMo, liquid surface corrections are to be based on the appropriate upright free surface inertia moment.*

c) *The vessel is to be loaded with:*
   - *all cargo tanks filled to a level corresponding to the maximum combined total of vertical moment of volume plus free surface inertia moment at 0° heel, for each individual tank*
   - *cargo density corresponding to the available cargo deadweight at the displacement at which transverse KM reaches a minimum value*
   - *full departure consumable*
   - *1% of the total water ballast capacity.The maximum free surface moment is to be assumed in all ballast tanks.*

1.2 Damage stability

1.2.1 General

The Ship is to comply with the subdivision and damage stability criteria as specified in [1.2.8], after the assumed side or bottom damage as specified in [1.2.2], for the standard of damage described in [1.2.3], and for any operating draught reflecting actual partial or full load conditions consistent with trim and strength of the ship as well as specific gravities of the cargo.

The actual partial or full load conditions to be considered are those specified in NR467, Pt B, Ch 3, App 2, [1.2.6].

1.2.2 Damage dimensions

The assumed extent of damage is to be as defined in Tab 1.

The transverse extent of damage is measured inboard the ship side at right angles to the centreline at the level of the summer load line.

For the purpose of determining the extent of assumed damage, suction wells may be neglected, provided such wells are not excessive in areas and extend below the tank for a minimum distance and in no case more than half the height of the double bottom.

The vertical extent of damage is measured from the moulded line of the bottom shell plating at centreline.

If any damage of a lesser extent than the maximum extent of damage specified in Tab 1 would result in a more severe condition, such damage is to be considered.

1.2.3 Standard of damage

The damage in [1.2.2] is to be applied to all conceivable locations along the length of the ship, according to Tab 2.

1.2.4 Calculation method

The metacentric heights (GM), the stability levers (GZ) and the centre of gravity positions (KG) for judging the final survival conditions are to be calculated by the constant displacement method (lost buoyancy).

1.2.5 Flooding assumptions

The requirements of [1.2.8] are to be confirmed by calculations which take into consideration the design characteristics of the ship, the arrangements, configuration and contents of the damaged compartments and the distribution, specific gravities and free surface effect of liquids.

Where the damage involving transverse bulkheads is envisaged as specified in [1.2.3], transverse watertight bulkheads are to be spaced at least at a distance equal to the longitudinal extent of assumed damage specified in [1.2.2] in order to be considered effective. Where transverse bulkheads are spaced at a lesser distance, one or more of these bulkheads within such extent of damage is to be assumed as non-existent for the purpose of determining flooded compartments.

1.2.6 Progressive flooding

If pipes, ducts or tunnels are situated within the assumed extent of damage penetration as defined in [1.2.2], arrangements are to be made so that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable in the calculation for each case of damage.

1.2.7 Permeabilities

The specific gravity of cargoes carried, as well as any outflow of liquid from damaged compartments, are to be taken into account for any empty or partially filled tank.

The permeability of compartments assumed to be damaged are to be as indicated in Tab 3.

1.2.8 Survival requirements

Ships having the service notation **auxiliary naval vessel** are to be regarded as complying with the damage stability criteria if the requirements of [1.2.9] and [1.2.10] are met.

Table 1 : Extent of damage

Damage		Longitudinal extent	Transverse extent	Vertical extent
Side		l_C = 1/3 $L_{LL}^{2/3}$ or 14,5 m **(1)**	t_C = B/5 or 11,5 m **(1)**	v_C = without limit
Bottom	For 0,3 L_{LL} from the forward perpendicular	l_S = 1/3 $L_{LL}^{2/3}$ or 14,5 m **(1)**	t_S = B/6 or 10,0 m **(1)**	v_S = B/15 or 6,0 m **(1)**
	any other part	l_S = 1/3 $L_{LL}^{2/3}$ or 5,0 m **(1)**	t_S = B/6 or 5,0 m **(1)**	v_S = B/15 or 6,0 m **(1)**
(1) Whichever is the lesser				

Table 2 : Standard of damage

Ship's length, in m	Damage anywhere in ship's length	Machinery space flooded
$L_{LL} \leq 225$	Yes	Yes, alone
$L_{LL} > 225$	Yes	Yes

Table 3 : Permeability

Compartments	Permeability
Appropriate for stores	0,60
Intended for ammunition storage	0,80
Occupied by accommodation	0,95
Occupied by machinery	0,85
Void compartments	0,95
Intended for consumable liquids	0 to 0,95 **(1)**
Intended for other liquids	0 to 0,95 **(1)**
(1) The permeability of partially filled compartments is to be consistent with the amount of liquid carried in the compartment. Whenever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.	

1.2.9 Final stage of flooding

a) The final waterline, taking into account sinkage, heel and trim, shall not immerse:

1) the lower edge of any opening through which progressive flooding may take place. Such openings shall include air-pipes and those which are closed by means of weathertight doors or hatch covers and may exclude those openings closed by means of watertight manhole covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and sidescuttles of the non-opening type

2) any part of the bulkhead deck considered an horizontal evacuation route for compliance with the requirements of Ch 4, Sec 7

3) The progressive flooding is to be considered in accordance with NR467, Pt B, Ch 3, Sec 3, [3.3].

b) Furthermore, the waterline after damage in any intermediate stage of flooding, or in the final stage of flooding shall not immerse:

1) any vertical escape hatch in the bulkhead deck intended for compliance with the requirements of Ch 4, Sec 7

2) any controls intended for operation of watertight doors, equalization devices, valves on piping or on ventilation ducts intended to maintain the integrity of watertight bulkheads from above the bulkhead deck. In addition, these controls shall remain accessible and operable

3) any part of piping or ventilation ducts carried out through a watertight boundary if not fitted with watertight means of closure at each boundary.

c) The maximum angle of heel after flooding but before equalization shall not exceed 20°. Where cross flooding fittings are required, the time for equalization shall not exceed 15 minutes. The controls are to be operable with a maximum heel angle of 20°.

The equalization system is to be independent without need of any power supply, and sufficient residual stability is to be maintained during all stages where equalisation is used.

In the final stage of flooding after equalization, the angle of heel shall not exceed 15°.

d) The stability is to be investigated and may be regarded as sufficient if the righting lever curve has at least a range of 20° beyond the position of equilibrium in association with a maximum residual righting lever, in m, of at least 0,1 within the 20° range; the area, in m·rad, under the curve within this range is to be not less than 0,0175.

1.2.10 Intermediate stage of flooding

The Society is to be satisfied that the stability is sufficient during the intermediate stages of flooding. To this end the Society applies the same criteria relevant to the final stage of flooding also during the intermediate stages of flooding.

1.2.11 Bottom raking damage

This requirement applies to auxiliary naval vessels of 20000 t deadweight and above.

The damage assumptions relative to the bottom damage prescribed in [1.2.2] are to be supplemented by the assumed bottom raking damage of Tab 4.

The requirements of [1.2.8] are to be complied with for the assumed bottom raking damage.

Table 4 : Bottom damage extent

Deadweight	Longitudinal extent	Transverse extent	Vertical extent
< 75000 t	0,4 L_{LL} **(1)**	B/3	**(2)**
≥ 75000 t	0,6 L_{LL} **(1)**	B/3	**(2)**
(1) Measured from the forward perpendicular. **(2)** Breach of the outer hull.			

1.2.12 Information to the Master

The Master of every ship having the service notation ***auxiliary naval vessel*** *is to be supplied in an approved form with:*

- *information relative to loading and distribution of cargo necessary to ensure compliance with the requirements relative to stability, and*
- *data on the ability of the ship to comply with damage stability criteria as determined in [1.2.8].*

1.2.13 Loading instrument

Ships having the service notation **auxiliary naval vessel** are to be provided with an approved loading instrument of a type to the satisfaction of the Society.

A simple and straightforward instruction manual is to be provided.

In order to validate the proper functioning of the computer hardware and software, pre-defined loading conditions are to be run in the loading instrument periodically, at least at every periodical class survey, and the print-out is to be maintained on board as check conditions for future reference in addition to the approved test conditions booklet.

The procedure to be followed, as well as the list of technical details to be sent in order to obtain loading instrument approval, are given in NR467, Pt B, Ch 11, Sec 2, [4].

2 Loading conditions

2.1 Propeller immersion

2.1.1 For all loading cases of the ship, including ballast conditions and ballast water exchange sequences, the draught at the after perpendicular is to be not less than that which is necessary to obtain full immersion of the propeller(s).

3 Structure

3.1 Application

3.1.1 The requirements of this article come in addition to those of NR467, Part B and NR467, Pt D, Ch 7, Sec 3, [2] to NR467, Pt D, Ch 7, Sec 3, [9].

3.2 Hull scantlings

3.2.1 Dry stores and ammunition transfer routes

All dry stores and ammunition transfer routes are to be checked with regards to wheeled load as defined in NR467, Pt B, Ch 5, Sec 6, [6] and strength criteria given in NR467, Part B, Chapter 7.

3.2.2 Height of door sills along transfer routes

Where sills are required on doors located along the dry stores or ammunition transfer routes, the fitting of alternative arrangements to enable their transfer by way of wheeled vehicles will be considered by the Society on a case by case basis.

3.3 Ammunition and dry stores elevators

3.3.1 Lifting operations

Lifting operations are to be described, with detailed information about Safe Working load of elevators, type of loads carried out and operating procedures with corresponding load dynamic amplification factors.

Dynamic amplification factors include combined effects of:

a) vertical acceleration induced by start and stop of lifting process

b) accelerations induced by behaviour of ship at sea.

When a ship motion damping system is fitted, it may be accepted, on a case by case basis, to reduce the accelerations mentioned in b) above. The reduction level, if any, will be defined after an analysis of operating procedures in normal conditions and in degraded conditions.

3.3.2 Loads on elevators

The design pressure exerted on the platform of the ammunition and dry stores elevators are to be taken in accordance with Pt B, Ch 5, Sec 6, [2], Pt B, Ch 5, Sec 6, [3] and Pt B, Ch 5, Sec 6, [4], as appropriate.

3.3.3 Plating

The scantlings of the plating of ammunition and dry stores elevators loads are to be in compliance with requirements of NR467, Pt B, Ch 7, Sec 1.

3.3.4 Ordinary stiffeners

The scantlings of the ordinary stiffeners of ammunition and dry stores elevators are to be in compliance with requirements of NR467, Pt B, Ch 7, Sec 2.

3.3.5 Primary structure

The scantlings of the primary structure of ammunition and dry stores elevators are generally to be checked on basis of three dimensional structural model, according to the requirements of NR467, Pt B, Ch 7, Sec 3, [3] and NR467, Pt B, Ch 7, Sec 3, [6].

3.3.6 Locking and lifting devices

The scantlings of locking and lifting devices and the surrounding reinforcements are to be assessed on first principle basis.

Design forces (amplitudes, directions) and associated safety coefficients are to be agreed upon on a case by case basis.

Section 4 Machinery and Systems

1 General

1.1 Documents to be submitted

1.1.1 The documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document **(1)**
1	General layout of cargo pump room with details of: • bulkhead penetrations • gas detection system • other alarms and safety arrangements
2	Diagram of cargo piping system
3	Diagram of the cargo tank venting system with: • indication of the outlet position • details of the pressure/vacuum valves and flame arrestors • details of the draining arrangements, if any
4	Diagram of the cargo tank level gauging system with overfill safety arrangements
5	Diagram of the cargo tank cleaning system
6	Diagram of the bilge and ballast systems serving the spaces located in the cargo area
(1)	Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems

2 Propulsion and steering capability

2.1 Propulsion availability

2.1.1 The ship propulsion system is to comply at least with the requirements of the additional class notation **AVM-APS** for alternative propulsion mode as defined in Part E, Chapter 3.

In addition, the control system for propulsion is to be such that ship speed and propeller speed can be changed by small steps of not more than 0,2 knots for ship speed or 2 rpm for propeller speed.

2.2 Steering

2.2.1 The steering system is to comply with the requirements given in Ch 4, Sec 8, [2.2].

3 Piping systems other than cargo piping system

3.1 General

3.1.1 Materials

a) Materials are to comply with the provisions of NR467, Pt C, Ch 1, Sec 10.

b) Spheroidal graphite cast iron may be accepted for bilge and ballast piping within double bottom or cargo tanks.

c) Grey cast iron may be accepted for ballast lines within cargo tanks, except for ballast lines to forward tanks through cargo tanks.

3.1.2 Independence of piping systems

a) Bilge system serving the cargo pump room and spaces located within the cargo area are to be independent from any piping system serving spaces located outside the cargo area.

b) Fuel oil and JP5-NATO (F44) systems referred in [3.5] are to:
   - be independent from the cargo piping system
   - have no connections with pipelines serving cargo or slop tanks, except as permitted by [3.5].

3.1.3 Passage through cargo tanks and slop tanks

a) Unless otherwise specified, bilge, ballast and fuel oil systems serving spaces located outside the cargo area are not to pass through cargo tanks or slop tanks.

b) Where expressly permitted, ballast pipes passing through cargo tanks are to fulfil the following provisions:
   - they are to have welded or heavy flanged joints the number of which is kept to a minimum
   - they are to be of extra-reinforced wall thickness as per NR467, Pt C, Ch 1, Sec 10, Tab 6
   - they are to be adequately supported and protected against mechanical damage.

c) Where required in order to meet the requirements of Ch 4, Sec 3, [1.2.6], lines of piping which run through cargo tanks are to be fitted with closing devices.

3.2 Bilge system

3.2.1 Bilge pumps

a) At least one bilge pump is to be provided for draining the spaces located within the cargo area. Cargo pumps or stripping pumps may be used for this purpose.

b) Bilge pumps serving spaces located within the cargo area are to be located in the cargo pump room or in another suitable space within the cargo area.

3.2.2 Draining of spaces located outside the cargo area

The bilge system for spaces located outside the cargo area are to comply with the requirements of NR467, Pt D, Ch 11, Sec [4].

3.2.3 Draining of pump rooms

a) Arrangements are to be provided to drain the pump rooms by means of power pumps or bilge ejectors.

b) Cargo pumps or stripping pumps may be used for draining cargo pump rooms provided that:
   - a screw-down non-return valve is fitted on the bilge suctions, and
   - a remote control valve is fitted between the pump suction and the bilge distribution box.

c) Bilge pipe diameter is not to be less than 50 mm.

d) The bilge system of cargo pump rooms is to be capable of being controlled from outside.

3.3 Ballast system

3.3.1 Ballast pipes passing through tanks

a) Ballast piping is not to pass through cargo tanks except in the case of short lengths of piping complying with [3.1.3], item b).

b) Sliding type couplings are not to be used for expansion purposes where ballast lines pass through cargo tanks. Expansion bends only are permitted.

3.4 Scupper pipes

3.4.1 Scupper pipes are not to pass through cargo tanks except, where this is impracticable, in the case of short lengths of piping complying with the following provisions:

- they are of steel
- they have only welded or heavy flanged joints the number of which is kept to a minimum
- they are of substantial wall thickness as per NR467, Pt C, Ch 1, Sec 10, Tab 25, column 1.

3.5 Arrangement for JP5-NATO (F44) and Fuel oil systems

3.5.1 General

In addition to specific requirements given in this Chapter, JP5-NATO (F44) systems are to comply with the general requirements of NR467 Pt C, Ch 1 applicable to fuel oil systems.

3.5.2 Dedicated tanks and piping are to be provided for the storage and distribution of JP5-NATO (F44) intended for the helicopters carried on board the vessel.

3.5.3 Tanks for JP5-NATO mentioned in [3.5.2] above are not to be located adjacent to a machinery space of category A.

3.5.4 The piping system referred in [3.5.2] and the ship fuel oil piping may be connected to the cargo piping system provided it complies with the following:

a) they comply with the requirements of [3.1.3], item b).

b) the piping outside of the cargo area is to be fitted at least 760 mm inboard.

c) Such piping is to be clearly identified and fitted with a shutoff valve at its connection to the cargo piping system within the cargo area. At this location, it shall also be capable of being separated by means of a removable spool-piece and blank flanges when not in use.

d) Arrangements are to be made to allow the piping outside the cargo area to be efficiently drained and purged.

3.5.5 Treatment systems

For JP5 NATO (F44), one means of treatment may be accepted.

3.5.6 Construction of JP5-NATO (F44) piping systems

JP5-NATO (F44) pipes and valves located on the refuelling line (i.e. downstream the treatment equipment) are to be of stainless steel.

3.5.7 Passage of JP5-NATO (F44) pipes through tanks

JP5-NATO (F44) pipes are not allowed to pass through tanks containing other fluids.

3.5.8 Passage of pipes through fuel oil or JP5-NATO (F44) tanks

JP5-NATO (F44) tanks are not to be passed through by any other piping system.

3.6 Heating systems

3.6.1 Thermal oil systems

Thermal oil systems are not accepted on board auxiliary naval vessels.

3.7 Heating systems intended for cargo

3.7.1 General

a) Heating systems intended for cargo are to comply with the relevant requirements of NR467, Pt C, Ch 1, Sec 10.

b) No part of the heating system is normally to exceed 220°C.

c) Blind flanges or similar devices are to be provided on the heating circuits fitted to tanks carrying cargoes which are not to be heated.

d) Heating systems are to be so designed that the pressure maintained in the heating circuits is higher than that exerted by the cargo oil. This need not be applied to heating circuits which are not in service provided they are drained and blanked-off.

e) Isolating valves are to be provided at the inlet and outlet connections of the tank heating circuits. Arrangements are to be made to allow manual adjustment of the flow.

f) Heating pipes and coils inside tanks are to be built of a material suitable for the heated fluid and of reinforced thickness as per NR467, Pt C, Ch 1, Sec 10, Tab 6. They are to have welded connections only.

3.7.2 Steam heating

To reduce the risk of liquid or gaseous cargo returns inside the engine or boiler rooms, steam heating systems of cargo tanks are to satisfy either of the following provisions:

- they are to be independent of other ship services, except cargo heating or cooling systems, and are not to enter machinery spaces, or
- they are to be provided with an observation tank on the water return system located within the cargo area. However, this tank may be placed inside the engine room in a well-ventilated position remote from boilers and other sources of ignition. Its air pipe is to be led to the open and fitted with a flame arrester.

3.7.3 Hot water heating

Hot water systems serving cargo tanks are to be independent of other systems. They are not to enter machinery spaces unless the expansion tank is fitted with:

- means for detection of flammable vapours
- a vent pipe led to the open and provided with a flame arrester.

4 Cargo pumping and piping systems

4.1 General

4.1.1 A complete system of pumps and piping is to be fitted for handling the cargo oil (including JP5-NATO (F44) carried as cargo). Except where expressly permitted, these systems are to be independent of any other piping system on board.

4.2 Cargo pumping system

4.2.1 Number and location of cargo pumps

a) Each cargo tank is to be served by at least two separate fixed means of discharging and stripping. However, for tanks fitted with an individual submerged pump, the second means may be portable.

b) Cargo pumps are to be located:
- in a dedicated pump room, or
- on deck, or
- when designed for this purpose, within the cargo tanks.

4.2.2 Use of cargo pumps

a) Except where expressly permitted in [3.2], cargo pumps are to be used exclusively for handling the liquid cargo and are not to have any connections to compartments other than cargo tanks.

b) Subject to their performance, cargo pumps may be used for tank stripping.

c) Cargo pumps may be used, where necessary, for the washing of cargo tanks.

4.2.3 Cargo pumps drive

a) Prime movers of cargo pumps are not to be located in the cargo area, except in the following cases:
- steam driven machine supplied with steam having a temperature not exceeding 220°C
- hydraulic motors
- electric motors in accordance with Ch 4, Sec 5.

b) Pumps with a submerged electric motor are not permitted in cargo tanks.

4.2.4 Design of cargo pumps

a) Materials of cargo pumps are to be suitable for the products carried.

b) The delivery side of cargo pumps is to be fitted with relief valves discharging back to the suction side of the pumps (bypass) in closed circuit. Such relief valves may be omitted in the case of centrifugal pumps with a maximum delivery pressure not exceeding the design pressure of the piping, with the delivery valve closed.

4.2.5 Monitoring of cargo pumps

Cargo pumps are to be monitored as required in Tab 2.

Table 2 : Monitoring of cargo pumps

Equipment, parameter	Alarm **(1)**	Indication **(2)**	Comments
Pump, discharge pressure		L	• on the pump **(3)**, or • next to the unloading control station

(1) H = high
(2) L = low
(3) and next to the driving machine if located in a separate compartment

4.2.6 Control of cargo pumps

Cargo pumps are to be capable of being stopped from:
- a position outside the pump room, and
- a position next to the pumps.

4.3 Cargo piping design

4.3.1 General

a) Unless otherwise specified, cargo piping is to be designed and constructed according to the requirements of NR467, Pt C, Ch 1, Sec 10.

b) Piping for JP5-NATO (F44) is to comply with requirements of [3.5], except [3.5.2]

c) For tests, refer to Article [7].

4.3.2 Materials

a) Materials readily rendered ineffective by heat are not to be used for valves, fittings, cargo vent piping and cargo piping so as to prevent the spread of fire to the cargo.

b) Cargo piping is, in general, to be made of steel or cast iron.

c) Valves, couplings and other end fittings of cargo pipe lines for connection to hoses are to be of steel or other suitable ductile material.

d) Spheroidal graphite cast iron may be used for cargo oil piping within the double bottom or cargo tanks.

e) Grey cast iron may be accepted for cargo oil lines:
- within cargo tanks, and
- on the weather deck for pressure up to 1,6 Mpa.

It is not to be used for manifolds and their valves of fittings connected to cargo handling hoses.

f) Plastic pipes may be used in the conditions specified in NR467, Pt C, Ch 1, App 3. Arrangements are to be made to avoid the generation of static electricity.

4.3.3 Connection of cargo pipe lengths

Cargo pipe lengths may be connected either by means of welded joints or, unless otherwise specified, by means of flange connections.

4.3.4 Expansion joints

a) Where necessary, cargo piping is to be fitted with expansion joints or bends.

b) Expansion joints including bellows are to be of a type approved by the Society.

c) Expansion joints made of non-metallic material may be accepted only inside tanks and provided they are:
- of an approved type
- designed to withstand the maximum internal and external pressure
- electrically conductive.

4.3.5 Valves with remote control

a) Valves with remote control are to comply with NR467, Pt C, Ch 1, Sec 10, [2.7.3].

b) Submerged valves are to be remote controlled. In the case of a hydraulic remote control system, control boxes are to be provided outside the tank, in order to permit the emergency control of valves.

c) Valve actuators located inside cargo tanks are not to be operated by means of compressed air.

4.4 Cargo piping arrangement and installation

4.4.1 Cargo pipes passing through tanks or compartments

a) Cargo piping is not to pass through tanks or compartments located outside the cargo area except where permitted in [4.4.3].

b) Cargo piping and similar piping to cargo tanks is not to pass through ballast tanks except in the case of short lengths of piping complying with [3.1.3], item b).

c) Cargo piping may pass through vertical fuel oil tanks adjacent to cargo tanks on condition that the provisions of [3.1.3], item b) are complied with.

d) Cargo piping passing through cargo tanks is to comply with the provisions of Ch 4, Sec 3, [1.2.6].

e) Cargo piping may pass through open superstructure

4.4.2 Cargo piping passing through bulkheads

Cargo piping passing through bulkheads is to be so arranged as to preclude excessive stresses at the bulkhead. Bolted flanges are not to be used in the bulkhead.

4.4.3 Cargo loading and unloading arrangement

Where the cargo transfer stations are located outside the cargo area, the following provisions are to be complied with:

a) the piping outside the cargo area is to be fitted with an isolating valve at its connection with the piping system within the cargo area

b) pipe connections outside the cargo area are to be of welded type only

c) arrangements are to be made to allow the piping outside the cargo area to be efficiently drained and purged

d) the piping outside of the cargo area may pass through low fire risk spaces provided the requirements of [3.1.3], item b) are complied with.

4.4.4 Valves

a) Stop valves are to be provided to isolate each tank.

b) A stop valve is to be fitted at each end of the cargo manifold.

c) When a cargo pump in the cargo pump room serves more than one cargo tank, a stop valve is to be fitted in the cargo pump room on the line leading to each tank.

d) Main cargo oil valves located in the cargo pump room below the floor gratings are to be remote controlled from a position above the floor.

e) Where required in order to meet the requirements of Ch 4, Sec 3, [1.2.6], lines of piping which run through cargo tanks are to be fitted with closing devices.

4.4.5 Prevention of the generation of static electricity

a) In order to avoid the generation of static electricity, the loading pipes are to be led as low as practicable in the tank.

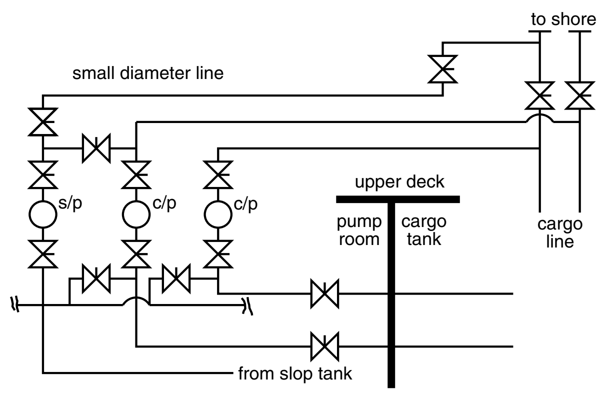
b) Cargo pipe sections and their accessories are to be electrically bonded together and to the ship's hull.

4.4.6 Draining of cargo pumps and oil lines

a) Oil piping is to be so designed and installed that oil retention in the lines is minimised, and

b) Means are to be provided to drain all cargo pumps and all oil lines at the completion of cargo discharge, where necessary by connection to a stripping device. The line and pump drainings are to be capable of being discharged both ashore and to a cargo tank or slop tank. For discharge ashore, a special small diameter line having a cross-sectional area not exceeding 10% of the main cargo discharge line is to be provided and is to be connected on the downstream side of the ship's deck manifold valves, both port and starboard, when the cargo is being discharged; see Fig 1.

Figure 1 : Connection of small diameter line to the manifold valve



4.4.7 Cleaning and gas-freeing

a) The cargo piping system is to be so designed and arranged as to permit its efficient cleaning and gas-freeing.

4.5 Arrangement of cargo pump rooms

4.5.1 Pump room ventilation

The ventilation of the cargo pump room is to comply with the following provisions:

a) Cargo pump rooms are to be mechanically ventilated and discharges from exhaust fans are to be led to a safe place on the open deck. The ventilation of these rooms is to have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of changes of air is to be at least 20 per hour, based upon the gross volume of the space. The air ducts are to be arranged so that all of the space is effectively ventilated. The ventilation is to be of the suction type using fans of the non-sparking type.

b) The ventilation ducts are to be so arranged that their suction is just above the transverse floor plates or bottom longitudinals in the vicinity of bilges.

c) An emergency intake located about 2,20 m above the pump room lower grating is to be provided. It is to be fitted with a damper capable of being opened or closed from the exposed deck and lower grating level.

Ventilation through the emergency intake is to be effective when the lower intakes are sealed off due to flooding in the bilges.

d) The foregoing exhaust system is in association with open grating floor plates to allow the free flow of air.

e) Arrangements involving a specific ratio of areas of upper emergency and lower main ventilator openings, which can be shown to result in at least the required 20 air changes per hour through the lower inlets, can be adopted without the use of dampers. When the lower access inlets are closed then at least 15 air changes per hour should be obtained through the upper inlets.

f) *Ventilation exhaust ducts are to discharge upwards in locations at least 3 m from any ventilation intake and opening to gas safe spaces.*

g) *Ventilation intakes are to be so arranged as to minimize the possibility of recycling hazardous vapours from ventilation discharge openings.*

h) *The ventilation ducts are not to be led through gas safe spaces, cargo tanks or slop tanks.*

5 Cargo tanks and fittings

5.1 Application

5.1.1 The provisions of Article [5] apply to cargo tanks and slop tanks.

5.2 Cargo tank venting

5.2.1 The relevant provisions of NR467, Pt C, Ch 1, Sec 10, [9] and NR467, Pt C, Ch 1, Sec 10, [11] are to be complied with.

5.2.2 Tank venting systems are to open to the atmosphere at a height of at least 760 mm above the weather deck.

5.2.3 Tanks may be fitted with venting systems of the open type provided with a flame screen.

5.2.4 Additional provisions for ships fitted with an inert gas system

a) *On ships fitted with an inert gas system, one or more pressure/vacuum-breaking devices are to be provided to prevent the cargo tanks from being subject to:*

   1) *a positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets are left shut, and*

   2) *a negative pressure in excess of 700 mm water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.*

   Such devices are to be installed on the inert gas main unless they are installed in the venting system or on individual cargo tanks.

b) *The location and design of the devices referred to in paragraph a) above are to be in accordance with requirements of NR467, Pt D, Ch 7, Sec 4, [4.2.1] to NR467, Pt D, Ch 7, Sec 4, [4.2.10].*

5.3 Cargo tank inerting, purging and/or gas-freeing

5.3.1 General

a) Arrangements are to be made for purging and/or gas-freeing of cargo tanks. The arrangements are to be such as to minimise the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank.

b) Ventilation/gas-freeing lines between fans and cargo tanks are to be fitted with means, such as detachable spool pieces, to prevent any back-flow of hydrocarbon gases through the fans when they are not used.

5.3.2 Ships provided with an inert gas system

The following provisions apply to ships provided with an inert gas system:

a) On individual cargo tanks the gas outlet pipe, if fitted, is to be positioned as far as practicable from the inert gas / air inlet and in accordance with [5.2]. The inlet of such outlet pipes may be located either at the deck level or at not more than 1 m above the bottom of the tank.

b) The arrangement of inert gas and cargo piping systems is to comply with the provisions of NR467, Pt C, Ch 4, Sec 15 [13].

5.4 Cargo tank level gauging systems

5.4.1 The relevant provisions of NR467, Pt C, Ch 1, Sec 10, [9] and NR467, Pt C, Ch 1, Sec 10, [11] are to be complied with.

5.4.2 Tanks may be fitted with gauging systems of the open type, such as a hand sounding pipe or other portable gauging device.

5.4.3 Ships provided with an inert gas system

a) On ships provided with an inert gas system, the gauging devices are to be of the closed type.

b) Use of indirect gauging devices will be given special consideration.

5.5 Protection against tank overfilling

5.5.1 General

a) Provisions are to be made to guard against liquid rising in the venting system of cargo or slop tanks to a height which would exceed the design head of the tanks. This is to be accomplished by high level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

b) Sufficient ullage is to be left at the end of tank filling to permit free expansion of liquid during carriage.

c) High level alarms, overflow control systems and other means referred to in a) are to be independent of the gauging systems referred to in [5.4].

5.5.2 High level alarms

a) High level alarms are to be type approved.

b) High level alarms are to give an audible and visual signal at the control station, where provided.

5.5.3 Other protection systems

a) Where the tank level gauging systems, cargo and ballast pump control systems and valve control systems are centralised in a single location, the provisions of [5.5.1] may be complied with by the fitting of a level gauge for the indication of the end of loading, in addition to that required for each tank under [5.4]. The readings of both gauges for each tank are to be as near as possible to each other and so arranged that any discrepancy between them can be easily detected.

b) Where a tank can be filled only from other tanks, the provisions of [5.5.1] are considered as complied with.

5.6 Tank washing systems

5.6.1 General

Adequate means are to be provided for cleaning the cargo tanks.

Note 1: Portable equipment may be used for cleaning the cargo tanks.

5.6.2 Washing machines

a) Tank washing machines are to be of a type approved by the Society.

b) Washing machines are to be made of steel or other electricity conducting materials with a limited propensity to produce sparks on contact.

5.6.3 Washing pipes

a) Washing pipes are to be built, fitted, inspected and tested in accordance with the applicable requirements of NR467, Pt C, Ch 1, Sec 10.

5.6.4 Installation of washing systems

a) Tank cleaning openings are not to be arranged in enclosed spaces.

b) The complete installation is to be permanently earthed to the hull.

6 Prevention of pollution by cargo oil

6.1 General

6.1.1 The provisions of Ch 4, Sec 2, [5.4] are to be complied with.

6.2 Oil discharge monitoring and control system

6.2.1 General

a) An oil discharge monitoring and control system is to be fitted.

b) A manually operated alternative method is to be provided.

6.2.2 Design of the discharge monitoring and control system

a) The discharge monitoring and control system is to be of a type approved in compliance with the provisions of IMO MEPC.108(49).

b) The discharge monitoring and control system is to be fitted with a recording device to provide a continuous record of the discharge in litres per nautical mile and total quantity discharged, or the oil content and rate of discharge. This record is to be identifiable as regards time and date.

c) The oil discharge monitoring and control system is to come into operation when there is any discharge of effluent into the sea and is to be such as will ensure that any discharge of oily mixture is automatically stopped when the instantaneous rate of discharge of oil content exceeds 30 litres per nautical mile.

d) Any failure of the monitoring and control system is to stop the discharge.

6.2.3 Oil/water interface detectors

Effective oil/water interface detectors approved by the Society are to be provided for a rapid and accurate determination of the oil/water interface in slop tanks and are to be available for use in other tanks where the separation of oil and water is effected and from which it is intended to discharge effluent directly to the sea.

6.3 Pumping, piping and discharge arrangements

6.3.1 Discharge manifold

a) A discharge manifold for connection to reception facilities for the discharge of oil contaminated water is to be located on the open deck on both sides of the ship.

b) A fixed container or enclosed deck area should be fitted around each oil loading manifold and each oil transfer connection point with a minimum capacity, in all conditions of list or trim encountered during loading according to Tab 3, depending on the size of hose(s) or loading arm(s) it serves.

Each container is to be equipped with means of draining or removing oil, without discharging it into the water, and with a mechanical means of closing each drain and scupper.

Table 3 : Minimum capacity of drip trays in way of manifolds

Inside diameter (inches)	less than 2	less than 4	less than 6	less than 12	12 or more
Capacity (barrels)	1/2	1	2	3	4

6.3.2 Discharge pipelines

In every oil tanker, pipelines for the discharge of oil contaminated water from cargo tank areas to the sea, where permitted, are to be led to the open deck or to the ship side above the waterline in the deepest ballast condition.

6.3.3 Discharge stopping

Means are to be provided for stopping the discharge into the sea of oil contaminated water from cargo tank areas, other than those discharges below the waterline permitted under [6.3.2], from a position on the upper deck or above located so that the manifold in use referred to in [6.3.1] and the discharge to the sea from the pipelines referred to in [6.3.2] may be visually observed. Means for stopping the discharge need not be provided at the observation position if a positive communication system such as a telephone or radio system is provided between the observation position and the discharge control position.

7 Certification, inspection and testing

7.1 Application

7.1.1 The provisions of this Article are related to cargo piping and other equipment fitted in the cargo area. They supplement those given in NR467, Pt C, Ch 1, Sec 10, [20] for piping systems.

7.2 Workshop tests

7.2.1 Tests for materials

Where required in Tab 4, materials used for pipes, valves and fittings are to be subjected to the tests specified in NR467, Pt C, Ch 1, Sec 10, [20.4.2].

7.2.2 Inspection of welded joints

Where required in Tab 4, welded joints are to be subjected to the examinations specified in NR467, Pt C, Ch 1, Sec 10, [3.6] for class II pipes.

7.2.3 Hydrostatic testing

a) Where required in Tab 4, cargo pipes, valves, fittings and pump casings are to be submitted to hydrostatic tests in accordance with the relevant provisions of NR467, Pt C, Ch 1, Sec 10, [20.5].

b) Expansion joints and cargo hoses are to be submitted to hydrostatic tests in accordance with the relevant provisions of NR467, Pt C, Ch 1, Sec 10, [20.5].

c) Where fitted, bellow pieces of gas-tight penetration glands are to be pressure tested.

7.2.4 Tightness tests

Tightness of the following devices is to be checked:

- gas-tight penetration glands
- cargo tank P/V and high velocity valves.

Note 1: These tests may be carried out in the workshops or on board.

7.2.5 Summarising table

Inspections and tests required for cargo piping and other equipment fitted in the cargo area are summarised in Tab 4.

Table 4 : Inspection and testing at works

No.	Item	Tests for materials		Inspections and tests for the products			References to the Rules
		Y/N **(1)**	Type of material certificate**(2)**	during manufacturing **(1)**	after completion**(1)(3)**	Type of product certificate**(2)**	
1	pipes, valves and fittings of class II (see [3.3.1])	Y	• C where ND > 100mm • W where ND ≤ 100mm	Y **(4)**	Y	C	[7.2.1] [7.2.1] [7.2.2] [7.2.3]
2	expansion joints and cargo hoses	Y**(5)**	W	N	Y	C	[7.2.1] [7.2.3]
3	cargo pumps	Y	C	Y **(6)**	Y	C	see note**(6)** [7.2.3]
4	gas-tight penetration glands	N		N	Y	C	[7.2.3], [7.2.4]
5	cargo tank P/V and high velocity valves	Y	C	Y	Y	C	[7.2.1] [7.2.2] [7.2.3], [7.2.4]
6	flame arresters	N		N	Y	C	see note**(3)**
7	Oil discharge monitoring and control system	N			Y **(7)**	C	see note**(3)**
8	Oil/water interface detector	N			Y **(7)**	C	see note**(3)**

(1) Y = required, N = not required.
(2) C = class certificate, W = works' certificate.
(3) includes the checking of the rule characteristics according to the approved drawings.
(4) only in the case of welded construction.
(5) if metallic.
(6) inspection during manufacturing is to be carried out according to a program approved by the Society.
(7) may also be carried out on board.

7.3 Shipboard tests

7.3.1 Pressure test

a) After installation on board, the cargo piping system is to be checked for leakage under operational conditions.

7.3.2 Survey of pollution prevention equipment

The ship is to be subjected to an initial survey before the ship is put in service, to ensure that the equipment, systems, fittings, arrangements and materials fully comply with the relevant provisions of [5.6] and [6].

8 Dry stores and ammunition handling

8.1 Internal movements

8.1.1 General

The movements of the dry stores and ammunition between their storage deck and the weather deck are operated by elevators.

The ammunition and dry stores elevators are to be considered as a secondary essential service in complement of NR46,7 Pt C, Ch 2, Sec 1, [3.4.1].

8.1.2 Ammunition and dry stores elevators

With regards to strength matters, ammunition and dry stores elevators are to comply with general requirements of Ch 4, Sec 3, [3.3], NR467, Pt B, Ch 9, Sec 8, and with requirements of NR526 Rules for lifting appliances, as far as they are applicable to unmanned platform elevator.

The following requirements are also to be complied with:

- a mechanical locking of the platform at the storage level deck and weather deck is to be provided
- disposition are to be taken to avoid any change in the level of the platform when removing the locking whatever load change occurred
- platforms are to be equipped to avoid any contact of staff or load with fixed parts of ship during movements of the platforms
- Storage level deck and weather deck are to be equipped with disposal to avoid any fall of staff or load when platform is not locked at the deck level.

In addition, the ammunition and dry stores elevators are to be in compliance with ISO 8383 standard.

Section 5 Electrical Installations

1 General

1.1 Application

1.1.1 The design is to be in accordance with IEC publication 60092-502.

1.2 Essential services

1.2.1 With regards to electrical distribution, the following services are considered as secondary essential services, in addition to those listed in NR467, Pt C, Ch 2, Sec 1, [3.4.1]:

a) Cargo Offloading system

b) Lifting appliances and hoses handling equipment.

1.3 Documentation to be submitted

1.3.1 In addition to the documentation requested in NR467, Pt C, Ch 2, Sec 1, Tab 1, the following are to be submitted for approval:

a) plan of hazardous areas

b) document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas

c) diagrams of tank level indicator systems, high level alarm systems and overflow control systems where requested.

1.3.2 The documentation dealing with the electrical system for watertight door and fire door systems as requested in:

- NR467, Pt C, Ch 2, Sec 1, Tab 1,
- NR467, Pt B, Ch 1, Sec 4, Tab 1 and
- NR467, Pt C, Ch 4, Sec 1, Tab 1,

is to be submitted for approval.

1.4 System of supply

1.4.1 The following systems of generation and distribution of electrical energy are acceptable:

a) direct current:
   - two-wire insulated

b) alternating current:
   - single-phase, two-wire insulated
   - three-phase, three-wire insulated.

1.4.2 Earthed systems with hull return are not permitted, with the following exceptions to the satisfaction of the Society:

a) impressed current cathodic protective systems

b) limited and locally earthed systems, such as starting and ignition systems of internal combustion engines, provided that any possible resulting current does not flow directly through any hazardous area

c) insulation level monitoring devices, provided that the circulation current of the device does not exceed 30 mA under the most unfavourable conditions.

1.4.3 Earthed systems without hull return are not permitted, with the following exceptions:

a) earthed intrinsically safe circuits and the following other systems to the satisfaction of the Society

b) power supplies, control circuits and instrumentation circuits in non-hazardous areas where technical or safety reasons preclude the use of a system with no connection to earth, provided the current in the hull is limited to not more than 5 A in both normal and fault conditions, or

c) limited and locally earthed systems, such as power distribution systems in galleys and laundries to be fed through isolating transformers with the secondary windings earthed, provided that any possible resulting hull current does not flow directly through any hazardous area, or

d) alternating current power networks of 1,000 V root mean square (line to line) and over, provided that any possible resulting current does not flow directly through any hazardous area; to this end, if the distribution system is extended to areas remote from the machinery space, isolating transformers or other adequate means are to be provided.

1.4.4 In insulated distribution systems, no current carrying part is to be earthed, other than:

a) through an insulation level monitoring device

b) through components used for the suppression of interference in radio circuits.

1.5 Electrical distribution and protection

1.5.1 Distribution systems shall be so arranged that fire in any main vertical zone as defined in NR467, Part C, Chapter 4 will not interfere with services essential for safety in any other such zone.

This requirement will be met if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

1.5.2 The main switchboard is to be divided in two parts.

1.5.3 It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Where essential services as defined in [1.2.1] have duplicated equipment, their power supplies are to be divided between the sections.

1.6 Earth detection

1.6.1 The devices intended to continuously monitor the insulation level of all distribution systems are also to monitor all circuits, other than intrinsically safe circuits, connected to apparatus in hazardous areas or passing through such areas. An audible and visual alarm is to be given, at a manned position, in the event of an abnormally low level of insulation.

1.7 Mechanical ventilation of hazardous spaces

1.7.1 Electric motors driving fans of the ventilating systems of hazardous spaces are to be located outside the ventilation ducting.

1.7.2 At the discretion of the Society, motors driving ventilating fans may be located within the ducting provided that they are of a certified safe type and are arranged with an additional enclosure (having a degree of protection of at least IP 44) which prevents the impingement of the ducted air stream upon the motor casing.

1.7.3 The materials used for the fans and their housing are to be in compliance with Ch 4, Sec 1, [1.2.9].

1.7.4 Cargo pump-rooms and other enclosed spaces which contain cargo-handling equipment and similar spaces in which work is performed on the cargo should be fitted with mechanical ventilation systems, capable of being controlled from outside such spaces.

1.7.5 Provisions are to be made to ventilate the spaces defined in [1.7.4] prior to entering the compartment and operating the equipment, in compliance with Ch 4, Sec 4, [4.5.1].

1.8 Electrical installation precautions

1.8.1 Precautions against inlet of gases or vapours

Suitable arrangements are to be provided, to the satisfaction of the Society, so as to prevent the possibility of gases or vapours passing from a gas-dangerous space to another space through runs of cables or their conduits.

2 Hazardous locations and types of equipment

2.1

2.1.1 Cargo tanks, slop tanks, cargo pump rooms, any pipe work of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo are to be classified as zone 2.

3 Emergency distribution of electrical power and emergency installations

3.1 Distribution of electrical power

3.1.1 The emergency source of electrical power is to be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 36 hours, emergency lighting:

   1) at every muster and embarkation station and over the sides

   2) in alleyways, stairways and exits giving access to the muster and embarkation stations

   3) in all service and accommodation alleyways, stairways and exits, personnel lift cars

4) in the machinery spaces and main generating stations including their control positions
5) in all control stations, machinery control rooms, and at each main and emergency switchboard
6) at all stowage positions for firemen's outfits
7) at the steering gear, and
8) at the fire pump, the sprinkler pump and the emergency bilge pump referred to in item d) below and at the starting position of their motors

b) for a period of 36 hours:
   1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force, and
   2) on ships constructed on or after 1 February 1995 the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS Consolidated Edition 1992, and, if applicable:
      - the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3
      - the ship earth station required by Regulation IV/10.1.1, and
      - the MF/HF radio installation required by Regulations IV/10.2.1, IV/10.2.2 and IV/11.1

c) for a period of 36 hours:
   1) all internal communication equipment required in an emergency (see [4.1.1])
   2) the shipborne navigational equipment as required by Regulation V/12; where such provision is unreasonable or impracticable the Head Office may waive this requirement for ships of less than 5,000 gross tonnage
   3) the fire detection and fire alarm system, the fire door holding and release system, and
   4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [4.1.2]) that are required in an emergency, unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency

d) for a period of 36 hours:
   1) one of the fire pumps required by the relevant provisions of NR467, Part C, Chapter 4
   2) the automatic sprinkler pump, if any, and
   3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves

e) for the period of time required in NR467, Pt C, Ch 1, Sec 14, [2], the steering gear if required to be so supplied

f) for a period of half an hour:
   1) any watertight doors required by Regulation II-1/15 to be power operated together with their indicators and warning signals
   2) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency

g) for a period of one hour
   1) Installations of cargo offloading, necessary for safety and cargo preservation
      (list of corresponding cargo offloading systems to be defined).

3.1.2 The transitional source of emergency electrical power required is to supply at least the following services if they depend upon an electrical source for their operation:

a) for half an hour:
   1) the lighting required by [3.1.1] b) 1) and NR467, Pt C, Ch 2, Sec 3, [3.6.7], item (a)
   2) all services required by [3.1.1], items c) 1), c) 3) and c) 4) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency

b) it is also to supply power to close the watertight doors as required by Regulation II-1/15.7.3.3, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided. Power to the control, indication and alarm circuits as required by Regulation II-1/15.7.2, for half an hour.

3.2 Low-location lighting

3.2.1 Auxiliary naval vessels are to be provided with a low-location lighting (LLL) system in accordance with NR467, Pt C, Ch 4, Sec 8, [2.2.3].

Where LLL is satisfied by electric illumination, it is to comply with the following requirements.

3.2.2 The LLL system is to be connected to the emergency switchboard and is to be capable of being powered either by the main source of electrical power, or by the emergency source of electrical power for a minimum period of 60 minutes after energising in an emergency.

3.2.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of cables of a fire-resistant type complying with Pt C, Ch 2, Sec 9, [1.1.7], and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.

3.2.4 Single lights and lighting assemblies are to be designed or arranged so that any single fault or failure in a light or lighting assembly, other than a short-circuit, will not result in a break in visible delineation exceeding 1 metre.

3.2.5 Light and lighting assemblies are to be flame-retardant as a minimum, to have an ingress protection of at least IP55 and to meet the type test requirements as specified in NR467, Pt C, Ch 3, Sec 6, Tab 1.

3.2.6 The LLL system is to be capable of being manually activated by a single action from the continuously manned central control station. It may, additionally, be continuously operating or be switched on automatically, e.g. by the presence of smoke within the space(s) being served.

3.2.7 When powered, the systems are to achieve the following minimum luminance:

- for any planar source: 10 cd/m² from the active parts in a continuous line of 15 mm minimum width
- for any point source: 35 mcd in the typical track directions of approach and viewing which is to be considered:
  - for sources which are required to be viewed from a horizontal position, i.e. deck mounted or horizontally bulkhead mounted fittings, within a 60° cone having its centre located 30° from the horizontal mounting surface of the point source and in line with the track direction, see Fig 1.
  - for sources which are required to be viewed vertically, i.e. the vertical LLL marking up to the door handles, within a 60° cone having its centre located perpendicular to the mounting service of the point source, see Fig 2.

Spacing between sources is not to exceed 300 mm.

Figure 1 :

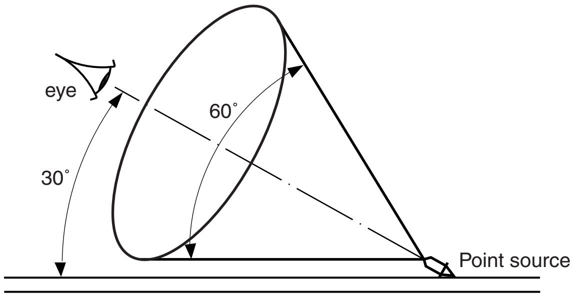
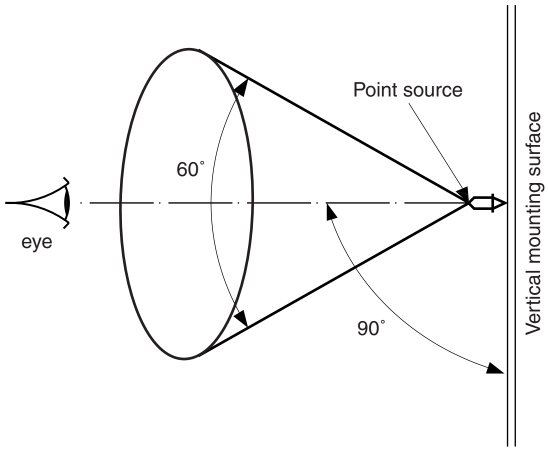


Figure 2 :



3.2.8 The lights or lighting assemblies are to be continuous except as interrupted by constructional constraints, such as corridors or cabin doors etc., are to provide a visible delineation along the escape route and, where applicable, are to lead to the exit door handles. Interruption of the LLL system due to constructional constraints is not to exceed 2 metres.

3.2.9 The lighting is to be provided on at least one side of the corridor or stairway. In corridors and stairways in excess of 2 metres width, lighting is to be provided on both sides.

3.2.10 In corridors the lighting is to be installed either on the bulkhead within 300 mm of the deck or, alternatively, on the deck within 150 mm of the bulkhead.

3.2.11 In stairways the lighting is to be installed within 300 mm above the steps such that each step may be readily identified from either above or below that step. The top and bottom steps are to be further identified to show that there are no further steps.

4 Internal communications

4.1 General

4.1.1 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment

b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled.

c) the means of communication which is provided between the officer of the watch and the person responsible for closing any watertight door which is not capable of being closed from a central control station.

d) External boundaries which are required in NR467, Pt C , Ch 4, Sec 7, [2.1.1] to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of auxiliary naval vessels to have A class integrity.

e) the means of communication between the navigating bridge and the main fire control station.

4.1.2 Internal signals required in an emergency generally include:

a) general alarm

b) watertight door indication

c) fire door indication.

4.2 General emergency alarm system

4.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren for sounding the general emergency alarm signal is to comply with the following requirements.

4.2.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in Ch 2, Sec 4, [4.2] or other suitable means of communication.

4.2.3 The entertainment sound system is to be automatically turned off when the general alarm system is activated.

4.2.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of the normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

4.2.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by Ch 2, Sec 4, [3.1] and Ch 2, Sec 4, [3.2].

4.2.6 The system is to be capable of operation from the navigation bridge and, except for the ship’s whistle, also from other strategic points.

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a cargo control station is normally to be regarded as strategic points.

4.2.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

4.2.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces and on all open decks.

4.2.9 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather.

4.2.10 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

4.2.11 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

4.2.12 For cables used for the general emergency alarm system, see NR467, Pt C, Ch 2, Sec 3, [9.6.1], NR467, Pt C, Ch 2, Sec 11, [5.2.1] and NR467, Pt C, Ch 2, Sec 11, [5.2.4].

4.2.13 Electrical cables and apparatus for the general emergency alarm system and their power supply are to be arranged so that the loss of the system in any one area due to localised fire is minimised.

4.2.14 Where the fire alarm to summon the crew operated from the navigating bridge or fire control station is part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm in the public spaces.

4.3 Public address system

4.3.1 The public address system is to be one complete system consisting of a loudspeaker installation which enables simultaneous broadcast of messages from the navigation bridge, and at least one other location on board for use when the navigation bridge has been rendered unavailable due to the emergency, to all spaces where crew members or special personnels, or both, are normally present (accommodation and service spaces and control stations and open decks), and to assembly stations (i.e. muster stations).

In spaces such as under deck passageways, bosun's locker, hospital and pump room, the public address system may not be required.

4.3.2 The public address system is to be arranged to operate on the main source of electrical power, the emergency source of electrical power and transitional sources of electrical power as required by NR467, Pt C, Ch 2, Sec 3, [2.3] and NR467, Pt C, Ch 2, Sec 3, [3.6].

4.3.3 The controls of the system on the navigation bridge are to be capable of interrupting any broadcast on the system from any other location on board.

4.3.4 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

4.3.5 The system is not to require any action by the addressee.

4.3.6 It is to be possible to address crew accommodation and work spaces separately from public spaces.

4.3.7 In addition to any function provided for routine use aboard the ship, the system is to have an emergency function control at each control station which:

a) is clearly indicated as the emergency function

b) is protected against unauthorised use

c) automatically overrides any other input system or program, and

d) automatically overrides all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces.

4.3.8 The system is to be installed with regard to acoustically marginal conditions, so that emergency announcements are clearly audible above ambient noise in all spaces where crew members or special personnels, or both, are normally present (accommodation and service spaces and control stations and open decks), and at assembly stations (i.e. muster stations).

4.3.9 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) in interior spaces 75 dB (A) and at least 20 dB (A) above the speech interference level, and

b) in exterior spaces 80 dB (A) and at least 15 dB (A) above the speech interference level.

Evidence of this level is to be shown with test result in open sea or equivalent quay measurement with appropriate correction factor.

4.3.10 The system is to be arranged to prevent feed-back or other interference.

4.3.11 The system is to be arranged to minimise the effect of a single failure so that the emergency messages are still audible (above ambient noise levels) also in the event of failure of any one circuit or component.

4.3.12 Each loudspeaker is to be individually protected against short-circuits.

4.3.13 For cables used for the public address system, see NR467, Pt C, Ch 2, Sec 3, [9.6.1], NR467, Pt C, Ch 2, Sec 11, [5.2.1] and NR467, Pt C, Ch 2, Sec 11, [5.2.4].

4.3.14 All areas of each fire zone are to be served by at least two dedicated loops of flame-retardant cables which are to be sufficiently separated throughout their length and supplied by two separate and independent amplifiers.

4.3.15 A temperature alarm is to be provided in the public address cabinets in case of forced air cooling.

4.4 Combined general emergency alarm - public address system

4.4.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of Ch 2, Sec 4, [4.1] and Ch 2, Sec 4, [4.2], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required.
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required.
- the system is arranged to minimise the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the event of failure of any one circuit or component, by means of the use of more than one device for generating an electronic sound signal.

4.5 Quality failure analysis

4.5.1 A quality failure analysis is to be submitted in accordance with NR467, Pt D, Ch 11, App 2.

5 Installation

5.1 Section and distribution boards

5.1.1 Cubicles and cupboards in areas which are accessible to any personnel are to be lockable.

6 Type approved components

6.1

6.1.1 Components for Low-Location Lighting systems (LLL) in auxiliary naval vessels escape routes are to be type approved or in accordance with [6.1.2].

6.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

Section 6 Fire Protection

1 General

1.1 Documents to be submitted

1.1.1 In addition to the documentation requested in Ch 4, Sec 2, Tab 1, the documents listed in Tab 1 are to be submitted for approval.

Table 1 : Documents to be submitted

No.	Description of the document **(1)**
1	General arrangement drawing
2	Specification of the fire integrity of bulkheads and decks
3	Specification of the instruments for measuring oxygen and flammable vapour concentrations
4	Diagram of the pressure water system within the cargo area
5	For the foam extinguishing system within the cargo area: • diagrammatic arrangement drawing • calculation note • foam agent specification • characteristics of foam monitors and hoses
6	For the fire-extinguishing system in cargo pump rooms: • general arrangement drawing • calculation note
(1)	Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

2 General requirements

2.1 Sources of ignition

2.1.1 Dangerous zones or spaces are not to contain:

- internal combustion engines
- steam turbines and steam piping with a steam temperature in excess of 220°C
- other piping systems and heat exchangers with a fluid temperature in excess of 220°C
- any other source of ignition.

Note 1: Dangerous zones and spaces correspond to hazardous areas defined in NR467, Pt C, Ch 2, Sec 1, [3.25].

2.1.2 Electrical equipment

For the installation of electrical equipment, refer to Ch 4, Sec 5.

3 Detection and alarm

3.1 Protection of machinery spaces

3.1.1 Installation

A fixed fire detection system and fire alarm system complying with the relevant provisions given in NR467, Pt C, Ch 4, Sec 15 is to be installed in any machinery space, as defined in Ch 4, Sec 1, [1.2.8].

Fire detecting system for unattended machinery spaces are to comply with Part E, Chapter 4.

3.1.2 Design

The fire detection system required in [3.1.1] shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in recesses and in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors are not permitted.

The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigating bridge.

3.2 Protection of accommodation and service spaces and control stations

3.2.1 The requirements of NR467, Pt C, Ch 4, Sec 3, [4.4] are to be replaced by the following:

- A fixed fire detection and fire alarm system complying with the provisions given in NR467, Pt C, Ch 4, Sec 3, [4.3] is to be installed in accommodation and service spaces and control stations.

3.3 Protection of ammunition spaces

3.3.1 Application and general requirements

Ammunition spaces are to be provided with a fixed fire detection and alarm system complying with the requirements of NR467, Pt C, Ch 4, Sec 15 and following additional requirement.

The detection system has to include smoke, temperature and temperature gradient detections.

Temperature and temperature gradient detection information replica has to be located outside near these spaces.

Smoke detectors are to be fitted in ammunition lift trunks.

3.3.2 Installation requirements

In general, a section of fire detectors which covers a control station, a service space or an accommodation space is not to include ammunition spaces.

Note 1: Where few ammunition spaces are concerned, a section of fire detectors which covers a control station, a service space or an accommodation space may include ammunition spaces, to the satisfaction of the Society.

4 Containment of fire

4.1 Thermal and structural subdivision

4.1.1 Fire integrity of bulkheads and decks

The requirements of NR467, Pt C, Ch 4, Sec 5, [1.3.4] are to be replaced by the following:

a) In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned in NR467, Pt C, Ch 4, Sec 5, [1.3.1] and NR467, Pt C, Ch 4, Sec 5, [1.3.2], the minimum fire integrity of bulkheads and decks shall be as prescribed in Tab 2 and Tab 3.

b) The following requirements govern application of the tables:

   1) Tab 2 and Tab 3 shall apply, respectively, to the bulkheads and decks separating adjacent spaces.

   2) For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (13) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of the present Section, or where it is possible to assign two or more classifications to a space, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have less than 30 % communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as prescribed in Pt C, Ch 4, Sec 5, Tab 1 and Pt C, Ch 4, Sec 5, Tab 2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

      - (1) Control stations

        Spaces containing emergency sources of power and lighting

        Wheelhouse and chartroom

        Spaces containing the ship's radio equipment for safety or ship navigation communication

        Fire control stations

        Control room for propulsion machinery when located outside the machinery space

        Spaces containing centralized fire alarm equipment

        Spaces containing network cabinets for computer and control centers, electronic cabinet systems or control computers managing data related to the control of the ship

        Spaces containing centralized emergency public address system stations and equipment.

        For the purpose of this Article, the space containing naval systems for detection, command, defence, offence, communication, combat (e.g. COC) or weapon control/operation; bridge for command, defence, operation or planning rooms and spaces containing centralised ship's operation equipment (e.g. COP) are assimilated as a control station.

      - (2) Corridors

        Corridors and lobbies.

      - (3) Accommodation spaces

        Spaces as defined in NR467, Pt C, Ch 4, Sec 1, [3.2] excluding corridors.

      - (4) Stairways

Interior stairways, lifts, totally enclosed emergency escape trunks, and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

In this connection, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door.

- (5) Service spaces (low risk)

  Lockers and store-rooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2 and drying rooms and laundries.

- (6) Machinery spaces of category A and equivalent spaces of high fire risk

  Spaces as defined in NR467, Pt C, Ch 4, Sec 1, [3.29].

  Aircraft refuelling stations, JP5 pump rooms and other pump rooms used for the refuelling of vehicles carried onboard

- (7) Other machinery spaces and oil fuel tanks

  Electrical equipment rooms (auto-telephone exchange, air-conditioning duct spaces)

  Spaces containing network cabinets for computer and control centers, electronic cabinet systems or control computers not managing data related to the control of the ship

  Spaces containing radio equipment not intended for safety or ship navigation communication

  Spaces as defined in NR467, Pt C, Ch 4, Sec 1, [3.28], excluding machinery spaces of category A

  Oil fuel tanks (where installed in a separate space with no machinery).

- (8) Cargo pump-rooms

  Spaces containing cargo pumps and entrances and trunks to such spaces.

- (9) Service spaces (high risk)

  Galleys, pantries containing cooking appliances, paint lockers, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, saunas and workshops other than those forming part of the machinery spaces

  Spaces and routes used for solid cargo transfer except ammunition.

- (10) Open decks

  Open deck spaces and enclosed promenades having little or no fire risk. Enclosed promenades shall have no significant fire risk, meaning that furnishing shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings

  Air spaces (the space outside superstructures and deckhouses).

- (11) Special purpose spaces

  Special category and ro-ro spaces as defined in NR467, Pt C, Ch 4, Sec 1, [3.40] and NR467, Pt C, Ch 4, Sec 1, [3.46]

  Vehicle spaces as defined in NR467, Pt C, Ch 4, Sec 1, [3.51]

  Helicopter hangars (when segregated from refuelling facilities)

  Helicopter decks.

- (12) Evacuation stations and external escape routes

  Survival craft stowage area

  Open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and lowering stations

  Assembly stations, internal and external

  External stairs and open decks used for escape routes

  The ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferaft and evacuation slide embarkation areas.

- (13) Ammunition spaces and other equivalent spaces

  Ammunition spaces as defined in Ch 4, Sec 1, [1.2.13] and lifts to such spaces

  Ammunition transfer spaces and routes.

c) Continuous B class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

d) External boundaries which are required in NR467, Pt C, Ch 4, Sec 7, [2.1.1] to be of steel or other equivalent material may be pierced for the fitting of windows and sidescuttles provided that there is no requirement for such boundaries of auxiliary naval vessels to have A class integrity. Similarly, in such boundaries which are not required to have A class integrity, doors may be constructed of materials which are to the satisfaction of the Society.

e) Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation shall be constructed of steel and insulated to A-60 standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. The distance of 3 m shall be measured horizontally and parallel to the middle line of the ship from the boundary which faces the cargo area at each deck level. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried up to the underside of the deck of the navigation bridge.

Windows and side scuttles within these limits are to be of the fixed type and constructed to the A-60 standard.

f) Skylights to cargo pump-rooms shall be of steel, shall not contain any glass and shall be capable of being closed from outside the pump-room.

g) In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers.

Table 2 : Fire integrity of bulkheads separating adjacent spaces

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7) [g]	(8)	(9)	(10)	(11)	(12)	(13)
Control stations	(1)	A-0 [c]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60	A-0	A-30
Corridors	(2)		C [e]	B-0 [e]	A-0 [a] B-0 [e]	B-0 [e]	A-60	A-0	A-60	A-0	*	A-15	A-0	A-30
Accommodation spaces	(3)			C [e]	A-0 [a] B-0 [e]	B-0 [e]	A-60	A-0	A-60	A-0	*	A-0	A-60	A-30
Stairways	(4)				A-0 [a] B-0 [e]	A-0 [a] B-0 [e]	A-60	A-0	A-60	A-0	*	A-15	A-0	A-30
Service spaces (low risk)	(5)					C [e]	A-60	A-0	A-60	A-0	*	A-0	A-15	A-30
Machinery spaces of category A and equivalent spaces of high fire risk	(6)						*	A-0	A-0	A-60	*	A-60	A-60	A-60
Other machinery spaces and oil fuel tanks [g]	(7)							A-0 [b]	A-0	A-0	*	A-0	A-15	A-30
Cargo pump room	(8)								*	A-60	*	A-60	A-60	-
Service spaces (high risk)	(9)									A-0 [b]	*	A-30	A-60	A-30
Open decks	(10)										–	A-0	*	A-30 [d]
Special purpose spaces	(11)											A-0	A-60	A-30
Evacuation stations and external escape routes	(12)												A-0	A-30
Ammunition spaces and other equivalent spaces	(13)													A-30

Note 1: (to be applied to Tab 2 and Tab 3, as appropriate)

[a] : For clarification as to which applies, see NR467, Pt C, Ch 4, Sec 5, [1.3.2] and NR467, Pt C, Ch 4, Sec 5, [1.3.5].

[b] : Where spaces are of the same numerical category and letter "b" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an A-0 bulkhead.

[c] : Bulkheads separating the wheelhouse and chartroom from each other may have a B-0 rating.

[d] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only "A-0" fire class standard is required.

[e] : For the application of item b) of NR467, Pt C, Ch 4, Sec 5, [1.3.1], B-0 and C, where appearing in Tab 2, are to be read as A-0.

[f] : Fire insulation need not be fitted if the machinery space in category (7), in the opinion of the Society, has little or no fire risk.

[g] : A-30 is required for bulkheads and decks separating spaces containing high voltage switchboards used at sea from other spaces

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material, but is not required to be of A class standard. However, where a deck, except in a category (10) space, is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke. Divisions between control stations (emergency generators) and open decks may have air intake openings without means for closure, unless a fixed gas fire-extinguishing system is fitted.

For the application of item b) of NR467, Pt C, Ch 4, Sec 5, [1.3.1], an asterisk, where appearing in Tab 3, except for categories (8) and (10), is to be read as A-0.

Table 3 : Fire integrity of decks separating adjacent spaces

SPACE below		SPACE above												
		(1)	(2)	(3)	(4)	(5)	(6)	(7) [g]	(8)	(9)	(10)	(11)	(12)	(13)
Control stations	(1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-30	A-0	A-30
Corridors	(2)	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-0	A-0	A-30
Accommodation spaces	(3)	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-0	A-60	A-30
Stairways	(4)	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-0	A-0	A-30
Service spaces (low risk)	(5)	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0	A-15	A-30
Machinery spaces of category A and equivalent spaces of high fire risk	(6)	A-60	A-60	A-60	A-60	A-60	*	A-60 [f]	A-30	A-60	*	A-60	A-60	A-60
Other machinery spaces and oil fuel tanks [g]	(7)	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0	A-15	A-30
Cargo pump room	(8)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*	A-0	A-60	A-30
Service spaces (high risk)	(9)	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-30	A-60	A-30
Open decks	(10)	*	*	*	*	*	*	*	*	*	–	A-0	*	A-30 [d]
Special purpose spaces	(11)	A-60	A-15	A-0	A-15	A-0	A-30	A-0	A-0	A-30	A-0	A-0	A-60	A-30
Evacuation stations and external escape routes	(12)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	A-30
Ammunition spaces and other equivalent spaces	(13)	A-30	A-30	A-30	A-30	A-30	A-60	A-30	A-30	A-30	A-30 [d]	A-30	A-30	A-30
Note 1: The notes to Tab 2 apply to this Table as appropriate.														

4.1.2 Exhaust ducts from galley ranges

The provisions of NR467, Pt C, Ch 4, Sec 5, [6.6.2] are to be replaced by the following:

In addition to the requirements in NR467, Pt C, Ch 4, Sec 5, [6.2], [6.3] and [6.4], exhaust ducts from galley ranges shall be constructed in accordance with NR467, Pt C, Ch 4, Sec 5, [6.3.4], item b) 1) and NR467, Pt C, Ch 4, Sec 5, [6.3.4], item b) 2). They shall also be fitted with:

a) a grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted;

b) a fire damper located in the lower end of the duct at the junction between the duct and the galley range hood which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct close to the outlet of the duct;

c) a fixed means for extinguishing a fire within the duct;

d) remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in item b) and for operating the fire-extinguishing system, which shall be placed in a position outside the galley close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

e) suitably located hatches for inspection and cleaning, including one provided close to the exhaust fan and one fitted in the lower end where grease accumulates.

The requirements given in item a) to item e) apply to all exhaust ducts from galley ranges in which grease or fat is likely to accumulate from galley ranges.

4.1.3 Ventilation ducts for ammunition spaces

The ventilation systems serving ammunition spaces shall be separated from the ventilation systems serving other types of space. No ventilation duct shall pass through any ammunition space except the ducts provided for the ventilation of this ammunition space. Torpedo magazines shall be provided with a dedicated ventilation system capable of being stopped locally.

Note 1: If a common duct serves several ammunition spaces, this common duct is to be located outside the served spaces.

Ducts provided for the ventilation of ammunition spaces shall not pass through other spaces unless:

a) the ducts comply with NR467 Pt C, Ch 4, Sec 5 [6.3.4] item a) 1) and item a) 2); and

b) the ducts are either:

   1) fitted with automatic fire dampers close to the boundaries of the ammunition space penetrated, and insulated as the penetrated division from the ammunition spaces to a point at least 5 m beyond each fire damper; or

   2) insulated as required in Tab 2 throughout the spaces penetrated; and

c) penetrations of main vertical zone divisions, if any, comply with NR467 Pt C, Ch 4, Sec 5 [6.3.6]

4.2 Ventilation systems

4.2.1 Application

a) Ventilation systems intended to be used during normal operation are to comply with the requirements of NR467 Pt C, Ch 4, Sec 5, [6] and with the present sub-article.

These requirements are not intended to apply to alternative configurations used solely in casualty situations. In any case, arrangements intended for use solely in casualty situations are not to impair compliance of the ventilation systems intended for normal operation with the requirements of NR467 Pt C, Ch 4, Sec 5, [6] and with those of the present sub-article.

b) For ships provided with CBRN protection, parts of the ventilation system not fully complying with the requirements of NR467 Pt C, Ch 4, Sec 5 [6] and with those of the present sub-article may be accepted provided that:

- they are used solely during CBRN operation, and suitably marked to this end, and
- they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and
- the ventilation system in use during normal operation is fully compliant with the requirements of the present Article, and
- suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 3, [2] for ships to be assigned the **CBRN** additional class notation.

4.2.2 Ammunition space

Ammunition spaces are to be fitted with a mechanical ventilation system in order to avoid the formation of condensation inside the space. The ventilation system is to be such as to provide at least 0,5 air change per hour.

4.2.3 Spaces for the storage of gas fire-extinguishing medium

Spaces dedicated to the storage of bottles or vessels containing the gas fire-extinguishing medium as mentioned in Tab 4, are to be fitted with a mechanical ventilation system designed to exhaust air from the bottom of the space and capable of providing at least 6 air changes per hour unless access to the space is provided from the open deck.

Table 4 : Summary of the fixed fire-extinguishing systems

Type of protected space	Applicable requirements	Type of fixed fire-extinguishing system
Machinery spaces of category A	NR467, Pt C, Ch 4, Sec 6, [4] NR467, Pt C, Ch 4, Sec 15 Pt C, Ch 4, Sec 13, [7.4]	• fixed gas fire-extinguishing system, or • fixed high-expansion foam fire-extinguishing system, or • fixed pressure water-spraying fire-extinguishing system**(2)**
JP5 pump rooms	[5.7] NR467, Pt C, Ch 4, Sec 15 Pt C, Ch 4, Sec 13, [7.4]	• fixed pressure water-spraying fire-extinguishing system**(2)**
Cargo pump rooms	[5.3] NR467, Pt C, Ch 4, Sec 15	• fixed CO2 system, or • fixed high-expansion foam fire-extinguishing system, or • fixed pressure water-spraying fire-extinguishing system
Ammunition spaces	[5.4] NR467, Pt C, Ch 4, Sec 15	Fixed pressure water-spraying fire-extinguishing system (drencher system)
Dry stores and ammunition transfer routes	[5.5]	Fixed pressure water-spraying fire-extinguishing system (drencher system)
Control stations, accommodation and service spaces	[5.6] NR467, Pt C, Ch 4, Sec 15	Automatic sprinkler system
Helicopter hangar	NR467, Pt C, Ch 4, Sec 13 NR467, Pt C, Ch 4, Sec 15 Pt C, Ch 4, Sec 13, [7.4]	Fixed pressure water-spraying fire-extinguishing system (drencher system) **(2)**
Flight deck	Pt C, Ch 4, Sec 10	Dry powder and foam system **(1)**
Cargo area and RAS station	[6]	Deck foam system

(1) Dry powder systems may consist of portable powder extinguishers with the same total capacity
(2) Thick water systems complying with Pt C, Ch 4, Sec 13, [7.4] may also be used.

4.2.4 Battery room

Spaces for the storage of batteries are to be fitted with a mechanical ventilation system complying with the requirements of NR467 Pt C, Ch 2, Sec 3, [10.4] and NR467 Pt C, Ch 2, Sec 11, [6.5]. When the formula of NR467 Pt C, Ch 2, Sec 11, [6.5.2] has not been applied, the ventilation system is to be capable of providing at least 15 air changes per hour.

4.2.5 Spaces dedicated to the storage of flammable liquids

Spaces dedicated to the storage of flammable liquids in closed containers are to be fitted with a mechanical ventilation system complying with the requirements of NR467, Pt C, Ch 2, Sec 3, [10.5] and capable of providing at least 6 air changes per hour.

4.2.6 Workshops for the handling of flammable liquid

Workshops which can be used for the handling of flammable liquids are to be fitted with a mechanical ventilation system capable of providing at least 10 air changes per hour.

4.2.7 Spaces containing welding gas (acetylene) bottle

In addition to the requirements of NR467, Pt C, Ch 1, Sec 10, [19.4.1] applicable to the spaces for the storage of welding gas (acetylene), spaces for the storage of welding gas bottles, including the workshops where welding operations are performed, are to be fitted with a mechanical ventilation system complying with the requirements of NR467, Pt C, Ch 2, Sec 3, [10.6] and capable of providing at least 6 air changes per hour.

4.2.8 Workshops for the maintenance of internal combustion machinery

Workshops for the maintenance of any internal combustion machinery using fuel having a flash-point below 60°C are to be fitted with a mechanical ventilation system capable of providing at least 15 air changes per hour.

5 Fire fighting

5.1 Fire mains and hydrants

5.1.1 Arrangement of fire pumps and fire mains

a) The fire pumps required in NR467, Pt C, Ch 4, Sec 6, [1.3] are to be so arranged that when the isolating valves referred to in [5.1.3] are shut, all the hydrants on the ship, except those in the cargo area between the isolating valves, and other fire fighting systems using the fire main as the main supply of sea water can be supplied with water by one or several of the fire pumps at the required pressure.

b) Attention is drawn to the provisions of item c) of [6.2.1].

5.1.2 Capacity of fire pumps

a) Total capacity of required fire pumps

   The required fire pumps are to be capable of supplying, at the pressure stated in NR467, Pt C, Ch 4, Sec 6, [1.2.6], two hydrants and the ship most demanding fire-fighting system using the fire main as the main supply of sea water.

Note 1: The expression “the ship most demanding systems” means the most demanding room associated with its adjacent ammunition stores.

b) Capacity of each fire pump

   Each of the required fire pumps shall have a capacity not less than 80% of the total required capacity divided by the minimum number of required fire pumps, but in any case not less than 25 m^3/hour, and each such pump shall in any event be capable of delivering at least the two required jets of water. These fire pumps shall be capable of supplying the fire main system under the required conditions. Where more pumps than the minimum of required pumps are installed, such additional pumps shall have a capacity of at least 25 m^3/h and shall be capable of delivering at least the two jets of water required in NR467, Pt C, Ch 4, Sec 6, [1.2.5] a).

5.1.3 Fire main isolating valves

In addition to the valves required in NR467, Pt C, Ch 4, Sec 6, [1.2.4], isolation valves are to be fitted in the fire main aft and forward of the cargo area in a protected position and on the tank deck at intervals of not more than 40 m to preserve the integrity of the fire main system in the event of fire or explosion.

5.2 Type of fixed fire-extinguishing systems

5.2.1 The different types of fixed fire-extinguishing systems required for auxiliary naval vessels are summarized in Tab 4.

5.3 Fire-extinguishing systems for cargo pump rooms

5.3.1 Cargo pump rooms of auxiliary naval vessels are to be provided with a fixed fire-extinguishing system complying with [5.3.2].

5.3.2 Design and arrangement of the fire-extinguishing system

a) *Each cargo pump-room is to be provided with one of the following fixed fire-extinguishing systems operated from a readily accessible position outside the pump-room. Cargo pump-rooms are to be provided with a system suitable for machinery spaces of category A.*

1) *Either a carbon dioxide system complying with the provisions of* NR467, Pt C, Ch 4, Sec 15, [4] *and with the following:*
   - *the alarms giving audible warning of the release of fire-extinguishing medium are to be safe for use in a flammable cargo vapour/air mixture,*
   - *a notice is to be exhibited at the controls stating that due to the electrostatic ignition hazard, the system is to be used only for fire extinguishing and not for inerting purposes.*
2) *A high-expansion foam system complying with the provisions of* NR467, Pt C, Ch 4, Sec 15, [5.2]*, provided that the foam concentrate supply is suitable for extinguishing fires involving the cargoes carried.*
3) *A fixed pressure water-spraying system complying with the provisions of* NR467, Pt C, Ch 4, Sec 15, [6.1.1].

b) *Where the extinguishing medium used in the cargo pump-room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.*

5.4 Fire-extinguishing systems for ammunition spaces

5.4.1 Ammunition spaces excluding lifts and transfer chambers shall be provided with a fixed water-spraying fire-extinguishing system complying with the provisions of NR467, Pt C, Ch 4, Sec 15, [6], except that:

a) spraying nozzles are provided in order to ensure the spraying of ceilings, bulkheads and shells above the waterline in such a way that it allow the spraying of the ceilings with a flow of at least 1000 l/h/m^2, and of the bulkheads and shells with a flow of at least 500 l/h/m^2
b) equipment are watered by the water falling down from the ceilings
c) the pressure water-spraying systems protecting the ammunition spaces are to be fed by the fire main.

Note 1: The Society may accept systems based on other standards recognised by the Naval Authority provided the Society considers that the fire safety of the ship is not impaired.

5.5 Fire-extinguishing systems for ammunition and dry stores transfer routes

5.5.1 Spaces forming part of the dry stores or ammunition transfer routes are to be provided with a fixed water-based fire-fighting system complying with the provisions of NR467, Pt C, Ch 4, Sec 15, [6.1.4]. The system is to be of the deluge type with manual release and is to be sized according to the prescriptive-based requirements.

The system may be supplied by the fire main provided that the requirements of [5.1] are complied with.

5.6 Fire-extinguishing arrangements in control stations, accommodation and service spaces

5.6.1 *An automatic sprinkler, fire detection and fire alarm system of an approved type complying with the requirements of NR467, Pt C, Ch 4, Sec 15 is to be fitted in all control stations, accommodation and service spaces, including corridors and stairways.*

Alternatively, control stations, where water may cause damage to essential equipment, may be fitted with an approved fixed fire-extinguishing system of another type.

Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with an automatic sprinkler system

5.6.2 Protection of Navy operational spaces

Operational spaces containing systems where water may cause damage to essential equipment may be protected by a section of the sprinkler system required in [5.6.1] and fitted with a stop valve provided the following requirements are complied with:

a) These stop valve are readily accessible in a location outside of the protected spaces
b) These stop valves is normally to be kept opened at sea
c) An indication is to be provided in a continuously manned central control station to indicate wether those valves are opened or closed, and visual and audible warning is to be provided when those valves are closed.
d) The valve's locations are to be clearly and permanently indicated. Means should be provided to prevent the operation of the stop-valves by an unauthorized person.

5.7 Protection of JP5 pump rooms

5.7.1 Fixed fire-extinguishing system

Each JP5-NATO (F44) pump room shall be provided with a fixed pressure water-spraying system or an equivalent fixed water based fire-extinguishing system complying with the provisions of the NR467 Pt C, Ch 4, Sec 15.

5.7.2 In addition of the system required above, and with consideration of the floor arrangement of the JP5-NATO (F44) pump room, a low expansion foam system, a thick water system, or any other approved system, is to be provided for the protection of bilge spaces under the machinery floors.

5.7.3 Quantity of fire-extinguishing medium

Where the extinguishing medium used in the fuel pump room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.

6 Fixed deck foam system

6.1 Application

6.1.1 Ships having the service notation **auxiliary naval vessel** are to be provided with a fixed deck foam system complying with the provisions of [6.2] and [6.3] or with an equivalent fixed installation.

Note 1: To be considered equivalent, the system proposed in lieu of the deck foam system is to:

- *be capable of extinguishing spill fires and also preclude ignition of spilled oil not yet ignited, and*
- *be capable of combating fires in ruptured tanks.*

6.2 System design

6.2.1 Principles

a) *The arrangements for providing foam are to be capable of delivering foam to the entire cargo tank deck area as well as into any cargo tank the deck of which has been ruptured.*

b) *The deck foam system is to be capable of simple and rapid operation.*

c) *Operation of a deck foam system at its required output is to permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main.*

Note 1: A common line for fire main and deck foam line can only be accepted if it can be demonstrated that the hose nozzles can be effectively controlled by one person when supplied from the common line at a pressure needed for operation of the monitors. Additional foam concentrate is to be provided for operation of two nozzles for the same period of time required for the foam system.

The simultaneous use of the minimum required jets of water is to be possible on deck over the full length of the ship, in the accommodation spaces, service spaces, control stations and machinery spaces.

d) *Foam from the fixed foam system is to be supplied by means of monitors and foam applicators.*

Note 2: On auxiliary naval vessels of less than 4000 tons deadweight, the Society may not require installation of monitors but only applicators.

e) *Applicators are to be provided to ensure flexibility of action during fire-fighting operations and to cover areas screened from the monitors.*

6.2.2 Foam solution - Foam concentrate

a) *The rate of supply of foam solution is not to be less than the greatest of the following:*

   1) *0,6 l/min per square metre of cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces,*

   2) *6 l/min per square metre of the horizontal sectional area of the single tank having the largest such area, or*

   3) *3 l/min per square metre of the area protected by the largest monitor, such area being entirely forward of the monitor, but not less than 1250 l/min.*

b) *Sufficient foam concentrate is to be supplied to ensure at least 20 minutes of foam generation in ships fitted with an inert gas installation or 30 minutes of foam generation in ships not fitted with an inert gas installation when using solution rates stipulated in item 1 above, whichever is the greatest. The foam expansion ratio (i.e. the ratio of the volume of foam produced to the volume of the mixture of water and foam-making concentrate supplied) is not generally to exceed 12 to 1. Where systems essentially produce low expansion foam but at an expansion ratio slightly in excess of 12 to 1 the quantity of foam solution available is to be calculated as for 12 to 1 expansion ratio systems. When medium expansion ratio foam (between 50 to 1 and 150 to 1 expansion ratio) is employed, the application rate of the foam and the capacity of a monitor installation is to be to the satisfaction of the Society.*

6.2.3 Monitors and foam applicators

a) *At least 50 per cent of the foam solution supply rate required in items a) 1) and a) 2) of [6.2.2] is to be delivered from each monitor.*

b) *The capacity of any monitor is to be at least 3 l/minute of foam solution per square metre of deck area protected by that monitor, such area being entirely forward of the monitor. Such capacity is to be not less than 1250 l/minute.*

c) *The capacity of any applicator is to be not less than 400 l/min and the applicator throw in still air conditions is to be not less than 15 m.*

Note 1: Where, in pursuance of [6.2.1], the installation of monitors is not required on auxiliary naval vessels of less 4000 tons deadweight, the capacity of each applicator is to be at least 25 per cent of the foam solution supply rate required in items a) 1) and a) 2) of [6.2.2].

6.3 Arrangement and installation

6.3.1 Monitors

a) The number and position of monitors are to be such as to comply with item a) of [6.2.1].

b) The distance from the monitor to the farthest extremity of the protected area forward of that monitor is not to be more than 75 per cent of the monitor throw in still air conditions.

c) A monitor and hose connection for a foam applicator are to be situated both port and starboard at the front of accommodation spaces facing the cargo tank deck.

6.3.2 Applicators

a) The number of foam applicators provided is to be not less than four. The number and disposition of foam main outlets are to be such that foam from at least two applicators can be directed on to any part of the cargo tank deck area.

b) The deck foam system is to be so arranged as to permit the protection of the loading or unloading arrangements by at least two foam applicators.

6.3.3 Isolation valves

Valves are be provided in the foam main, and in the fire main when this is an integral part of the deck foam system, downstream of any monitor position to isolate damaged sections of those mains.

6.3.4 Main control station

The main control station for the system is to be suitably located outside the cargo area, adjacent to the accommodation spaces and readily accessible and operable in the event of fire in the areas protected.

7 Equipment for measuring oxygen and flammable vapours concentration

7.1 Provisions applicable to all ships

7.1.1 All ships are to be provided with at least two portable gas detectors capable of measuring flammable vapour concentrations in air (%LEL) and at least two portable oxygen analysers. Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

Note 1: The number of portable detection instruments required above is considered equivalent to one portable instrument for measuring flammable vapour concentration, one portable instrument for measuring oxygen and sufficient spares.

7.1.2 The gas detectors required in [7.1.1] are to be of a type approved by the Society.

7.2 Additional provisions for ships fitted with an inert gas system

7.2.1 In addition to the provisions of [7.1], for ships fitted with inert gas systems, at least two portable gas detectors are to be capable of measuring concentrations of flammable vapours in inerted atmosphere. Gas detectors are to be capable of measuring any gas content from 0 to 100% in volume.

Section 7 Escape

1 Means of escape

1.1 Means of escape from control stations, accommodation spaces and service spaces

1.1.1 The requirements of NR467, Pt C, Ch 4, Sec 8, [2.2.3], items a) and b) are to be replaced by:

a) Escape from spaces below the bulkhead deck

   1) Below the bulkhead deck, two means of escape, at least one of which shall be independent of watertight doors, shall be provided from each watertight compartment or similarly restricted space or group of spaces. Exceptionally, the Society may dispense with one of the means of escape for crew spaces that are entered only occasionally, if the required escape route is independent of watertight doors.

   2) Where the Society has granted dispensation under the provisions of 1) above, this sole means of escape shall provide safe escape. However, stairways shall not be less than 700 mm in clear width with handrail at least on one side.

b) Escape from spaces above the bulkhead deck

   Above the bulkhead deck there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which shall give access to a stairway forming a vertical escape.

1.1.2 Direct access to stairway enclosures

The requirements of NR467, Pt C, Ch 4, Sec 8, [2.2.3], item c) are to be replaced by:

Stairway enclosures in accommodation and service spaces are to have direct access from the corridors and be of a sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency.

Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment and open information counters are permitted. Only public spaces, corridors, lifts, public toilets, pantries containing no cooking appliances, ro-ro and vehicle spaces, other escape stairways required by [1.1.3] or escape stairways from machinery spaces other that category A machinery spaces and external areas are permitted to have direct access to these stairway enclosures. Small corridors or “lobbies” used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of 4,5 m^2, a width of not less than 900 mm and contain a fire hose station.

1.1.3 Details of means of escape

The requirements of NR467, Pt C, Ch 4, Sec 8, [2.2.3], item d) are to be replaced by:

1) At least one of the means of escape required by [1.1.1] items a) and b) shall consist of a readily accessible enclosed stairway, which shall provide continuous fire shelter from the level of its origin to the appropriate lifeboat and liferaft embarkation decks, or to the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by way of external open stairways and passageways shall be provided and shall have emergency lighting in accordance with NR467, Pt C, Ch 2, Sec 3 and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck shall have fire integrity, including insulation values, in accordance with Ch 4, Sec 6, Tab 2 and Ch 4, Sec 6, Tab 3, as appropriate.

2) Protection of access from the stairway enclosures to the lifeboat and liferaft embarkation areas shall be provided either directly or through protected internal routes which have fire integrity and insulation values for stairway enclosures as determined by Ch 4, Sec 6, Tab 2 and Ch 4, Sec 6, Tab 3, as appropriate.

3) The widths, number and continuity of escapes shall be in accordance with the requirements in NR467, Pt C, Ch 4, Sec 15, except that the requirements of NR467, Pt C, Ch 4, Sec 15, [12.1.1] and NR467, Pt C, Ch 4, Sec 15, [12.1.2] item c) are replaced by [1.1.4] and [1.1.6] respectively.

1.1.4 Width of stairways

The requirements of NR467, Pt C, Ch 4, Sec 15, [12.1.1] are to be replaced by:

a) Stairways are not to be less than 700 mm in net width. The minimum net width of stairways is to increase by 10 mm for every person provided in excess of 70 persons. The total number of persons to be evacuated by such stairways is assumed to be two thirds of the total number of the crew and special persons in the areas served by such stairways.

b) The width of the stairways is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13, [2.1.2], considering the distribution of persons given in [1.1.5] hereafter.

1.1.5 Distribution of persons

For the application of the provision of the Fire Safety System Code, Chapter 13, [2.1.2.2.2.1], cases 1 and 2 are to be replaced by:

a) Case 1 (night-time)
- the total number of the members of crew not operating by watch in its cabins and berthing
- 2/3 of the members of the crew operating by watch in its cabins and berthing spaces, and
- 1/3 of the crew operating by watch in its service spaces.

b) Case 2 (daytime)
- 1/4 of the members of crew not operating by watch in its public spaces
- 3/4 of the members of crew not operating by watch in its service spaces
- 1/3 of the crew operating by watch in its cabins and berthing spaces
- 1/3 of the crew operating by watch in its service spaces, and
- 1/3 of the crew operating by watch in its public spaces.

Note 1: For the application of the provision of Fire Safety System Code, Chapter 13 [2.1.2.1.4], the number of persons to be distributed in each public space is to be proportional to the deck area of these public spaces, as per the following formula:

$n = N \quad a / A$

where:

N : Total number of persons to be distributed in the public spaces

a : Deck area of the selected public space

A : Total deck area of the public spaces available to the total number of persons to be distributed in the public spaces.

Note 2: Other cases of distribution of persons may be considered in replacement of, or in addition to, cases 1 and 2 above by more effective scenarios given by the Naval Authority.

1.1.6 Vertical rise and inclination of stairways

The requirements of NR467, Pt C, Ch 4, Sec 15, [12.1.2] item c) is to be replaced by:

Stairways are not to exceed 3,5 m in vertical rise without the provision of a landing. Their angle of inclination is to be in general 45°, but not greater than 50°, and, in machinery spaces and small spaces, not greater than 60°.

1.1.7 Evacuation analysis

Escape routes are to be evaluated by an evacuation analysis early in the design process.

The analysis is to be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of crew along escape routes. In addition, the analysis is to be used to demonstrate that escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty.

Note 1: For the application of the IMO Circular MSC.1/Circ.1533 , the scenarios and given values such as Response duration (R), Total travel duration (T), Embarkation and launching duration (E+L), counterflow factor, walking speed, etc. may be replaced by more effective scenarios and values given by the Naval Authority.

Section 8 Replenishment at Sea

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable to auxiliary naval vessel installations for underway Replenishment At Sea (RAS) of liquid and solid supplies.

1.2 Documents to be submitted

1.2.1 The plans and documents to be submitted to the Society are listed in Tab 1.

1.3 Definitions

1.3.1 Replenishment at sea (RAS)

RAS means refuelling at sea or underway replenishment at sea of solid and liquid supplies.

1.3.2 Vertical Replenishment (VERTREP)

Vertical Replenishment (VERTREP) means transfer of unitized cargo by means of helicopter.

1.3.3 RAS station

A Replenishment at Sea (RAS) station is the deck area fitted with RAS equipment providing the capability to carry out underway replenishment of liquid and/or solid cargo.

Table 1 : Documentation to be submitted

No.	A / I **(1)**	Description of document
1	I	Description and operation manuals of the ship's RAS systems and equipment
2	A	Plans showing each proposed combination of equipment, fully rigged
3	I	Details of solid cargo to be transferred: maximum weight and dimensions
4	A	Details of liquid cargo to be transferred and diagram of the fluid transfer system
5	I	Details of maximum sea state and environmental conditions under which RAS operations are permitted
6	I	General arrangement showing: • relative disposition of RAS stations and associated clearances • location of RAS control stations • arrangement of solid cargo and ammunition transfer routes
7	A	Lifting appliances: plans and construction drawings of all lifting appliances, masts, derricks, rigs
8	A	Details of equipment identified for RAS operations. Design and installation loads on the equipment together with details of securing and holding down arrangements. Details of the access required for maintenance and to operate the equipment
9	I	Description of safety devices (emergency breakaway, antislack devices, alarms, limit switches…)
10	A	Drawings of the foundations of lifting appliances and winches, including footprint and reaction forces
11	I	National or international regulations, standards or specifications used for type testing of equipment requiring type testing according to Tab 4
12	I	SWL of all components of RAS installation
13	A	Test and inspection programme for the test onboard: static load test, checking verifications, dynamic overload tests
14	A	Details of structural reinforcement under RAS stations dump areas
15	A	Diagram of internal ship communication system
16	I	Diagram of ship to ship communication system
17	I	Standards used for ship to ship and ship to helicopter communication systems
18	I	Arrangement plan of low intensity lightning of RAS stations and transfer routes
(1) I = to be submitted for information; A = to be submitted for approval		

1.3.4 VERTREP area

Deck area where VERTREP operations are carried out. It includes the clear deck space for helicopter rotor, fuselage and landing gear, and VERTREP load clearances (including dump areas).

1.3.5 RAS control station

A RAS control station is a station from which it is possible to operate RAS equipment and observe the RAS operations performed at RAS station(s).

1.3.6 RADHAZ

A hazard caused by a transmitter/antenna installation that generates electromagnetic radiation in the vicinity of personnel or fueling operations in excess of established safe levels or increases the existing levels to a hazardous level.

1.4 Standardization

1.4.1 RAS operations are to be conducted in accordance with ATP-16 or equivalent National Standard.

2 Design and construction

2.1 RAS equipment

2.1.1 Typical arrangement

Fig 1 shows a tensioned liquid replenishment installation which may be used as reference.

Fig 2 shows a tensioned solid replenishment installation also for reference purpose.

Other types of RAS installations may be used and are to be submitted to the Society for special examination.

Figure 1 : Tensioned liquid replenishment installation

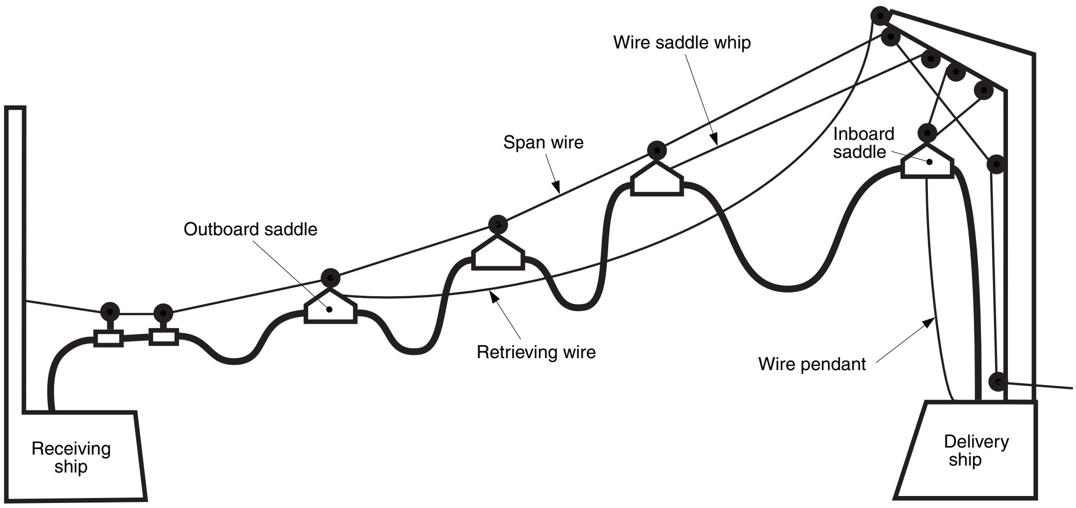
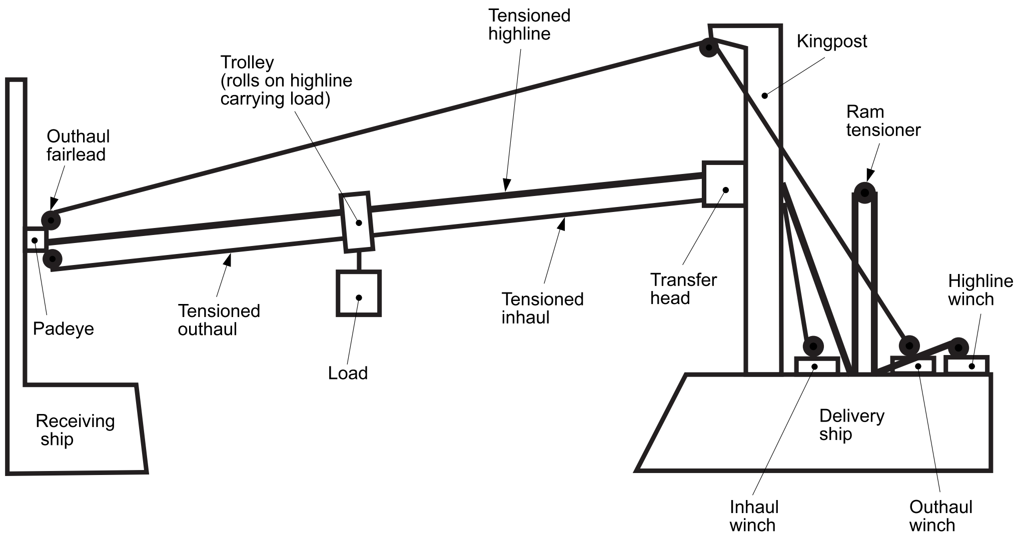


Figure 2 : Tensioned solid replenishment installation



2.1.2 General

RAS pieces of equipment onboard ships having the service notation **auxiliary naval vessel** are to comply with the following requirements:

- they are to be type approved according to the requirements in [4.1]
- certificates of inspection of materials and equipment are to be provided as indicated in [4.2]
- fitting onboard of the RAS equipment is to be witnessed by a Surveyor of the Society and the relevant certificate is to be issued
- demonstration of the strength, structural integrity and good working of RAS equipment is to be effected for each ship through shipboard testing as mentioned in [4.4] and this is to be reported in the above certificate.

2.1.3 Emergency breakaway

All RAS equipment and facilities are to be designed to permit the application of emergency breakaway procedures that should normally be complete within one minute of the commencement of initiation. Use may be made of quick release couplings and/or breakable couplings. Attention is to be given to the attachment of wires and ropes to winch drums and the selection of emergency breakaway equipment (wire cutters, axes, etc.).

2.1.4 Protection

All deck mounted electrical equipment and enclosures have to be designed with IP56 ingress protection rating.

2.1.5 Survey of elements within the scope of ship classification

The fixed parts of the RAS equipment and connections to ship structure (masts, winches and equipment foundations, local reinforcements under the dump area and transfer lanes) are to be surveyed at the yard by a Surveyor of the Society within the scope of ship classification.

2.1.6 Safe Working Load (SWL) of RAS equipment

The safe working load of RAS components is to be sufficient to withstand the maximum load to which such component may be subjected during the RAS operation. The safe working load is to be indicated by the designer.

For tensioned spanwire or highline systems, the SWL of the rigging components is the maximum design tension of the spanwire or highline given by the designer.

As a rule, the SWL of the components which are not part of the tensioned line is not to be less than the values from Tab 2.

Table 2 : Safe working loads of non-tensioned components

RAS system component	SWL, in kN
Riding and retrieving lines	35
Inhaul and outhaul rigging and saddle whips	25

2.1.7 Winches

Winches are to incorporate safety features that permit safe RAS operations and cater for the unique loading conditions that may arise during RAS operations. The following functions are to be fulfilled:

a) quick and efficient engagement and disengagement of the service brake by both automatic and manual means

b) long term locking of the winch drum having manual engagement and disengagement

c) for highline, spanwire and inhaul winches, an overload protection preventing the wire/rope being overstressed during RAS operations (e.g. when ships move or roll apart)

d) proper spooling of the wire onto the drum

e) for highline, spanwire and outhaul winches, slack rope prevention that maintains tension in the wire when the winch is operating under no load.

Combined stress resulting from application in the most unfavourable conditions of a tension in the cable equal the breaking load of this cable should not be higher than 80% of the comparison elastic limit of the material of which strength elements such as frame, drum, drum axles, assembly welds, etc. are made.

Minimum braking force of service brakes is not to be less than 1,5 times the safe working force on the brake.

2.1.8 Steel wire ropes

Steel wire ropes used for RAS operations are to be in compliance with requirements of NR216 Materials and Welding, Ch 4, Sec 1, [4].

The ratio of the specified breaking load of the cable to its SWL is not to be taken less than 3,5.

2.1.9 Hoses and fittings

Hoses for transferring liquids are to be in accordance with standards applicable to the intended application.

Where probe fuelling systems are part of the design, the following features are to be incorporated:

a) automatic latching mechanism with sleeve valve that opens on proper engagement and automatically closes on disengagement

b) disengagement on application of a specified load

c) swivel arm that keeps probe receiver aligned with the spanwire

d) manual release lever

e) quick release hook

f) indication of incorrect probe engagement.

2.1.10 Masts

Masts, cranes, derricks and rigs intended for RAS operations are to comply with the relevant requirements of NR526 Rules for lifting appliances, considering the most unfavourable combination of all safe working loads applied to the mast.

2.2 Steering capability

2.2.1 General

The steering gear system is to fulfil the requirements defined in NR467, Pt C, Ch 1, Sec 14.

2.2.2 Electrical Power supply

An alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

The independent source is to be used only for this purpose.

The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

2.2.3 Steering control systems

Any single failure in the steering control system including its interfaces to the navigation system is not to impair the steering capability which is to be continuously maintained.

Such single failure may affect any active component as defined in NR467, Pt F, Ch 2, Sec 1, [1.2.5] from interfaces to the navigation system to interfaces to the mechanical steering actuators.

Compliance with the above requirements of [2.2.3] is to be demonstrated by a risk analysis performed in compliance with NR467, Pt F, Ch 2, App 1, Procedures for Failure Modes and Effect Analysis.

3 Arrangement and installation

3.1 General

3.1.1 RAS systems are to be designed and installed such that degradation or failure of any RAS system will not render another ship system inoperable.

3.2 Arrangement of RAS stations

3.2.1 Location of RAS stations

The distance separating two alongside RAS stations is recommended not to be less than 20 m and not to exceed 40 m.

As far as practicable, one side RAS station is to be located amidships to maximise crew protection during RAS operations during heavy weather conditions.

3.2.2 Clearance requirements

A clearance of at least 30° aft and forward of each side RAS station is to be provided.

For the stern station, if any, sufficient clearance is to be provided for safe deployment of refuelling equipment with regards to deck and stern equipment.

3.3 Communication

3.3.1 Bridge conning position

A conning position for the officer in charge of RAS operations is to be provided on the navigating bridge with a duplicated position on both bridge wings.

From this conning position, it is to be possible to observe the ship's heading and relative movement of the ships conducting RAS operations. In addition, a gyro compass readout and rudder angle indicator are to be readily visible from the conning position.

3.3.2 Ship internal communication systems

Means of communication are to be provided between each RAS Station and the RAS control station.

Such communication system is to be such that communication between RAS Stations and RAS control station can be maintained in case of equipment single failure.

As a minimum, means of effective ship internal communications are to be provided in accordance with Tab 3.

3.3.3 Ship to ship communications

a) Means are to be provided to allow continuous ship to ship distance measurement during side by side replenishment at sea operations.

b) Visual and aural means of communication are to be provided between the ships conducting RAS operations.

c) If some equipment such as distance line is to be transferred from one ship to another in order to conduct the RAS operations, the following is to be complied with:

- the distance line securing points are to be clear of all RAS stations and arranged so that the distance line is visible from the bridge conning position.

Table 3 : Internal communications

Position	Conning position	RAS station	RAS control station	Remarks
Conning position		X	X	
RAS station (including Helideck deck control station for VERTREP operations)	X		X	Each RAS station is to be able to communicate with the conning position and RAS control station
RAS control station	X	X		

3.4 RAS station arrangement

3.4.1 Protection of personnel

a) Bulwarks, guard rails or other equivalent arrangement are to be provided in exposed upper deck positions with regards to personnel protection, in accordance with NR467, Pt B, Ch 12, Sec 2.

b) In general, RAS operations are to be carried out with guard rails in position. Where, for operational reasons, this is not practicable, alternative equivalent arrangements are to be provided.

c) Slip-free surfaces are to be provided in the areas where RAS operations are conducted, and tripping hazards are to be minimized.

d) A minimum distance of at least 3 m between any RAS station superstructure and the edge of the weather deck is to be provided.

e) The arrangements and operational procedures are to be such that the personnel involved in RAS operations will not be exposed to RADHAZ.

3.4.2 Access

The rigging securing points are to be arranged so that safe access is provided to them, including ladders and walkways on the masts.

3.4.3 RAS equipment stores

RAS equipment and fittings are to be stored in dedicated stores, readily accessible from their RAS station. The stores are to have direct access to the weather deck.

3.4.4 Sources of high intensity noise

RAS stations are to be arranged so that exposure to high intensity noise (above 85 db) is as low as practicable during RAS operations.

3.5 RAS control station arrangement

3.5.1

a) A RAS control station is to be provided for control and monitoring of each RAS station equipment.

b) The controls for RAS equipment are to be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society.

c) The RAS control station is to be located so it provides a clear view of all RAS stations and associated equipment.

3.6 Fluid transfer

3.6.1 General

a) The filling connections for liquid transfer operations are to be located within the RAS station and are to be fitted with a shut-off valve operable from the weather deck.

b) As far as practicable, separate filling connections are to be provided for each type of fluid that may be taken on board. To reduce the risk of inadvertent incorrect hose connection, the filling connections are to be of different types and separated as far as possible from each other for each type of liquid to be transferred.

c) Each filling connection is to be provided with means of sampling and a filter capable of being cleaned.

d) Each filling connection is to be provided with a permanently attached notice identifying the fluid storage system(s) connected to the filling connection.

e) Filling connections are to be designed to allow an emergency breakaway as per [2.1.4].

f) Fluid transfer piping is to be in compliance with Ch 4, Sec 4.

g) Emergency stop of the cargo pumps is to be provided at the RAS control station.

3.7 Solid transfer

3.7.1 General

To prevent ingress of water into the ship, sills or alternative equivalent arrangements are to be provided at the entrances to the interior of the ship from each RAS station.

3.7.2 Ship’s structure

a) Each RAS station intended for solid transfer operations is to be provided with a designated dump area.

   The dump area is to be suitably reinforced to withstand the impact loads that may arise due to landing of stores and equipment on board during RAS operations.

b) The dump area is to extend for at least 1m outside of the largest expected solid cargo foot print. A factor of safety of not less than four times the maximum load to be transferred is to be used in the design of the structure.

3.8 VERTREP

3.8.1 VERTREP stations are to be provided with facilities and equipment to permit the discharge of static electricity from the helicopter or cargo whilst airborne.

3.9 Night RAS operation

3.9.1 Night operation

The following requirements are to be complied in order to carry out RAS operation at night:

- low intensity red lighting is to be provided at each RAS station, along the transfer routes to and from the RAS station to the stores and within the stores
- provision is also to be made for suitable low intensity lighting inside the RAS control station for control and monitoring of RAS equipment.

4 Certification, inspection and testing

4.1 Type approval procedure

4.1.1 RAS components are to be type approved according to the following procedure:

- the design is to comply with the requirements of this section and either national or international standards, or recognized codes or specifications, which are to be indicated
- each component of the RAS equipment is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [4.2]
- types tests are to be carried out as specified under [4.3].

Table 4 : Materials and equipment certification

Item	Material certification	Product certification					Remarks
		Design assessment index	Examinations and tests			Certification	
			During fabrication	After completion	Running tests		
Lifting appliances: masts, cranes, derricks	C (1)	DA	X (2)	X (2)	X (3)	C	(1) As per NR216 (2) As per relevant provisions of NR526 (3) Shop tests and running tests onboard as per [4.4]
Winches, anti-slack devices, Ram tensioner	C (1)	TA (2)	X	X	X (3)	C	(1) As per NR216 (2) As a rule, no individual design assessment of winches and RAS equipment (3) Onboard tests as per [4.4]
Electric motors and electrical equipment used for RAS operations (1)	W	DA or TA		X (2)	X (2)	W	(1) Considered as intended for secondary essential services (2) Testing of electric motors includes type tests and routine tests as per NR467, Pt C, Ch 2, Sec 4, [3]
Hydraulic cylinders, piping of class I and equipment essential for RAS operation (winches, Ram tensioner)	C		X s	X h		C	
Control systems of winches and essential systems for RAS operation (Ram tensioner)		DA			X (1)	C	(1) According to an agreed programme for onboard tests as per [4.4]
Cargo transfer hoses and pipes couplings, including breakaway couplings	C (1)	TA		X s h (2)	X (3)	C	(1) Only for metallic pieces and couplings (2) Non-destructive and hydraulic tests as per recognized standards or specification to be specified by the manufacturer (3) Emergency breakaway capabilities to be demonstrated onboard
Loose gear and accessories, including blocks, hooks, shackles, swivels …	W	DA (1)		X (2)		C	(1) Only for elements not complying with a national or international standard (2) Proof load as per [4.3]
Steel wire ropes	W			X (1)		C	(1) As per requirement of NR216 or in compliance with a national or international standard (ISO 3178 for instance)

"C" indicates that a product certificate of the Society is required with invitation of the Society surveyor to attend the tests unless otherwise agreed.
"W" indicates that a manufacturer's certificate is required.
index "h" means that an hydraulic pressure test is required.
index "s" means that non destructive tests are required, as per Rules, standard or specification.
"TA" means a type approval is required.
"DA" means a design approval of the product is required, either for the specific unit produced, or using the type approval procedure.
Note: Where nothing is mentioned in the design index assessment column, a design assessment of the specific unit is not required.

4.2 Inspection at works of the RAS equipment

4.2.1 The materials and equipment are to be inspected and certified as specified in Tab 4.

4.3 Prototype tests

4.3.1 Prototype tests are to be witnessed by a Surveyor from the Society and to include load test of the RAS equipment under a proof load at least equal to 2 times the safe working load defined in [2.1.7].

4.4 Tests on board

4.4.1 General

The RAS arrangements are to undergo the following tests and inspections after their installation on board:

- static load test demonstrating the strength of the complete rigging of RAS equipment under a load condition larger than the operational one
- after static load test, a visual inspection and functional test to demonstrate that the system is operational and has not suffered damages from the static load tests
- overload tests to demonstrate proper functioning of the equipment on overload.

These tests are to be carried out according to a test programme submitted to the Society.

Testing and marking of the RAS equipment is to be in accordance with the relevant requirements of NR526 Rules for lifting appliances, Ch 4, Sec 1.

4.4.2 Static load tests

Static load tests are to be performed using dedicated test wire rope, different from the ship's wire rope used onboard.

The test loads should be greater than twice the rated SWL of the rigging to be tested. In addition, for tensioned spanwire or highline systems, the test load should not be less than 20% of the breaking strength of the spanwire or highline.

4.4.3 Overload tests

Repeated load cycles specific to each type of equipment are to be performed according to a test programme submitted to the Society. As a rule, the test load is to be 1,5 times the rated operating load corresponding to the SWL.

On winches with adjustable clutches, the clutch need temporary readjustment in order to perform the overload tests. After completion of the test, the clutch or limiting devices are to be readjusted to the normal value and retested.

Section 9 Carriage of Limited Quantities of Flammable Products with Flashpoint ≤ 60°C

1 General

1.1 Application

1.1.1 Ships having the service notation **auxiliary naval vessel** and complying with the requirements of this Section may carry flammable liquids with flashpoint ≤ 60°C in limited amounts not exceeding the maximum specified in [1.2.1].

1.2 Maximum capacity of flammable liquid with flashpoint ≤ 60°C

1.2.1 The total capacity of cargo tanks designed to carry oil product having a flashpoint ≤ 60°C is to be less than 1000 m^3.

1.3 Definitions

1.3.1 Integral tank

Integral tank means a cargo containment envelope which forms part of the ship's hull and which may be stressed in the same manner and by the same loads which stress the contiguous hull structure and which is normally essential to the structural completeness of the ship's hull.

1.3.2 Independent tank

Independent tank means a cargo-containment envelope which is not contiguous with, or part of, the hull structure. An independent tank is built and installed so as to eliminate whenever possible (or in any event to minimize) its stressing as a result of stressing or motion of the adjacent hull structure. An independent tank is not essential to the structural completeness of the ship's hull.

1.3.3 Cargo area

With regards to the carriage of flammable liquids with flashpoint ≤ 60°C and corresponding requirements of this Section, the cargo area is that part of the ship where cargo and cargo vapours are likely to be present and includes cargo tanks, cargo pump rooms, hold spaces in which independent tanks are located, cofferdams, ballast or void spaces surrounding integral tanks and the following deck areas:

- within 3 m of a cargo tank installed on deck
- within 3 m of a cargo tank outlet in case of independent tanks installed below deck
- within 3 m of a cargo tank outlet in case of integral tanks installed below deck and separated from the weather deck by a cofferdam
- the deck area above an integral tank without an overlaying cofferdam plus the deck area extending transversely and longitudinally for a distance of 3 m beyond each side of the tank
- within 3 m of any cargo liquid or vapour pipe, flange, cargo valve, gas or vapour outlet, or entrance or ventilation opening to a cargo pump-room.

1.3.4 Gas-dangerous spaces

Gas-dangerous spaces include the spaces listed in NR467, Pt D, Ch 7, Sec 5, Tab 1, corresponding to hazardous area zones 0, 1 and 2.

2 General arrangement

2.1 Compartment arrangement

2.1.1 Cargo tank capacity

The total capacity of cargo tanks designed to carry flammable liquids with flashpoint ≤ 60°C is to comply with the requirements stipulated in [1.2.1].

2.1.2 Length of cargo tanks

The length of each cargo tank may not exceed 10 metres or one of the values of Tab 1, as applicable, whichever is the greater.

Table 1 : Length of cargo tanks

Longitudinal bulkhead	Type of cargo tank	b_i/B **(1)**	Centreline bulkhead	Length (m)
No bulkhead	–	–	–	$(0,5\ b_i/B + 0,1)\ L$ **(2)**
Centreline bulkhead	–	–	–	$(0,25\ b_i/B + 0,15)\ L$
Two or more bulkheads	Wing cargo tank	–	–	0,2 L
	Centre cargo tank	• if $b_i/B \geq 1/5$	–	0,2 L
		• if $b_i/B < 1/5$	no	$(0,50\ b_i/B + 0,10)\ L$
			yes	$(0,25\ b_i/B + 0,15)\ L$

(1) b_i : Minimum distance from the ship side to the outer longitudinal bulkhead of the tank in question measured inboard at right angles to the centreline at the level corresponding to the assigned summer freeboard.
(2) The cargo tank length is not to exceed 0,2 L.

2.1.3 Cargo segregation

Cargo tanks designed to carry flammable liquids with flashpoint ≤ 60°C are to:

a) be segregated from other cargoes or fuel oils by means of a cofferdam, void space, cargo pump room, pump room or empty tank

b) have separate pumping and piping systems which may not pass through other cargo tanks, unless encased in a tunnel, and

c) have separate tank venting systems.

2.2 Access arrangements

2.2.1 Access to spaces within the cargo area

The access to spaces within the cargo area is to meet the requirements of Ch 4, Sec 2, [4.2.2].

2.2.2 Access to the gas-safe spaces

Gas-safe spaces such as accommodation, service, machinery and other similar spaces may not have any direct communication with gas-dangerous spaces defined in [1.3.4].

Nevertheless, access openings to gas-safe spaces below the weather deck, which are located less than 10 metres but not less than 3 metres from the outlets of gas vents in cargo tanks and cargo storage vessels, may be permitted where they are intended as emergency means of escape from normally attended spaces or as access to normally unattended spaces, provided that the relevant doors are kept permanently closed when the ship is not gas-freed.

Suitable warning plates are to be fixed in the proximity of such openings.

3 Machinery systems

3.1 Bilge system

3.1.1 Cargo pump rooms, duct keels below cargo tanks, hold spaces in which independent cargo tanks are installed and all gas-dangerous spaces, dry cofferdams are to be served by an independent bilge pumping system entirely situated within the cargo area as defined in [1.3.3] and fitted with pumps or ejectors. No connection is permitted with the bilge system serving gas-safe spaces of the ship.

3.2 Other piping systems not intended for cargo

3.2.1 Piping systems serving ballast tanks

Pumps, ballast lines, vent lines and other similar equipment serving permanent ballast tanks are to be independent of similar equipment serving cargo tanks.

3.2.2 Air pipes and sounding pipes of gas-dangerous cofferdams

Gas-dangerous cofferdams are to be provided with air pipes led to the open and, where not accessible, also with sounding pipes.

4 Cargo systems

4.1 Cargo segregation

4.1.1 For cargo handling, a pumping and piping system entirely separate from other pumping and piping systems on board is to be provided. Such systems are not to pass through any accommodation, service or machinery space other than cargo pump rooms.

4.2 Materials

4.2.1 Materials for construction of tanks, piping, fittings and pumps are to be in accordance with Ch 4, Sec 4, [4.3.2].

4.3 Installation of independent portable tanks

4.3.1 Independent portable tanks, to be fitted on the weather deck, may be used as cargo storage vessels subject to the following conditions:

- the portable tanks are to be securely fastened to the hull structure
- in the zone on the weather deck where the portable tanks are arranged, a suitable possibly removable containment coaming is to be fitted such as to prevent any spillage and/or leakages from flowing to gas-safe areas
- a space is to be left between tanks and ship sides sufficient to allow easy passage of ship personnel and transfer of fire-fighting arrangements
- the cargo handling system serving portable tanks is to be such that liquid heads higher than those allowable for cargo tanks, if any, served by the same system cannot occur.

Provisions are to be made such that any portable tank is easily identifiable by means of markings or suitable plates.

4.4 Cargo pumping system, piping system and pump rooms

4.4.1 Cargo pump room

a) The cargo pump room is to comply with the applicable requirements for oil tankers. Refer to NR467, Pt D, Ch 7, Sec 4.

b) For the construction, installation and operation of cargo pumps, the applicable requirements for oil tankers are to be complied with. Refer to NR467, Pt D, Ch 7, Sec 4.

4.4.2 Piping system

a) The cargo piping system is to be installed, except as stipulated in [4.4.3], within the cargo tank and cargo storage vessel area and is not to run through tanks, fuel oil tanks and other compartments not belonging to the cargo system.

b) Where necessary, cargo piping is to be provided with joints or expansion bends.

c) Pipe lengths serving tanks are to be provided with shut-off valves operable from the weather deck.

d) In order to prevent any generation of static electricity, the outlets of filling lines are to be led as low as possible in the tanks.

4.4.3 Loading and unloading connections

a) Pipe ends, valves and other fittings to which hoses for cargo loading and unloading are connected are to be of steel or other ductile material and are to be of solid construction and effectively secured.

b) Connecting couplings for cargo hoses are to be fitted with devices which automatically shut off the cargo piping when the hose is disconnected and with means for quick-release of the hose, to be provided by the installation either of a coupling hydraulically controlled from outside the cargo area or of a weak link assembly which will break when subjected to a pre-determined pull.

c) Where a pipe end to which hoses for cargo loading and unloading are connected is arranged outside the cargo tank area, the connection piping to such end is to be provided, in way of its connection to the manifold in the cargo tank area, with a blank spectacle flange or a spool piece, irrespective of the number and type of valves fitted in way of such connection. The space within a range of 3 metres from the above pipe end is to be considered gas-dangerous as far as electrical installations or other sources of ignition are concerned.

4.5 Cargo tanks and cargo storage vessels

4.5.1 Design and construction of portable tanks

a) The cargo handling system serving portable tanks is to be such that liquid heads higher than those allowable for cargo tanks, if any, served by the same system cannot occur.

b) Scantling of portable tanks is to be in compliance with the provisions Pt C, Ch 1, App 3, except that the minimum thickness is not to be less than 5 mm.

c) Provisions are to be made such that any portable tank is easily identifiable by means of markings or suitable plates.

d) Portable tanks are to be provided with appropriate access hatches allowing the use of portable gas-freeing equipment.

4.5.2 Level gauging systems

a) Each cargo tank or cargo storage vessel is to be fitted with at least one level gauging device of the closed type as defined in NR467, Pt D, Ch 7, Sec 4, [4.4.2].

b) Sounding pipes may be accepted provided that they are so constructed and installed as to minimise the quantity of gas released during sounding operations. Such sounding pipes are not to be arranged within enclosed spaces.

4.5.3 Venting systems

Cargo tanks and cargo storage vessels are to be provided with gas venting systems entirely separate from any vent pipes serving other compartments. Such systems are to comply with the requirements of NR467, Pt D, Ch 7, Sec 4, [4.2] for gas venting systems of cargo tanks of oil tankers.

4.5.4 Cargo tank inerting, purging and/or gas-freeing

In addition to the requirements given in Ch 4, Sec 4, [5.3], the following is to be complied with:

a) Discharge outlets are to be located at least 10 m measured horizontally from the nearest air intake and openings to enclosed spaces with a source of ignition and from deck machinery equipment which may constitute an ignition hazard.

b) The cargo tanks designed to carry oil product having a flashpoint ≤ 60°C are to be fitted with an inert gas system complying with the provisions of NR467 Pt C, Ch 4, Sec 15 [13] or with an equivalent system.

   This system is to be entirely separate from another inert gas system serving other cargo tanks, if fitted.

Note 1: To be considered equivalent, the system proposed in lieu of the fixed inert gas system is to:

- be capable of preventing dangerous accumulation of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations, and
- be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

c) On individual cargo tanks the gas outlet pipe, if fitted, is to be positioned as far as practicable from the inert gas / air inlet and in accordance with Ch 4, Sec 4, [5.2]. The inlet of such outlet pipes may be located either at the deck level or at not more than 1 m above the bottom of the tank.

d) The cross-sectional area of such gas outlet pipe referred to in a) above is to be such that an exit velocity of at least 20 m/s can be maintained when any three tanks are being simultaneously supplied with inert gas. Their outlets are to extend not less than 2 m above deck level.

e) Each gas outlet referred to in d) above is to be fitted with suitable blanking arrangements.

f) The arrangement of inert gas and cargo piping systems is to comply with the provisions of NR467 Pt C, Ch 4, Sec 15 [13.2.3], item b) 7).

g) The cargo tanks are first to be purged in accordance with the provisions of a) to d) above until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2% by volume. Thereafter, gas-freeing may take place at the cargo tank deck level.

5 Electrical installations

5.1 Hazardous locations and types of equipment

5.1.1 In addition to the general requirements of Ch 4, Sec 5, electrical equipment and hazardous areas definitions are to comply with requirements of NR467, Pt D, Ch 7, Sec 5, [2].

CHAPTER 5
AMPHIBIOUS VESSEL

Section 1	General
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Section 3	Hull and Stability
Section 4	Machinery and Systems
Section 5	Electrical Installations
Section 6	Fire Protection
Section 7	Escape
Section 8	Facilities for Flammable Products with Flashpoint ≤ 60 °C

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **amphibious vessel**, as defined in Pt A, Ch 1, Sec 2, [4.6].

1.1.2 The requirements of this Chapter apply to ships intended for amphibious power projection and possibly for airborne power projection.

In addition with aircrafts and vehicles, flammable products with flashpoint ≤ 60°C may be carried subject to the requirements of Ch 5, Sec 8.

1.1.3 As a rule, the requirements of this Chapter apply to ships carrying 240 persons or more.

However, ships carrying less than 240 persons could be considered on a case by case basis.

1.1.4 Ships dealt with in this Chapter are to comply with:

- Part A
- NR216 Materials and Welding
- applicable requirements according to Tab 1.

1.1.5 As an alternative, recognised Naval Standards may be used instead of requirements of the present Chapter.

These Standards must be specified at the beginning of the design process and formally accepted by Bureau Veritas.

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Part B, Chapter 2 • Ch 5, Sec 2
Hull	• Part B • Ch 5, Sec 3
Stability	• Part B, Chapter 3 • Ch 5, Sec 3
Machinery and systems	• Part C, Chapter 1 • Ch 5, Sec 4
Electrical installations	• Part C, Chapter 2 • Ch 5, Sec 5
Automation	• Part C, Chapter 3
Fire protection, detection and extinction	• Part C, Chapter 4 • Ch 5, Sec 6 and Ch 5, Sec 7
Carriage of flammable products	• Ch 5, Sec 8

1.2 Definitions

1.2.1 Embarked troops

The embarked troops are the persons on board that are not considered as crew members.

The embarked troops are considered in the present Rules as well trained, organized and healthy persons.

1.2.2 Accommodation spaces

Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, secretariats, meeting rooms, pantries containing no cooking appliances and similar spaces.

Pantries (including isolated pantries) containing no cooking appliances may contain:

- coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances, each with a maximum power of 5 kW
- electrically heated cooking plates and hot plates for keeping food warm, each with a maximum power of 2 kW and a surface temperature not greater than 150°C.

A dining room containing such appliances is not regarded as a pantry.

1.2.3 Well dock

The well dock is the floodable part of the ship that is used to launch and recover landing crafts or other utilities vessels.

The well dock may be fitted with a weathertight aft door so designed as to be operated at sea to flood the well dock and that could be operated in harbour as a loading ramp.

The well dock is to be flooded at sea under controlled favourable weather conditions, to be specified by the designer. These conditions are to be not more than sea state 3 according to Stanag 4154. On the contrary, a consequence assessment will have to be performed on a case by case basis.

1.2.4 Aircrafts

Aircrafts for this chapter are to be understood as aircrafts (VTOL or STOL), helicopters or Unmanned Combat Airplane Vehicle (UCAV).

1.2.5 Flight deck

If existing, the flight deck is the uppermost platform deck used for aircraft operations.

1.2.6 Hangar space

The hangar space is the enclosed shelter structure surrounding the platform deck used for storage and maintenance of the aircrafts.

The hangar space may be connected to the flight deck by means of one or several aircraft elevators.

1.2.7 Ro-Ro cargo spaces

Ro-Ro cargo spaces are spaces not normally subdivided in any way and normally extending to either a substantial length or the entire length of the ship, in which motor infantry vehicles with fuel in their tanks for their own propulsion and/or goods can be loaded and unloaded normally in horizontal direction.

The various Ro-Ro cargo decks are served by internal ramps or elevators and by side or aft external door ramps.

The lower Ro-Ro cargo deck may be in direct connection with the fore part of the well dock.

1.2.8 Cargo area

The cargo area is the part of the ship that contains the hangar space, the Ro-Ro cargo spaces and the well dock.

1.2.9 Cargo service spaces

Cargo service spaces are spaces within the cargo area used for workshops, lockers and storerooms of more than 2 m^2 in area, intended for cargo handling equipment.

1.2.10 Cofferdam

For the purpose of Ch 5, Sec 2, a cofferdam is an isolating space between two adjacent steel bulkheads or decks. It is to meet the following criteria:

a) The minimum distance between the two bulkheads or decks is to be sufficient for safe access and inspection.

b) In order to meet the single failure principle, in the particular case when a corner-to-corner situation occurs, this principle may be met by welding a diagonal plate across the corner.

1.2.11 Fuel oil

Fuel oil means any oil used as fuel in connection with the propulsion and auxiliary machinery of the ship on which such oil is carried.

1.2.12 Machinery spaces

Machinery spaces are all machinery spaces of category A and all other spaces containing propulsion machinery, boilers, fuel cells systems, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

1.2.13 Service spaces

Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, laundries, waste compactors, ironing rooms, laboratories, oven, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

a) Main pantries and pantries containing cooking appliances may contain:
   1) coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances, each with a power of more than 5 kW
   2) electrically heated cooking plates and hot plates for keeping food warm, each with a maximum power of 5 kW.
b) Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 5, Sec 6, as galleys.

1.2.14 Ammunition spaces

Ammunition spaces are the spaces (integral magazines, independent magazines, small magazines, magazines lockers, magazines boxes and pyrotechnics lockers) used for the storage of ammunition (missiles, shells, mines, demolition stores, etc. charged with explosives, propellant, pyrotechnics, initiating compositions or nuclear, biological or chemical material) for use in conjunction with offensive, defensive, training or non operating purposes, including those parts of the weapons systems containing explosives. Lifting spaces for ammunition are to be considered as ammunition spaces for the purpose of this Chapter.

1.2.15 Open superstructure

An open superstructure is a superstructure which is:

- open at both ends, or
- open at one end and provided with adequate natural ventilation effective over the entire length through permanent openings to outside of at least 10% of the total area of the space sides, or
- provided with adequate natural ventilation effective over the entire length though permanent openings to outside of at least 30% of the total area of the space sides.

Note 1: the total area of the space sides excludes the deck area of the space.

1.2.16 Breadth (B)

Breadth (B) means the maximum breadth of the ship, measured amidships to the moulded line of the frame. The breadth shall be measured in metres.

Section 2 Ship Arrangement

1 Ship arrangement

1.1 Well dock arrangement

1.1.1 The well dock being exposed to high risk of shocks, its sides and bottom are to be protected by wooden defences and sheating or equivalent, providing adequate protection of the ship structure for all intended operational situation.

Appropriate means are to be fitted to read the water depth at any time.

Adequate bollards, or equivalent system, are to be fitted to secure the landing crafts when afloat. Appropriate passageways are to be fitted eitherside of the well dock for easy access to the bollard system.

1.2 Well dock watertight/weathertight boundaries

1.2.1 The watertight boundaries of the well dock are made of:

- well dock bottom
- well dock sides (port and starboard)
- first full breadth transverse bulkhead limiting the forward end of the sloped part

The aft ramp constitutes a weathertight boundary.

1.3 Number and disposition of transverse watertight bulkheads

1.3.1 Where the distance between transverse bulkheads is considered excessive by the Society, ships are to be fitted with a system of partial bulkheads, side transverse frames and deck transverses such as to provide equivalent transverse strength.

Section 3 Hull and Stability

1 Intact and damage stability in transit

1.1 General

1.1.1 For the transit condition, the requirements of Pt B, Ch 3, Sec 2, Pt B, Ch 3, Sec 3, Pt B, Ch 3, App 1, Pt B, Ch 3, App 2 and Pt B, Ch 3, App 3 are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4].

2 Intact stability requirements for the well dock into operation

2.1 General intact stability criteria

2.1.1 The intact stability criteria of Pt B, Ch 3, Sec 2, [2.1.8] are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4] when the well dock is into operation (ie the door of the well dock is open) except for the angle of the GZmax which can be less than 30° but in no case less than 15° subject to the compliance with the following additional criteria defined in [2.1.2].

2.1.2 The area under the curve of the righting levers (GZ curve) should not be less than 0,095 m.rd up to an angle of 15° when the maximum righting lever (GZ) occurs at 15° and 0,080 m.rd when the maximum righting lever (GZ) occurs at an angle of 30° or above. Where the maximum righting lever (GZ) occurs at angles of between 15° and 30° the corresponding area under the righting lever curve should be:

$0,080 + 0,001\ (30° - \theta\ GZmax)$

2.2 Severe wind and rolling criteria

2.2.1 The severe wind and rolling criteria of Pt B, Ch 3, Sec 2, [2.3] are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4] when the well dock is into operation (ie door open), with a reduced wind speed of 15 knots.

2.3 Ice accretion

2.3.1 The stability criteria of Pt B, Ch 3, Sec 2, [2.4] for the ice accretion are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4] when the well dock is into operation (ie door open) considering the following amount of ice:

- 30 kg per square meter on exposed weather decks
- 7,5 kg per square meter for projected lateral area of each side of the vessel above the waterline

2.4 Crowding of embarked troops

2.4.1 The stability criteria of Pt B, Ch 3, Sec 2, [2.7] for the crowding of embarked troops on one side are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4] when the well dock is into operation (ie door open).

2.4.2 For the purpose of the crowding of the embarked troops, it has to be considered only the embarked troops not already in the well dock on board the crafts. The number of crafts and the maximum number of embarked troops per craft have to be also indicated.

3 Damage stability requirements for the well dock into operation

3.1 General

3.1.1 The damage stability criteria of [3.3] and [3.4] are to be complied with for the loading conditions of Pt B, Ch 1, Sec 2, [5.2], Pt B, Ch 1, Sec 2, [5.3] and Pt B, Ch 1, Sec 2, [5.4] when the well dock is on operation (ie door open) considering the damage definition and the assumptions as described in [3.2].

3.2 Damage definition

3.2.1 The damage to take into account is to be applied anywhere within the ship's length L. All positions of the damage along the ship are to be considered.

a) Longitudinal damage extension: The extension of the damage causes the flooding of two adjacent watertight compartments.

b) Vertical damage extension: The vertical extension of the damage is to be such that all the decks closures and platforms within the damaged area are destroyed.

c) Transversal damage extension: The transversal extension of the damage may reach the centerline of the ship without nevertheless including it.

For the purpose of the damage stability calculations, the following requirements are to be considered:

- Pt B, Ch 3, Sec 3, [2.1.1]
- Pt B, Ch 3, Sec 3, [2.1.2]
- Pt B, Ch 3, Sec 3, [2.2]
- Pt B, Ch 3, Sec 3, [2.3.2]
- Pt B, Ch 3, Sec 3, [2.4.3] to Pt B, Ch 3, Sec 3, [2.4.7].

3.2.2 The permeability of the well dock is to be considered equal to 0,90.

3.3 Damage stability criteria at the final stage of flooding and after equalization

3.3.1 The waterline, taking into account sinkage, heel and trim, should be below the lower edge of any opening through which progressive flooding or down flooding may take place. A complete list of the openings (air pipes, doors, hatch, scuttles,…) including their coordinates and tightness will have to be submitted into the damage stability booklet. The location and tightness of those opening will have to be confirmed on board by a surveyor of the Society.

3.3.2 The positive residual righting lever curve shall have a minimum range of 15° beyond the angle of equilibrium. This range may be reduced to a minimum of 10°, in the case where the area under the righting lever curve is that specified in [3.3.3], increased by the ratio: 15/range, where the range is expressed in degrees.

3.3.3 The area under the righting lever curve shall be at least 0,015 m.rd measured from the angle of equilibrium to the lesser of:

- The angle at which progressive flooding occurs
- 30° (from the upright).

3.3.4 A residual righting lever is to be obtained within the range of positive stability, taking into account the greatest of the following heeling moments:

- The wind effect considering a wind speed equal to 15knots
- The crowding of all embarked troops on one side:

  $M = (0{,}075\ N)\ (0{,}45\ B)$

  where N is the number of embarked troops not already in the well dock on board the crafts.

The righting lever GZ, in m, is to be calculated by the formula:

$GZ = \text{heeling moment} / \text{displacement} + 0{,}04$

However in no case this righting lever is to be less than 0,1 m.

3.3.5 In the case of unsymmetrical flooding, the angle of heel shall not exceed 15°.If a more restrictive angle is included in the specification or in the contract, this angle is to be considered instead of 15°.

3.4 Damage stability criteria at the intermediate stages of flooding including before equalization

3.4.1 The maximum righting lever shall be at least 0.05 m and the range of positive righting levers shall be at least of 7°.

3.4.2 The maximum angle of heel shall not exceed 20°. If a more restrictive angle is included in the specification or in the contract, this angle is to be considered instead of 20°.

4 Loading conditions

4.1 Well dock operation

4.1.1 Loading conditions corresponding to all specified well dock operations are to be submitted.

Longitudinal strength and stability have to be checked for all these loading conditions.

4.1.2 Maximum draft at aft end during all specified well dock operations are to be submitted.

5 Structure design principles

5.1 General information

5.1.1 Aircrafts

The types of aircraft as defined in Ch 5, Sec 1, [1.2.4] for which the amphibious vessel is designed, are to be formally given as a list.

Particularly, this list must clearly indicates:

- the types of aircraft allowed to land and take-off (structure design of flight deck)
- the types of aircraft for which maintenance on board is considered (structure design of aircraft elevators and hangar deck).

For helicopters, the requirements of Pt B, Ch 8, Sec 10 are also to be complied with.

For aircrafts other than helicopters, the following data are to be indicated:

- the number of axles and the relative arrangement of axles
- the number of wheels per axle and their relative arrangement
- the maximum mass of the aircraft, for each operational case (take-off, landing, parking)
- the maximum load, in kN, per wheel, and the corresponding tyre print for each operational case (parking, normal landing, hard and emergency landing, take-off). It is accepted to consider that the load per tyre and the corresponding tyre print are proportional.

5.1.2 Armoured vehicles

The types of armoured vehicles for which amphibious vessel is designed are to be formally given as a list.

Particularly, this list must clearly indicates the data:

- the number of axles and the relative arrangement of axles
- the number of wheels per axle and their relative arrangement
- the maximum mass of the vehicle

5.1.3 Landing crafts

The types of landing crafts for which amphibious vessel is designed are to be formally given as a list.

Particularly, this list must clearly indicates:

- the maximum displacement of the craft
- the contact surface when grounded

5.1.4 Tractors and mobile cranes

The types of engined tractors intended to be used on flight deck, elevators and hangar deck are to be formally specified.

The following data are to be indicated:

- the number of axles and the relative arrangement of axles
- the maximum load per axle
- the number of wheels per axle and their relative arrangement.

Any movable crane used on flight deck (for removal of crashed aircraft or other operations) is also to be formally specified, with respect to its operational use and Safe Working Load.

5.1.5 Lifting devices for maintenance

All eye plates permanently fitted in decks and used for lifting operations during maintenance are to comply with Pt B, Ch 9, Sec 5.

The SWL of each eye plate permanently fitted in decks is to be indicated on drawings.

Moreover, each lifting eye is to be fitted with information about SWL and load testing, in tons.

The strength verification is to be performed as follows:

- for all SWL: initial load test at 2 x SWL and verification of absence of deformation
- in addition, for SWL > 1.5 tons: combined stress σ_{VM} not exceeding 0.5 $Rp_{0.2}$ in lifting eye, connection weld and supporting structure

Load test are to be performed periodically, with a load test equal to 125% of SWL.

5.2 Well dock

5.2.1 Corrosion margin

The corrosion addition t_c for side and bottom structures exposed to sea water during flooding operation is to be as defined for ballast tank in Pt B, Ch 4, Sec 2, Tab 2.

5.2.2 Protection of well dock

Any possible protection against shocks and contact during operation, by wooden sheating or equivalent, is to be indicated and described.

5.2.3 Mooring fittings of landing craft

The fittings integrated in the well dock to allow mooring of the landing craft during loading/unloading operation are to be clearly shown on structure drawings.

Their design is to be submitted, with information about their Safe Working Load (SWL) and the detail of their integration into the well dock.

5.3 Flight deck

5.3.1 Description of zones

The partitioning of the flight deck into various zones considered for design is to be formally documented with respect to their functional use at sea (parking / normal landing / emergency landing / take-off). This information is also to include the type, number and arrangement of aircraft in each zone.

Where one area of the flight deck is concerned by several functional uses, the scantlings are to be checked for all specified loads.

5.3.2 Coating of flight deck

Any possible coating or sheating on flight deck is to be indicated and described. Its protective index is to be given, with respect to mechanical shocks and sea water corrosion.

5.3.3 Emergency landing zone

If any, the emergency landing zone is to be clearly specified, together with relevant design criteria.

5.3.4 Flight deck openings

The various openings in flight deck are to be clearly defined with respect to their location and size (Ammunition elevators, etc.).

Particularly, the transverse and longitudinal extent of the flight deck recesses are to be clearly marked on relevant structure drawings.

5.3.5 Aircraft lashing devices

The lashing devices fitted in the flight deck are to be clearly shown on structure drawings.

Their design is to be submitted, with information about their Safe Working Load (SWL) and the detail of their fitting into the flight deck.

The strength verification is to be performed as follows:

- for all SWL: initial load test at 2 x SWL and verification of absence of deformation
- in addition, for SWL > 1.5 tons: combined stress σ_{VM} not exceeding 0.5 $Rp_{0.2}$ in lashing eye, connection weld and supporting structure

Load test are to be performed periodically, with a load test equal to 125% of SWL.

5.3.6 Fixed crane on deck

Any fixed crane fitted on flight deck is to be clearly specified, with respect to its operational use and Safe Working Load.

5.4 Hangar

5.4.1 General

General information about hangar are to be submitted, particularly regarding the open or closed situation with respect to wave loads.

5.4.2 Description of zones

Various zones of hangar deck considered during design are to be documented, with respect to their functional use at sea (maintenance of aircraft, cargo area, etc.).

In particular, the design loads on the various structural mezzanines in the hangar are to be specified.

5.4.3 Doors in outside shell in way of aircraft elevators

The doors on transom in way of aircraft elevators are to be weathertight.

They are to comply with Pt B, Ch 8, Sec 6.

5.4.4 Hangar deck opening

The various openings in hangar deck are to be clearly defined with respect to their location and size.

In particular, any deck recess in way of hangar fire doors is to be detailed, if relevant.

5.4.5 Aircraft lashing devices

The lashing devices fitted in the hangar deck are to be clearly shown on structure drawings.

Their design is to be submitted, with information about heir Safe Working Load (SWL) and the detail of their fitting into the deck.

Strength verification and load tests are to be performed according to [5.3.5].

5.4.6 Hangar gantry crane

Any gantry crane fitted in hangar is to be clearly specified, with respect to its operational use and Safe Working Load.

5.5 Accomodation spaces

5.5.1 Description of zones

Various zones of accomodation spaces considered during design are to be documented, with respect to their functional use (cabins, kitchens, hospital, etc.).

In particular, the design loads on the various accomodation decks are to be specified.

5.5.2 Accomodation deck opening

The various openings in accomodation decks are to be clearly defined with respect to their location and size.

5.6 Aircraft elevators

5.6.1 General

General information about aircraft elevators location and type (i.e. internal or deck edge) are to be submitted.

5.6.2 Lifting operations

Lifting operations are to be described, with detailed information about Safe Working Load of elevators, type of loads carried out and operating procedures with corresponding load dynamic amplification factors.

Dynamic amplification factors include combined effects of:

a) vertical acceleration induced by start and stop of lifting process

b) accelerations induced by behaviour of ship at sea.

When a ship motion damping system is fitted, it may be accepted, on a case by case basis, to reduce the accelerations mentioned in item b) above. The reduction level, if any, will be defined after an analysis of operating procedures in normal conditions and in degraded conditions.

5.6.3 Securing devices

If any, securing devices are to be specified, with information about their design and operation.

5.7 Ammunition elevators

5.7.1 Lifting operations

Lifting operations are to be described, with detailed information about Safe Working load of elevators, type of loads carried out and operating procedures with corresponding load dynamic amplification factors.

Dynamic amplification factors include combined effects of:

a) vertical acceleration induced by start and stop of lifting process

b) accelerations induced by behaviour of ship at sea.

When a ship motion damping system is fitted, it may be accepted, on a case by case basis, to reduce the accelerations mentioned in b) above. The reduction level, if any, will be defined after an analysis of operating procedures in normal conditions and in degraded conditions.

5.7.2 Securing devices

If any, securing devices are to be specified, with information about their design and operation.

6 Design loads

6.1 Loads in well dock

6.1.1 Sea pressure

Sea pressure is to be taken as:

- static pressure p_s : according to Pt B, Ch 5, Sec 5, [1.1] with T_1 taken equal to maximum water depth in well dock during operation
- wave pressure p_w : according to Pt B, Ch 5, Sec 5, [2] with h_1 taken equal to the significant wave height of the maximum design weather conditions defined in Ch 5, Sec 1, [1.2.3].

Operating precautions are to be such as to limit transverse resonance in the well dock.

6.1.2 Impact pressure

Impact pressure is to be taken as the combination of:

- still water pressure p_s, in kN/m², from the following formulae:

  $p_S = \rho_L\, g\, (0{,}7\, H + d_{TB} - z)$ for $z < 0{,}7\, H + d_{TB}$

  $p_S = 0$ for $z \geq 0{,}7\, H + d_{TB}$

- wave pressure p_w, in kN/m², from the following formulae:

  $p_w = 0{,}61\ \rho_L\ g\ (0{,}75\ B - 8)\ b_c\ A_R$

With:

H : Height of the longitudinal bulkheads in the well dock.

d_{TB} : Vertical distance, in m, from the baseline to the tank bottom

d_F : Filling level, in m, of the well dock to be taken as the vertical distance from the bottom of the well dock to the free surface of the sea water inside the well dock.

b_c : Transverse distance, in m, between longitudinal bulkheads of the well dock.

A_R : Roll amplitude as defined Pt B, Ch 5, Sec 3, [2.4].

6.1.3 Wheeled loads

The design wheeled loads to be considered for the assessment of the well dock are to cover all types of vehicles operating on the bottom of the well dock.

The wheeled loads are to be indicated by the designer:

- for tractors and mobile cranes: according to [5.1.4]
- for armoured vehicles: according to [5.1.2].

Design pressures are to be taken according to Pt B, Ch 5, Sec 6, [4].

6.1.4 Other loads

Any other relevant loads due to operation in well dock have to be submitted.

6.2 Loads on flight deck

6.2.1 General

Loads to be considered on flight deck are sea pressure and wheeled loads. Above type of loads can be considered separately.

6.2.2 Sea pressure

Sea pressure is to be taken according to Pt B, Ch 5, Sec 5, [3].

As a Rule, φ can be considered as 0,75.

6.2.3 Wheeled loads

For helicopters, the wheeled loads are to be considering according to Pt B, Ch 8, Sec 10, [5].

For aircrafts other than helicopters, the design wheeled loads to be considered are to cover all types of tyred vehicles operating on the flight deck (aircraft, tractors, mobile cranes, etc.), in all possible operating conditions.

The wheeled loads are to be indicated by the designer:

- for aircrafts: according to [5.1.1]
- for tractors and mobile cranes: according to [5.1.4].

Design pressures for aircrafts during landing operation are to be taken according to Tab 1, for each aircraft and each possible operating mass. Maximum vertical forces are to be considered per wheel or group of wheels loading the structural member under consideration.

Design pressures for aircrafts during parking operations and for tractors and mobile cranes are to be taken according to Pt B, Ch 5, Sec 6, [4].

Table 1 : Design pressures for aircrafts

Operation	Mass of aircraft (t)	Main undercarriage			Fore under carriage		
		Maximum vertical force (kN)	Still water force F_S (kN)	Inertial force F_W (kN)	Maximum vertical force (kN)	Still water force F_S (kN)	Inertial force F_W (kN)
Landing - Normal	M_1	F_{MN}	0	F_{MN}	F_{FN}	0	F_{FN}
Landing - Hard	M_1	F_{MH}	0	F_{MH}	F_{FH}	0	F_{FH}
Landing - Exceptional	M_1	F_{ME}	0	F_{ME}	F_{FE}	0	F_{FE}

6.2.4 Loads on sponsons

- Sideshell of sponsons:

Load heights on sides of sponsons are to be taken according to Pt B, Ch 5, Sec 5, Tab 3 for upright ship conditions and Pt B, Ch 5, Sec 5, Tab 5 for inclined ship conditions.

For inclined ship conditions, the roll amplitude A_R is to be calculated according to Pt B, Ch 5, Sec 3, without any consideration given to the motion damping system, if any.

- Front wall and aft wall of sponsons:

  Load heights on front wall of sponsons are to be taken according to Pt B, Ch 5, Sec 5, Tab 3 for upright ship conditions and Pt B, Ch 5, Sec 5, Tab 5 for inclined ship conditions.

  For inclined ship conditions, the roll amplitude A_R is to be calculated according to Pt B, Ch 5, Sec 3, without any consideration given to the motion damping system, if any.

- Undersides of sponsons:

  For transverse sections located longitudinally such than x/L is less than 0,7, the sea pressure to be considered on the underside of sponsons is the normal sea pressure acting on side shell.

  For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the sea impact pressure on the underside of sponsons p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = C_S C_Z (0{,}22 + 0{,}15\tan\alpha)(0{,}4V\sin\beta + 0{,}6\sqrt{L})^2$$

where:

C_S : Coefficient depending on the type of structures on which the impact pressure is considered to be acting:
- $C_S = 1{,}8$ for plating and ordinary stiffeners
- $C_S = 0{,}5$ for primary supporting members

C_Z : Coefficient depending on the distance between the full load waterline and the calculation point:
- for $z \geq 2\,C + T - 11$:

  $C_Z = C - 0{,}5\,(z - T)$
- for $z < 2\,C + T - 11$:

  $C_Z = 5{,}5$

C : Wave parameter:

$$C = 10{,}75 - \left(\frac{300 - L}{100}\right)^{1{,}5} \quad \text{for } 90 \text{ m} \leq L < 300 \text{ m}$$

$$C = 10{,}75 \quad \text{for } 300 \text{ m} \leq L \leq 350 \text{ m}$$

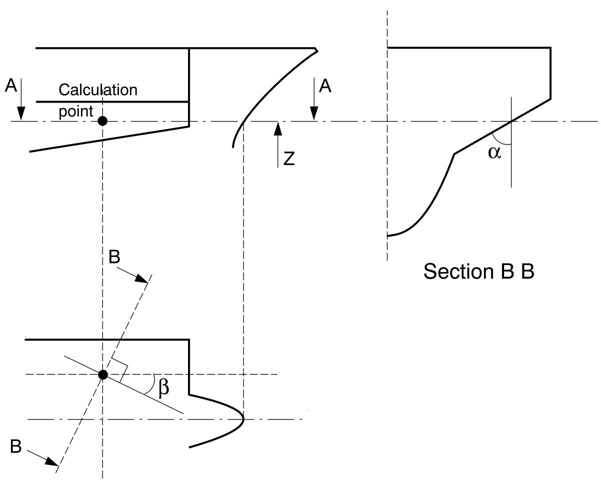
$$C = 10{,}75 - \left(\frac{L - 350}{150}\right)^{1{,}5} \quad \text{for } L > 350 \text{ m}$$

α : Flare angle at the calculation point, defined as the angle between a vertical line and the tangent to the underside plating, measured in a vertical plane normal to the horizontal tangent to the shell plating (see Fig 1) and not to be taken greater than 80°

β : Entry angle at the calculation point, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane (see Fig 1)

V : Maximum service speed, in knots.

Figure 1 : Definition of angles α and β



6.3 Loads on island and bridge

6.3.1 Loads on front, aft and side walls of island and bridge are to be calculated according to Pt B, Ch 8, Sec 4. For this application, it is accepted that the lowest tier of the island be considered as a second tier.

Loads on decks of island and bridge are calculated according to Pt B, Ch 8, Sec 4.

6.4 Loads on hangar decks

6.4.1 Cargo loads

The design cargo loads on the hangar deck are to be taken in accordance with Pt B, Ch 5, Sec 6, [2] and Pt B, Ch 5, Sec 6, [3].

The design cargo loads on the various structural mezzanines in the hangar are to be taken according to Pt B, Ch 5, Sec 6, [2] and Pt B, Ch 5, Sec 6, [3]. In specific areas used only as companionway, the minimum still water pressure p_S , in kN/m^2, to be considered in Pt B, Ch 5, Sec 6, Tab 3 is to be taken equal to $p_S = 5$.

6.4.2 Wheeled loads

The design wheeled loads to be considered for the assessment of the hangar deck are to cover all types of vehicles operating on that deck.

The wheeled loads are to be indicated by the designer:

- for aircrafts: according to [5.1.1] (parking condition)
- for tractors and mobile cranes: according to [5.1.4]
- for armoured vehicles: according to [5.1.2].

Design pressures are to be taken according to Pt B, Ch 5, Sec 6, [4].

6.5 Loads in accomodation spaces

6.5.1 Accomodation loads

The design accomodation loads on the various accomodation decks are to to be taken in accordance with Pt B, Ch 5, Sec 6, [5].

6.6 Loads on aircraft elevators

6.6.1 Cargo loads

When aircraft elevators are not exposed to sea loads, the design pressure exerted on the platform of the aircraft elevators are to be taken in accordance with Pt B, Ch 5, Sec 6, [2] and Pt B, Ch 5, Sec 6, [3].

6.6.2 Wheeled loads

The wheeled loads on the aircraft elevator platform exerted by aircrafts subject to maintenance are to be taken in accordance with [5.1.1] for parking situation.

The wheeled loads on the aircraft elevator platform exerted by tractors are to be taken in accordance with [5.1.4] for parking situation.

Dynamic amplification factors according to [5.6.2] are also to be considered.

6.7 Loads on ammunition elevators

6.7.1 The design pressure exerted on the platform of the ammunition elevators are to be taken in accordance with Pt B, Ch 5, Sec 6, [2] and Pt B, Ch 5, Sec 6, [3].

7 Hull scantling

7.1 Well dock

7.1.1 Plating

The scantling of the plating of well dock bottom and sides under sea pressure as defined in [6.1.1] and well dock bottom under wheeled load as defined in [6.1.3] are to be in compliance with requirements of Pt B, Ch 7, Sec 1.

The scantling of the plating of well dock sides under impact pressure as defined in [6.1.2] are to be in compliance with requirements of Pt B, Ch 7, Sec 1 using partial safety factors of Tab 2.

7.1.2 Ordinary stiffeners

The scantling of the ordinary stiffeners of well dock bottom and sides under sea pressure as defined in [6.1.1] and well dock bottom under wheeled load as defined in [6.1.3] are to be in compliance with requirements of Pt B, Ch 7, Sec 2.

The scantling of the ordinary stiffeners of well dock sides under impact pressure as defined in [6.1.2] are to be in compliance with requirements of Pt B, Ch 7, Sec 1 using partial safety factors of Tab 2.

7.1.3 Primary supporting structure

The scantling of the primary supporting members of well dock bottom and sides under sea pressure as defined in [6.1.1] and well dock bottom under wheeled load as defined in [6.1.3] are to be in compliance with requirements of Pt B, Ch 7, Sec 3.

Table 2 : Impact pressure on well dock sides - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,00
Material	γ_m	1,02	1,02
Resistance	γ_R	1,02	1,02

7.2 Flight deck

7.2.1 Plating

The scantling of the plating of flight deck under sea pressure as defined in [6.2.2]and under wheeled load as defined in [6.2.3]are to be in compliance with requirements of Pt B, Ch 7, Sec 1 with partial safety factors according to Tab 3.

7.2.2 Ordinary stiffeners

The scantling of the ordinary stiffeners of flight deck under sea pressure as defined in [6.2.2]and under wheeled load as defined in [6.2.3]are to be in compliance with requirements of Pt B, Ch 7, Sec 2 with partial safety factors according to Tab 4.

7.2.3 Primary supporting structure

The scantling of the primary supporting structure of flight deck under sea pressure as defined in [6.2.2] and under wheeled load as defined in [6.2.3] are to be in compliance with requirements of Pt B, Ch 7, Sec 2 with partial safety factors according to Tab 4.

Table 3 : Plating of flight deck - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Sea pressure	Landing Normal	Landing Hard	Landing Emergency	Parking
Still water hull girder loads	γ_{S1}	1,00	0	0	0	1,00
Wave hull girder loads	γ_{W1}	1,15	0	0	0	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20	1,05	1,20
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20	1,20	1,20	1,20	1,20

Table 4 : Stiffeners of flight deck - Partial safety factors

Partial safety factors covering uncertainties regarding	Symbol	Sea pressure	Landing Normal	Landing Hard	Landing Emergency	Parking
Still water hull girder loads	γ_{S1}	1,00	0	0	0	1,00
Wave hull girder loads	γ_{W1}	1,15	0	0	0	1,15
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,20	1,20	1,20	1,05	1,20
Material	γ_m	1,02	1,02	1,02	1,02	1,02
Resistance	γ_R	1,20	1,02	1,02	1,02	1,02

7.3 Sponsons

7.3.1 Side Shell

The scantlings of plating, ordinary stiffeners and primary members of side shell of sponsons are to be in accordance with Part B, Chapter 7, with loads according to [6.2.4].

When sponsons are not contributing to hull girder strength, the scantlings are to checked according to Part B, Chapter 7, with loads according to [6.2.4] and with longitudinal stress σ_1 equal to 0.

7.3.2 Front wall and aft wall

The scantlings of front wall and aft wall of sponsons are to be in accordance with Part B, Chapter 7, with loads according to [6.2.4] and with longitudinal stress σ_1 equal to 0.

7.3.3 Partial safety factors for underside

For transverse sections located longitudinally such than x/L is less than 0,7, the partial safety factors to be considered are given in Pt B, Ch 7, Sec 1, Pt B, Ch 7, Sec 2 or Pt B, Ch 7, Sec 3, as applicable.

For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the partial safety factors to be considered are to be taken as follows:

- Tab 5 for plating and ordinary stiffeners of the underside of sponsons
- Pt B, Ch 7, Sec 3 for primary structure of the underside of sponsons.

Table 5 : Reinforcements of the underside of sponsons - Partial safety factors

Partial safety factors covering uncertainties regarding:	Partial safety factors		
	Symbol	Plating	Ordinary stiffeners
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,10	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,30	1,02

7.3.4 Plating and ordinary stiffeners for underside

For transverse sections located longitudinally such than x/L is less than 0,7, the net scantlings of plating and ordinary stiffeners of the underside of cantilever quarters below flight deck are to be checked according to Pt B, Ch 7, Sec 1 or Pt B, Ch 7, Sec 2, as applicable. However, the net scantlings of plating and ordinary stiffeners are to be not less than the minimum values given in Tab 6.

For transverse sections located longitudinally such than x/L is greater than or equal to 0,7, the net scantlings of plating and ordinary stiffeners of the underside of cantilever quarters below flight deck are to be not less than the values obtained from the formulae in Tab 6 and the minimum values in the same Table.

7.3.5 Intercostal stiffeners for underside

Intercostal stiffeners are to be fitted at mid-span where the angle between the stiffener web and the attached plating is less than 70°.

7.3.6 Primary supporting members for underside

Primary supporting members are generally to be verified through direct calculations carried out according to Pt B, Ch 7, Sec 3, considering the sea impact pressures defined in [6.2.4].

7.3.7 Strengthening of sponsons underside in way of workboats / lifeboats

Stiffening of undersides of cantilever quarters in way of workboats / lifeboats is to be compatible with the launching operation. Cantilever quarters in way of launching appliances are to be adequately strengthened.

Table 6 : Reinforcements of plating and ordinary stiffeners of the underside of sponsons

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 11 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{W2} p_{FI}}{R_y}}$	Net minimum thickness, in mm: $t = (0{,}03\ L + 5{,}5)\ k^{1/2}$
Ordinary stiffeners	Net section modulus, in cm³: $w = \gamma_R \gamma_m \beta_b \frac{\gamma_{W2} p_{FI}}{18 c_P R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$	Web net minimum thickness, in mm, to be not less than the lesser of: • $t = 1{,}5\ L_2^{1/3}\ k^{1/6}$ • the thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{W2} p_{FI}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$	

Note 1:
c_P : Ratio of the plastic section modulus to the elastic section modulus of the ordinary stiffeners with attached shell plating, to be taken equal to 1,16 in the absence of more precise evaluation.

7.4 Island and bridge

7.4.1 The scantlings of island and bridge are to be in accordance with Pt B, Ch 8, Sec 4, applicable to deckhouses.

Special consideration is to be given to support of masts and aerials at top of island. Strength continuity downwards through several decks may be requested.

7.5 Hangar

7.5.1 Hangar decks

The scantlings of the hangar decks structure under cargo loads as defined in [6.4.1] and under wheeled loads as defined in [6.4.2] are to be in compliance with requirements of Part B, Chapter 7.

7.5.2 Transverse racking effect

The transverse partial bulkheading structure in the hangar is to be checked against transverse racking effect induced by transverse accelerations exerted on deck structure between hangar and flight deck.

The most severe conditions are to be considered for loads and transverse accelerations.

Stress criteria are given in Pt B, Ch 7, Sec 3, [2].

7.6 Accomodation spaces

7.6.1 Accomodation decks

The scantling of the accomodation decks under accomodation loads as defined in [6.5] are to be in compliance with requirements of Part B, Chapter 7.

7.7 Aircraft elevators

7.7.1 Plating

The scantlings of the plating of aircraft elevators under wheeled loads are to be in compliance with requirements of Pt B, Ch 7, Sec 1.

7.7.2 Ordinary stiffeners

The scantlings of the ordinary stiffeners of aircraft elevators under wheeled loads are to be in compliance with requirements of Pt B, Ch 7, Sec 2.

7.7.3 Primary supporting structure

The scantlings of the primary structure of aircraft elevators under wheeled loads are generally to be checked on basis of three dimensional structural model, according to the requirements of Pt B, Ch 7, Sec 3, [2] and Pt B, Ch 7, Sec 3, [5].

7.7.4 Locking and lifting devices

The scantlings of locking and lifting devices and the surrounding reinforcements are to be assessed on first principle basis.

Design forces (amplitudes, directions) and associated safety coefficients are to be agreed upon on a case by case basis.

7.8 Ammunition elevators

7.8.1 Plating

The scantlings of the plating of ammunition elevators loads are to be in compliance with requirements of Pt B, Ch 7, Sec 1.

7.8.2 Ordinary stiffeners

The scantlings of the ordinary stiffeners of ammunition elevators are to be in compliance with requirements of Pt B, Ch 7, Sec 2.

7.8.3 Primary supporting structure

The scantlings of the primary structure of ammunition elevators are generally to be checked on basis of three dimensional structural model, according to the requirements of Pt B, Ch 7, Sec 3, [2] and Pt B, Ch 7, Sec 3, [5].

7.8.4 Locking and lifting devices

The scantlings of locking and lifting devices and the surrounding reinforcements are to be assessed on first principle basis.

Design forces (amplitudes, directions) and associated safety coefficients are to be agreed upon on a case by case basis.

7.9 Transfer routes

7.9.1 Hull scantling for dry store and ammunition transfer routes

All dry stores and ammunition transfer routes are to be checked with regards to wheeled loads as defined in Pt B, Ch 5, Sec 6, [4] and strength criteria given in Part B, Chapter 7.

7.9.2 Height of door sills along transfer routes

Where coamings are required on doors located along the dry stores or ammunition transfer routes, the fitting of alternative arrangements to enable their transfer by way of wheeled vehicles will be considered by the society on a case by case basis.

SECTION 4 MACHINERY AND SYSTEMS

1 Main propulsion

1.1 Availability

1.1.1 According to the missions of this type of ships, a special consideration will be given to the general arrangement of the main propulsion.

Therefore the main propulsion system is to comply at least with the requirements of the additional class notation **AVM-APM** as defined in Pt E, Ch 3, Sec 1.

Note 1: relaxation to this requirement may be granted to ships not operating aircrafts with a limited number of persons aboard.

2 Well dock systems

2.1 Ballast system dedicated to well dock operation

2.1.1 Availability of system

Failure of one ballast pump or other active equipment used instead of pump for water transfer shall not render unable to operate transfer of water:

- between aft and fore ballasts
- between port and starboard ballasts.

2.2 Drainage of well dock

2.2.1 Communication between well dock and the sea

If any piping is installed for direct communication between well dock and sea, it should be fitted with isolating valve operable from above DC deck. These valves do not need to be installed if review of intact and damage stability is found satisfactory without them.

2.2.2 Drainage of well dock

a) General: a pumping system and/or gravity discharges shall be installed in order to dry up well dock when it is no more flooded because of amphibious operations. Drainage system capacity shall be able to evacuate water falling into well dock in case fire fighting systems of compartments drained to well dock or in communication with it are used.

b) Arrangement and dimensioning of system: the drainage system shall be sized to remove no less than 125% of the combined capacity of both the water-spraying system pumps and the required number of fire hose nozzles. The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls. Bilge wells shall be of sufficient holding capacity and shall be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment. IMO Circular MSC.1-Circ.1320 may be used as guidelines.

c) Number and capacity of pumps: If pumps are necessary at least two pumps shall be able to serve this system. Only one of them needs to be dimensioned with capacity related to evacuation of water used for fire fighting.

d) Segregation from source of ignition: scuppers if any should not be led to compartments where sources of ignition may be present, like machinery spaces. Pumps connected to drainage system of well dock are not to be located in compartments where sources of ignition may be present.

2.3 Control and monitoring of ballast system dedicated to well dock

2.3.1 Location of valve controls

Remote control for ballast system valves dedicated to well dock operation shall be provided and available from a control room. Position of valves shall be monitored from this control room.

Local means are to be provided in order to operate valves when remote control is not available. When valve in itself is not reachable, local means may be located at a convenient place permanently reachable by crew close to the valve.

2.3.2 Location of pump control

Remote control for ballast system pumps dedicated to well dock operation shall be provided and available from a control room.

2.3.3 Capacity of pumps

When Naval Authority requires some minimum delay for well dock operation, calculation is to be provided in order to asses capacity of pumps.

Note 1: corresponding water flow is to be taken into account regarding requirement for water velocity mentioned in Pt C, Ch 1, Sec 10, [5.8].

3 Aircraft handling

3.1 Internal movements

3.1.1 General

The movements of the aircraft between the flight deck and the hangar deck are operated by aircraft elevators.

The movements of the aircraft on a deck are operated with tractors.

Deck crane is also to be provided for handling of a crashed aircraft.

The aircraft elevators are to be considered as a secondary essential service in complement of Pt C, Ch 2, Sec 1, [3.4.1].

3.1.2 Aircraft elevators

Aircraft elevators are to comply with general requirements of Pt B, Ch 8, Sec 8, and with requirements of NR526 Rules for lifting appliances, as far as they are applicable to unmanned platform elevator. The following requirements are also to be complied with:

- a mechanical locking of the platform at the two levels hangar deck and flight deck is to be provided
- disposition are to be taken to avoid any change in the level of the platform when removing the locking whatever load change occurred
- platforms are to be equipped to ensure security of staff and load against falling
- platforms are to be equipped to avoid any contact of staff or load with fixed parts of ship during movements of the platforms
- hangar deck and flight deck are to be equipped with disposal to avoid any fall of staff or load when platform is not locked at the deck level.

4 Aircraft supplying

4.1 General

4.1.1 The supply of the aircraft needs among others handling, storage or production for:

- fuel
- ammunition
- oxygen for breathing purpose
- special ingredients and fluids for aircraft
- aircraft electric power.

4.1.2 Refuelling system

Refuelling system is to comply with requirements for helicopter platform as per Pt C, Ch 1, Sec 10, [11] and Pt C, Ch 4, Sec 10, [4].

4.1.3 Weapons elevators

With regards to strength matters, ammunition elevators are to comply with general requirements of Ch 5, Sec 3, [7.8], and with requirements of NR526 Rules for lifting appliances, as far as they are applicable to unmanned platform elevator.

The following requirements are also to be complied with:

- a mechanical locking of the platform at the two levels, hangar deck and flight deck, is to be provided
- disposition are to be taken to avoid any change in the level of the platform when removing the locking whatever load change occurred
- platforms are to be equipped to ensure security of staff and load against falling
- platforms are to be equipped to avoid any contact of staff or load with fixed parts of ship during movements of the platforms
- hangar deck and flight deck are to be equipped with disposal to avoid any fall of staff or load when platform is not locked at the deck level.

In addition, the weapons elevators are to be in compliance with ISO 8383 standard.

4.1.4 Oxygen production and storage

A special consideration for risk of high concentration of oxygen is to be taken into account for aircraft breathing oxygen storage and production installation. Whenever liquefied oxygen is present on board, special consideration for consequences of leakage is to be taken into account. These consequences are to include fire risk and damage to ship structures.

Section 5 Electrical Installations

1 General

1.1 Applicable requirements

1.1.1 In addition to the relevant requirements given in Ch 5, Sec 1, Tab 1, electrical installations in spaces intended for the carriage of motor vehicles with fuel in their tanks for their propulsion are to comply with those of Part C, Chapter 4.

1.2 Documentation to be submitted

1.2.1 In addition to the documentation requested in Pt C, Ch 2, Sec 1, Tab 1, the following are to be submitted for approval:

a) plan of hazardous areas
b) document giving details of types of cables and safety characteristics of the equipment installed in hazardous areas
c) diagrams of electrical systems of fire doors, shell doors, loading doors and similar appliances, television surveillance or water leakage detection systems as requested in NR467, Pt B, Ch 1, Sec 4, Tab 1 and Pt C, Ch 4, Sec 1, Tab 1.
d) diagrams of the supplies to the supplementary emergency lighting systems.

1.3 Electrical distribution and protection

1.3.1 In an amphibious ships, distribution systems shall be so arranged that fire in any main vertical zone as defined in Part C, Chapter 4 will not interfere with services essential for safety in any other such zone.

This requirement will be met if main and emergency feeders passing through any such zone are separated both vertically and horizontally as widely as is practicable.

1.3.2 For generators arranged to operate in parallel and for individually operating generators, arrangements are to be made to disconnect automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed. The operation of such device is to activate a visual and audible alarm.

2 Emergency source of electrical power and emergency installations

2.1 General

2.1.1 A self-contained emergency source of electrical power shall be provided.

2.1.2 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

Whilst the vessel is at sea, the following can be understood as exceptional conditions:

a) blackout situation
b) dead ship situation
c) routine use for testing
d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless instructed otherwise by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of Pt C, Ch 2, Sec 3, [2.4] are complied with.

2.1.3 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

2.1.4 The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in [2.2.3] for the period specified, if they depend upon an electrical source for their operation.

2.1.5 The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services stated in [2.2.6] for the periods specified therein, if they depend upon an electrical source for their operation.

2.1.6 An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power referred to in Pt C, Ch 2, Sec 3, [2.3.13] and Pt C, Ch 2, Sec 3, [2.3.14] are being discharged.

2.1.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor converters, means are to be provided for supplying such services also in the event of failure of the converter (e.g. providing a bypass feeder or a duplication of converter).

2.1.8 Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which:

- The main propulsion plant, boilers and auxiliaries are not in operation
- No stored energy for starting the propulsion plant and the main source of electrical power are available.
- Equipment of Propulsion systems, main source of electrical power and other essential auxiliaries is to be assumed available.
- means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator stored starting energy is not to be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

2.1.9 Provision shall be made for the periodical testing of the complete emergency system and shall include the testing of automatic starting arrangements.

2.1.10 For starting arrangements of emergency generating sets, see Pt C, Ch 1, Sec 2, [3.1].

2.1.11 The emergency source of electrical power may be either a generator or an accumulator battery, which shall comply with the provisions of [2.1.12] or [2.1.13], respectively.

2.1.12 Where the emergency source of electrical power is a generator, it shall be:

a) driven by a suitable prime mover with an independent supply of fuel having a flashpoint (closed cup test) of not less than 43°C
b) started automatically upon failure of the electrical supply to the emergency switchboard from the main source of electrical power and shall be automatically connected to the emergency switchboard; those services referred to in [2.2.6] shall then be transferred automatically to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s, and
c) provided with a transitional source of emergency electrical power according to [2.1.14].

2.1.13 Where the emergency source of electrical power is an accumulator battery, it shall be capable of:

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage
b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power, and
c) immediately supplying at least those services specified in [2.2.6].

2.1.14 The transitional source of emergency electrical power required by [2.1.12] shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the services in [2.2.6] if they depend upon an electrical source for their operation.

2.1.15 Where the emergency and/or transitional source of power is an uninterruptible power system (UPS), it is to comply with the requirements of Pt C, Ch 2, Sec 6, [2].

2.2 Distribution of electrical power

2.2.1 The emergency switch board shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

2.2.2 In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.

2.2.3 The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 36 hours, emergency lighting:
   1) at every muster and embarkation station and over the sides
   2) in alleyways, stairways and exits giving access to the muster and embarkation stations
   3) in all service and accommodation alleyways, stairways and exits, personnel lift cars
   4) in the machinery spaces and main generating stations including their control positions
   5) in all control stations, machinery control rooms, and at each main and emergency switchboard
   6) at all stowage positions for firemen's outfits
   7) at the steering gear, and
   8) at the fire pump, the sprinkler pump and the emergency bilge pump referred to in (d) below and at the starting position of their motors
b) for a period of 36 hours:
   1) The navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force.
   2) the VHF radio installation required by Regulation IV/7.1.1 and IV/7.1.2 of SOLAS Consolidated Edition 1992, and, if applicable:
      - the MF radio installation required by Regulations IV/9.1.1, IV/9.1.2, IV/10.1.2 and IV/10.1.3
      - the ship earth station required by Regulation IV/10.1.1, and
      - the MF/HF radio installation required by Regulations IV/10.2.1, IV/10.2.2 and IV/11.1.
c) for a period of 36 hours:
   1) all internal communication equipment required in an emergency (see [2.2.4])
   2) the shipborne navigational equipment as required by Regulation V/12; where such provision is unreasonable or impracticable the Head Office may waive this requirement for ships of less than 5,000 gross tonnage
   3) the fire detection and fire alarm system, the fire door holding and release system, and
   4) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals (see [2.2.5]) that are required in an emergency, unless such services have an independent supply for the period of 36 hours from an accumulator battery suitably located for use in an emergency
d) for a period of 36 hours:
   1) one of the fire pumps required by the relevant provisions of Part C, Chapter 4
   2) the automatic sprinkler pump, if any, and
   3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves
e) for the period of time required in Pt C, Ch 1, Sec 12, [2], the steering gear if required to be so supplied
f) for a period of half an hour:
   1) any watertight doors required by Regulation II-1/15 to be power operated together with their indicators and warning signals
   2) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The lift cars may be brought to deck level sequentially in an emergency.

2.2.4 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment, if any
b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled
c) the means of communication which is provided between the officer of the watch and the person responsible for closing any watertight door which is not capable of being closed from a damage control station
d) the public address system or other effective means of communication throughout the accommodation, public and service spaces
e) the means of communication between the navigating bridge and the main fire control station.

2.2.5 Internal signals required in an emergency generally include:

a) general alarm
b) watertight door indication
c) fire door indication.

2.2.6 The transitional source of emergency electrical power required is to supply at least the following services if they depend upon an electrical source for their operation:

a) for half an hour:

1) the lighting required by [2.2.3] (b) and Pt C, Ch 2, Sec 3, [3.5.6] (a)

2) all services required by [2.2.3] (c1, 3 and 4) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency

b) it is also to supply power to close the watertight doors as required by Regulation II-1/15.7.3.3, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided. Power to the control, indication and alarm circuits as required by Regulation II-1/15.7.2, for half an hour.

2.3 Low-location lighting

2.3.1 Amphibious vessels are to be provided with a low-location lighting (LLL) system in accordance with Pt C, Ch 4, Sec 8, [2.3.2].

Where LLL is satisfied by electric illumination, it is to comply with the following requirements.

2.3.2 The LLL system is to be connected to the emergency switchboard and is to be capable of being powered either by the main source of electrical power, or by the emergency source of electrical power for a minimum period of 60 minutes after energising in an emergency.

2.3.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of cables of a fire-resistant type complying with Pt C, Ch 2, Sec 9, [1.1.7], and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.

2.3.4 Single lights and lighting assemblies are to be designed or arranged so that any single fault or failure in a light or lighting assembly, other than a short-circuit, will not result in a break in visible delineation exceeding 1 metre.

2.3.5 Light and lighting assemblies are to be flame-retardant as a minimum, to have an ingress protection of at least IP55 and to meet the type test requirements as specified in Pt C, Ch 3, Sec 6, Tab 1.

2.3.6 The LLL system is to be capable of being manually activated by a single action from the continuously manned damage control station. It may, additionally, be continuously operating or be switched on automatically, e.g. by the presence of smoke within the space(s) being served.

2.3.7 When powered, the systems are to achieve the following minimum luminance:

- for any planar source: 10 cd/m² from the active parts in a continuous line of 15 mm minimum width
- for any point source: 35 mcd in the typical track directions of approach and viewing which is to be considered:
  - for sources which are required to be viewed from a horizontal position, i.e. deck mounted or horizontally bulkhead mounted fittings, within a 60° cone having its centre located 30° from the horizontal mounting surface of the point source and in line with the track direction, see Fig 1
  - for sources which are required to be viewed vertically, i.e. the vertical LLL marking up to the door handles, within a 60° cone having its centre located perpendicular to the mounting service of the point source, see Fig 2.

Spacing between sources is not to exceed 300 mm.

Figure 1 :

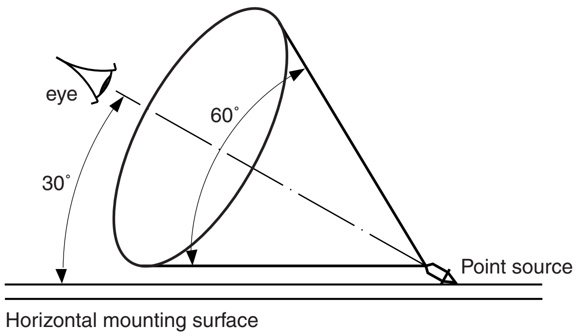
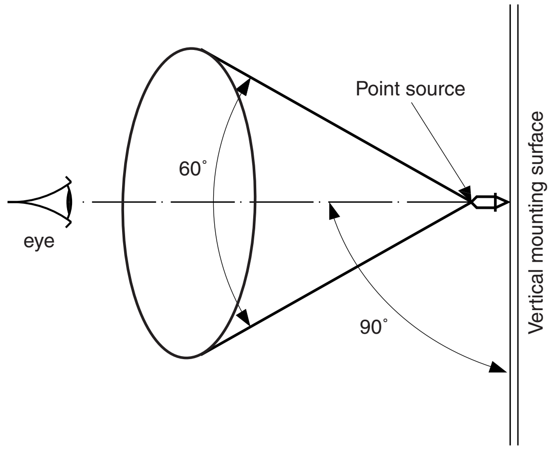


Figure 2 :



2.3.8 The lights or lighting assemblies are to be continuous except as interrupted by constructional constraints, such as corridors or cabin doors etc., are to provide a visible delineation along the escape route and, where applicable, are to lead to the exit door handles. Interruption of the LLL system due to constructional constraints is not to exceed 2 metres.

2.3.9 The lighting is to be provided on at least one side of the corridor or stairway. In corridors and stairways in excess of 2 metres width, lighting is to be provided on both sides.

2.3.10 In corridors the lighting is to be installed either on the bulkhead within 300 mm of the deck or, alternatively, on the deck within 150 mm of the bulkhead.

2.3.11 In stairways the lighting is to be installed within 300 mm above the steps such that each step may be readily identified from either above or below that step. The top and bottom steps are to be further identified to show that there are no further steps.

2.4 Supplementary emergency lighting

2.4.1 In addition to the emergency lighting required in [2.2], on every amphibious vessel with ro-ro cargo spaces or special category spaces:

a) all public spaces and alleyways shall be provided with supplementary electric lighting that can operate for at least three hours when all other sources of electrical power have failed and under any condition of heel. The illumination provided shall be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting shall consist of accumulator batteries located within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Alternatively, any other means of lighting which is at least as effective may be accepted by the Society. The supplementary lighting shall be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided shall be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service;

b) a portable rechargeable battery operated lamp shall be provided in every crew space alleyway and recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required in (a), is provided.

2.5 Emergency lighting in cabins

2.5.1 In amphibious ships, supplementary emergency lighting shall be provided in all cabins to clearly indicate the exit so that occupants will be able to find their way to the door. Such lighting, which may be connected to an emergency source of power or have a self-contained source of electrical power in each cabin, shall automatically illuminate when power to the normal cabin lighting is lost and remain on for a minimum of 30 min.

3 General emergency alarm and public address systems

3.1 General emergency alarm system

3.1.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren for sounding the general emergency alarm signal is to comply with the following requirements.

3.1.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.2] or other suitable means of communication.

3.1.3 The entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.1.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of the normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.1.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.1] and Ch 2, Sec 4, [3.2].

3.1.6 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle, also from other strategic points.

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a petrol control station is normally to be regarded as strategic points.

3.1.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.1.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces and on all open decks.

3.1.9 The minimum sound pressure level for the emergency alarm tone in interior and exterior spaces is to be 80 dB (A) and at least 10 dB (A) above ambient noise levels existing during normal equipment operation with the ship underway in moderate weather.

3.1.10 In cabins without a loudspeaker installation, an electronic alarm transducer, e.g. a buzzer or similar, is to be installed.

3.1.11 The sound pressure level at the sleeping position in cabins and in cabin bathrooms is to be at least 75 dB (A) and at least 10 dB (A) above ambient noise levels.

3.1.12 For cables used for the general emergency alarm system, see Pt C, Ch 2, Sec 3, [9.6.1], Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.5].

3.1.13 Electrical cables and apparatus for the general emergency alarm system and their power supply are to be arranged so that the loss of the system in any one area due to localised fire is minimised.

3.1.14 Where the fire alarm to summon the crew operated from the navigating bridge or fire control station is part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm in the embarked troops spaces.

3.2 Public address system

3.2.1 The public address system is to be one complete system consisting of a loudspeaker installation which enables simultaneous broadcast of messages from the navigation bridge, and at least one other location on board for use when the navigation bridge has been rendered unavailable due to the emergency, to all spaces where crew members or embarked troops, or both, are normally present (accommodation and service spaces and control stations and open decks), and to assembly stations (i.e. muster stations).

In spaces such as under deck passageways, bosun's locker, hospital and pump room, the public address system may not be required.

3.2.2 The public address system is to be arranged to operate on the main source of electrical power, the emergency source of electrical power and transitional sources of electrical power as required by Pt C, Ch 2, Sec 3, [2.3] and Pt C, Ch 2, Sec 3, [3.5].

3.2.3 The controls of the system on the navigation bridge are to be capable of interrupting any broadcast on the system from any other location on board.

3.2.4 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

3.2.5 The system is not to require any action by the addressee.

3.2.6 It is to be possible to address crew accommodation and work spaces separately from embarked troops.

3.2.7 In addition to any function provided for routine use aboard the ship, the system is to have an emergency function control at each control station which:

a) is clearly indicated as the emergency function
b) is protected against unauthorised use
c) automatically overrides any other input system or program, and
d) automatically overrides all volume controls and on/off controls so that the required volume for the emergency mode is achieved in all spaces.

3.2.8 The system is to be installed with regard to acoustically marginal conditions, so that emergency announcements are clearly audible above ambient noise in all spaces where crew members or embarked troops, or both, are normally present (accommodation and service spaces and control stations and open decks), and at assembly stations (i.e. muster stations).

3.2.9 With the ship underway in normal conditions, the minimum sound pressure level for broadcasting emergency announcements is to be:

a) in interior spaces 75 dB (A) and at least 20 dB (A) above the speech interference level, and

b) in exterior spaces 80 dB (A) and at least 15 dB (A) above the speech interference level.

Evidence of this level is to be shown with test result in open sea or equivalent quay measurement with appropriate correction factor.

3.2.10 The system is to be arranged to prevent feed-back or other interference.

3.2.11 The system is to be arranged to minimise the effect of a single failure so that the emergency messages are still audible (above ambient noise levels) also in the event of failure of any one circuit or component.

3.2.12 Each loudspeaker is to be individually protected against short-circuits.

3.2.13 For cables used for the public address system, see Pt C, Ch 2, Sec 3, [9.6.1], Pt C, Ch 2, Sec 11, [5.2.1] and Pt C, Ch 2, Sec 11, [5.2.5].

3.2.14 All areas of each fire zone are to be served by at least two dedicated loops of flame-retardant cables which are to be sufficiently separated throughout their length and supplied by two separate and independent amplifiers.

3.2.15 A temperature alarm is to be provided in the public address cabinets in case of forced air cooling.

3.3 Combined general emergency alarm - public address system

3.3.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.1] and [3.2], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required.
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required.
- the system is arranged to minimise the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the event of failure of any one circuit or component, by means of the use of more than one device for generating an electronic sound signal.

4 Installation

4.1 Electrical equipment located in special spaces

4.1.1 Electrical equipment located in fuel oil tanks (Diesel oil, JP5, petrol) are to be certified intrinsically safe apparatus Ex(ia). They are to be explosion group IIa and temperature class T3 minimum.

4.1.2 The following spaces are to be considered as hazardous areas and electrical equipment located in these areas are to be of certified safe type temperature class T6, explosive group IIa:

- ammunition storage
- ammunition transit room
- ammunition elevator.

4.1.3 Following spaces are to be considered as hazardous areas and electrical equipment related to these areas are to comply with the requirements of Pt C, Ch 2, Sec 3, [10.4]:

- paint stores or tanks
- medical product storage rooms
- workshop where solvent are used.

4.1.4 Flour storage spaces are to be considered as hazardous areas and electrical equipment related to these areas are to have a degree of protection IP 65 and maximum surface temperature of 100°C.

4.1.5 Following spaces are to be considered as hazardous areas and electrical equipment related to these areas are to comply with the requirements of Pt C, Ch 2, Sec 3, [10.3]:

- hydrogen distribution dispenser
- batteries rooms
- oxygen plant.

4.2 Installations in special category spaces situated above the bulkhead deck

4.2.1 On any deck or platform, if fitted, on which vehicles are carried and on which explosive vapours might be expected to accumulate, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment and cables are to be installed at least 450 mm above the deck or platform.

Electrical equipment is to be as stated in Pt C, Ch 2, Sec 3, [10.1.6] and electrical cables as stated in Pt C, Ch 2, Sec 3, [10.2.3].

4.2.2 Where the installation of electrical equipment and cables at less than 450 mm above the deck or platform is deemed necessary for the safe operation of the ship, the electrical equipment is to be of a certified safe type as stated in Pt C, Ch 2, Sec 3, [10.1.5] and the electrical cables are to be as stated in Pt C, Ch 2, Sec 3, [10.2.2].

4.2.3 Electrical equipment and cables in exhaust ventilation ducts are to be as stated in [4.2.2].

4.2.4 The requirements in this item are summarised in Tab 1.

4.3 Installations in special category spaces situated below the bulkhead deck

4.3.1 Any electrical equipment installed is to be as stated in Pt C, Ch 2, Sec 3, [10.1.5] and electrical cables are to be as stated in Pt C, Ch 2, Sec 3, [10.2.2].

4.3.2 Electrical equipment and cables in exhaust ventilation ducts are to be as stated in [4.3.1].

4.3.3 The requirements in this item are summarised in Tab 2.

4.4 Installations in petrol spaces other than special category spaces intended for the carriage of motor vehicles

4.4.1 The requirements for installations in special category spaces situated below the bulkhead deck, as stated in [4.3], apply.

4.4.2 All electric circuits terminating in petrol holds are to be provided with multipole linked isolating switches located outside the holds. Provision is to be made for locking in the off position.

This requirement does not apply to safety installations such as fire, smoke or gas detection systems.

Table 1 : Electrical equipment permitted in special category spaces above the bulkhead deck

No.	Description of spaces	Electrical equipment	Hazardous area
1	Areas at less than 450 mm above the deck or platforms for vehicles, if fitted, without openings of sufficient size permitting penetration of petrol gases downward	a) any type that may be considered for zone 0 or zone 1	Zone 1
2	Exhaust ventilation ducts	As stated under item 1.	Zone 1
3	• areas above a height of 450 mm from the deck • areas above a height of 450 mm from each platform for vehicles, if fitted, without openings of sufficient size permitting penetration of petrol gases downward • areas above platforms for vehicles, if fitted, with openings of sufficient size permitting penetration of petrol gases downward	a) any type that may be considered for zone 1 or zone 2	Zone 2

Table 2 : Electrical equipment permitted in special category spaces below the bulkhead deck

No.	Description of spaces	Electrical equipment	Hazardous area
1	Special category spaces	a) any type that may be considered for zone 0 and zone 1	Zone 1
2	Exhaust ventilation ducts	As stated under item 1.	Zone 1

4.5 Electrical installation in well-dock space

4.5.1 When embarked vessels are foreseen to be supplied by ship power system, then provision of suitable means for preventing earth faults on connected vessel from affecting the main distribution system is to be made (galvanic isolation, tripping of the faulty circuit).

4.5.2 When electrical equipment needs to be installed in the higher part of the dock-well, appropriate design and protection against high temperatures caused by exhaust gas of embarked vessels are to be arranged.

4.6 Wheelhouse arrangement

4.6.1 The visibility from the wheelhouse is to be in accordance with Pt E, Ch 11, Sec 4, [6.2.1]. Where there is blind sectors larger than 5°, due to the asymmetrical location of the wheelhouse, cameras or equivalent vision systems are to be provided in appropriate location so as to cover the blind area.

4.6.2 No blind space of the landing area is to be found from the wheelhouse. If this is not achievable, cameras are to be provided in appropriate location so as to cover the blind area, unless appropriate visibility is possible from a dedicated bridge for aeronautical activities.

4.6.3 A status panel is to be provided in wheelhouse console to indicate the positions of the hangar doors and the positions of the helicopter elevators.

4.6.4 Due to asymmetric location of the wheelhouse, port bridge wing may be omitted.

5 Type approved components

5.1

5.1.1 Components for Low-Location Lighting systems (LLL) in escape routes are to be type approved or in accordance with [5.1.2].

5.1.2 Case-by-case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

5.1.3 Accumulator lamps for the supplementary electric lighting, alarm systems for closing devices of openings and water leakage detection systems if of electronic type, and television surveillance systems are to be type approved or in accordance with [5.1.2].

Section 6 Fire Protection

1 General

1.1 Application

1.1.1 The installations or equipment used for specific military operations which are not permanently fixed to the hull of the ship, such as mobile containers used to occasionally accommodate a mobile hospital or a mobile headquarters, are not required to comply with the requirements of this section. All other installations and equipment, including portable equipment required in this section, are to comply with the relevant requirements outlined in this Section.

1.2 Documents to be submitted

1.2.1 The interested party is to submit to the Society the documents listed in Pt C, Ch 4, Sec 1, [1.3].

2 General requirements

2.1 Vertical subdivisions

2.1.1 The interior of the ship, shall be subdivided into at least two main vertical zones by A-60 class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary they shall also be A-60 class divisions. Where a category (5), (9) or (10) space defined in item b) of Pt C, Ch 4, Sec 5, [1.2.3] is on one side or where fuel or diesel oil or JP5 NATO (F44) tanks or water capacity are on both sides of the division, the standard can be reduced to A-0.

2.1.2 The subdivisions into main vertical zones and vertical safety zones shall fall into line between each others. That means that a main vertical zone shall not be astride on two vertical safety zones and one vertical safety zone.

2.1.3 The length of each vertical safety zones is not to exceed 80 m but may be extended to a maximum of 100 m in order to bring the furthermost ends of the ship such as its bow or corbelled parts of the ship. If the length of the vertical safety zone exceed 80 m, the total area of the vertical safety zone is not to be more than 3400 m^2 on any deck. The maximum length of a vertical safety zone is the maximum distance between the furthermost points of the bulkheads bounding it.

2.1.4 If the part of the ship located forward of the collision bulkhead forms one vertical safety zone, or if the hangar or well dock forms one horizontal safety zone, this safety zone is to contain only one main vertical zone. This vertical safety zone and main vertical zone need not to comply with the requirements of Pt C, Ch 4, Sec 6, [1.3.2] for the fire pump and Pt C, Ch 4, Sec 8, [4.4.1] for the assembly and embarkation stations but the provisions of [3.3.1] for ventilation apply.

2.2 Horizontal subdivisions

2.2.1 The ship may accommodate some additional horizontal safety zones to enclose any large ro-ro or vehicles spaces or well dock. In this case, the horizontal safety zone may contain only one main horizontal zone.

2.2.2 These horizontal safety zones may extend on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

2.2.3 The requirements of ventilation systems and ducts, openings in A class divisions and penetrations in A class divisions for maintaining the integrity of vertical safety zone in this Chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal safety zones from each other and from the remainder of the ship. That means that the requirements for A-30 class steel ducts and A-30 class divisions of Pt C, Ch 4, Sec 5, [1.2.1] item a) are to be replaced by requirements for A-60 class steel ducts and A-60 class divisions.

2.3 Damage control stations

2.3.1 One damage control station is to be provided in each safety zone and so equipped in such a way that one damage control station can be replaced by an other one.

3 Containment of fire

3.1 Fire integrity of bulkheads and decks

3.1.1 The fire integrity of all bulkheads and decks prescribed in Pt C, Ch 4, Sec 5, Tab 1 and Pt C, Ch 4, Sec 5, Tab 2 is to be replaced by the requirements of the following Tab 1and Tab 2.

Table 1 : Bulkheads not bounding neither vertical zones nor horizontal zones nor safety zones

SPACES		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces	(1)	B-0 [a]	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Stairways	(2)		A-0 [a]	A-0	A-0	A-0	A-0	A-15	A-15	A-0 [c]	A-0	A-15	A-30	A-15	A-30	A-30
Corridors	(3)			B-15	A-60	A-0	B-15	B-15	B-15	B-15	A-0	A-15	A-30	A-0	A-30	A-30
Evacuation stations and external escape routes	(4)				–	A-0	A-60 [b] [d]	A-60 [b] [d]	A-60 [b] [d]	A-60 [d]	A-0	A-60 [b]	A-60 [b]	A-60 [b]	A-60 [b]	A-30
Open deck spaces	(5)					–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [e]
Accommodation spaces of minor fire risk	(6)						B-0	B-0	B-0	C	A-0	A-0	A-30	A-0	A-30	A-30
Services spaces and accommodation spaces of moderate fire risk	(7)							B-0	B-0	C	A-0	A-15	A-60	A-15	A-60	A-30
Accommodation spaces of greater fire risk	(8)								B-0	C	A-0	A-30	A-60	A-15	A-60	A-30
Sanitary and similar spaces	(9)									C	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, voids and auxiliary machinery spaces having little or no fire risk	(10)										A-0 [a]	A-0	A-0	A-0	A-0	A-30 [e]
Auxiliary machinery spaces and other similar spaces of moderate fire risk	(11)											A-0 [a]	A-0	A-0	A-15	A-30
Machinery spaces of category A and equivalent spaces of high fire risk	(12)												A-0 [a]	A-0	A-60	A-60
Service spaces of high risk	(13)													A-0 [a]	A-0	A-30
Special purpose spaces	(14)														A-30	A-30
Ammunition spaces and other equivalent spaces	(15)															A-30

Note 1:[a] : Where adjacent spaces are in the same numerical category and letter "a" appears, a bulkhead or deck between such spaces need not be fitted if deemed unnecessary by the Society. For example, in category (12) a bulkhead need not be required between a galley and its annexed pantries provided the pantry bulkheads and decks maintain the integrity of the galley boundaries. A bulkhead is, however, required between a galley and machinery space even though both spaces are in category (12).

[b] : The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to liferafts and evacuation slides may be reduced to A-30.

[c] : Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of B class integrity.

[d] : Where spaces of category (6), (7), (8) and (9) are located completely within the outer perimeter of the assembly station, the bulkheads of these spaces are allowed to be of B-0 class integrity. Control positions for audio, video and light installations may be considered as part of the assembly station.

[e] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only "A-0" fire class standard is required.

Table 2 : Decks not forming steps in main vertical zones nor bounding horizontal zones nor safety zones

SPACE below		SPACE above														
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces	(1)	A-30	A-30	A-15	A-0	A-0	A-0	A-15	A-30	A-0	A-0	A-0	A-60	A-0	A-60	A-30
Stairways	(2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30	A-30
Corridors	(3)	A-15	A-0	A-0 [a]	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-30	A-0	A-30	A-30
Evacuation stations and external escape routes	(4)	A-0	A-0	A-0	A-0	–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Open deck spaces	(5)	A-0	A-0	A-0	A-0	–	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [e]
Accommodation spaces of minor fire risk	(6)	A-60	A-15	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Services spaces and accommodation spaces of moderate fire risk	(7)	A-60	A-15	A-15	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Accommodation spaces of greater fire risk	(8)	A-60	A-15	A-15	A-60	A-0	A-15	A-15	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Sanitary and similar spaces	(9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, voids and auxiliary machinery spaces having little or no fire risk	(10)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [a]	A-0	A-0	A-0	A-0	A-30 [e]
Auxiliary machinery spaces and other similar spaces of moderate fire risk	(11)	A-60	A-60	A-60	A-60	A-0	A-0	A-15	A-30	A-0	A-0	A-0 [a]	A-0	A-0	A-30	A-30
Machinery spaces of category A and equivalent spaces of high fire risk	(12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30	A-30 [a]	A-0	A-60	A-60
Service spaces of high fire risk	(13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Special purpose spaces	(14)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-0	A-30	A-30	A-0	A-30
Ammunition spaces and other equivalent spaces	(15)	A-30	A-30	A-30	A-30	A-30 [e]	A-30	A-30	A-30	A-30	A-30 [e]	A-30	A-60	A-30	A-30	A-30
Note 1: The notes of Tab. 1 apply to Tab.2, as appropriate.																

3.1.2 Fire integrity of the flight decks

Except when a space of category (5), (9) or (10) is located below the flight decks, the flight decks shall be of A-30 class standard.

In addition, A-60 fire insulation is to be applied below the helideck landing areas.

Note 1: When accepted by the Naval Authority, the above requested A-30 fire class standard may locally be reduced to A-0.

Note 2: The A-60 fire insulation indicated above does not take account of the landing operation of STOVL aircrafts.

3.2 Protection of openings in fire-resistant divisions

3.2.1 The requirements of item d) of Pt C, Ch 4, Sec 5, [3.1.1] are to be replaced by the following requirements applicable to fire doors in main vertical zone bulkheads, stairway enclosures and galley boundaries, other than watertight doors and those which are normally locked:

a) The doors are to be self-closing and be capable of closing with an angle of inclination of up to 3,5° opening closure.

b) The approximate time of closure for hinged fire doors is to be not more than 40 s and not less than 10 s from the beginning of their movement with the ship in upright position. The approximate uniform rate of closure for sliding doors is to be not more than 0,2 m/s and not less than 0,1 m/s with the ship in upright position.

c) The doors, except those for emergency escape trunks, are to be capable of remote release from the continuously manned damage control station, either simultaneously or in groups, and are to be capable of release also individually from a position at both sides of the door. Release switches are to have an on-off function to prevent automatic resetting of the system.

d) Hold-back hooks not subject to remote release from the continuously manned damage control station are prohibited.

e) A door closed remotely from a damage control station is to be capable of being re-opened from both sides of the door by local control. After such local opening, the door is to close again automatically.

f) Indication is to be provided at the fire door indicator panel in the continuously manned damage control station whether each door is closed.

g) The release mechanism is to be so designed that the door is to close automatically in the event of disruption of the control system or central power supply.

h) Local power accumulators for power-operated doors are to be provided in the immediate vicinity of the doors to enable the doors to be operated at least ten times (fully opened and closed) after disruption of the control system or central power supply using the local controls.

i) Disruption of the control system or central power supply at one door is not to impair the safe functioning of the other doors.

j) Remote-release sliding or power-operated doors are to be equipped with an alarm that sounds at least 5 s but not more than 10 s after the door begins to move, and continues sounding until the door is completely closed.

k) A door designed to re-open upon contracting an object in its path is to re-open not more than 1 m from the point of contact.

l) Double-leaf doors equipped with a latch necessary for their fire integrity are to have a latch that is automatically activated by the operation of the doors when released by the system.

m) Doors giving direct access to ro-ro spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in items c) and J).

n) The components of the local control system are to be accessible for maintenance and adjusting.

o) Power-operated doors are to be provided with a control system of an approved type which is to be able to operate in case of fire and be in accordance with the Fire Test Procedure Code. This system is to satisfy the following requirements:

- the control system is to be able to operate the door at the temperature of at least 200°C for at least 60 min., served by the power supply
- the power supply for all other doors not subject to fire is not to be impaired, and
- at temperatures exceeding 200°C, the control system is to be automatically isolated from the power supply and is to be capable of keeping the door closed up to at least 945°C.

3.2.2 Hose ports

With reference to the provision of Pt C, Ch 4, Sec 5, [3.1.1], as far as practicable, self-closing hose ports are to be provided on all A class doors except watertight doors, weathertight doors (semi-watertight doors), doors leading to the open decks and doors required to be gas-tight.

As far as practicable, where a weathertight door is fitted in a respective internal weathertight bulkhead, a respective weathertight opening capable of being opened from both sides of the bulkhead is to be provided on this bulkhead close to the door for permitting the passage of a fire hose through this bulkhead when the door is closed. Suitable measures are to be taken to ensure that this opening is closed at sea.

3.2.3 Stairway enclosures

a) With reference to the provision of Pt C, Ch 4, Sec 5, [1.2.4], stairways not enclosed within enclosures formed of A class divisions in compliance with Tab 1 and Tab 2 are not to be permitted.

b) Nevertheless, stairways which are fitted in accordance with Ch 5, Sec 7, [1.1.4] may not be enclosed within A class divisions, provided that the stairway penetrates a single deck and is protected, at a minimum, at one level by at least B class divisions and self-closing doors.

3.3 Ventilation sytems

3.3.1 Application

For the application of this Chapter, the requirement of Pt C, Ch 4, Sec 5, [6.3.7] is to be replaced by:

“The ventilation fans shall be so disposed that the ducts reaching the various spaces remain within the main vertical zones.

The air conditioning units shall not serve more than one main vertical zone. However the air inlets and outlets of the ventilation system serving one main vertical zone may be located outside the main vertical zone provided that they are located inside the same vertical safety zone. In this case, the requirement of Pt C, Ch 4, Sec 5, [6.3.7] will apply for the dedicated ventilation duct passing through the main vertical zone boundary.

If the part of the ship located forward the collision bulkhead forms one vertical safety zone containing one single main vertical zone, the dedicated air conditioning units serving this main vertical zone can be located outside this main vertical zone provided that they are located inside the immediately adjacent aftward main vertical zone. In the same way, the air inlets and outlets of the ventilation system serving this vertical safety zone can be located outside this vertical safety zone provided that they are located inside the immediately adjacent aftward safety zone. In these two cases, the requirement of Pt C, Ch 4, Sec 5, [6.3.9] will apply for the dedicated duct passing through the main vertical zone boundary or vertical safety zone boundary.

Except for the particular cases mentionned above, a ventilation duct is to pass neither through a main vertical zone boundary nor through a vertical safety zone boundary."

3.3.2 Ventilation dedicated to Well docks

The requirements and the general provisions for ro-ro spaces as defined in Pt C, Ch 4, Sec 12, [2] are applicable to well docks except for Pt C, Ch 4, Sec 12, [2.1.4] item b), for which the A-30 class is to be replaced by A-60 class.

4 Fire-extinguishing arrangement

4.1 Fire pump capacity

4.1.1 The capacity of each large capacity fire pump required by Pt C, Ch 4, Sec 6, [1.3.2] is to be not less than 100 m^3/h.

4.2 Sprinkler installation

4.2.1 A sprinkler system of an approved type and complying with the requirements of Pt C, Ch 4, Sec 13, [8] is to be fitted in all control stations, accommodation and service spaces.

Alternatively, control stations where water may cause damage to essential equipment, may be fitted with an approved fixed fire-extinguishing system of another type.

Spaces having little or no fire risk such as voids, public toilets, carbon dioxide rooms and similar spaces need not be fitted with a sprinkler system.

5 Flight decks

5.1 General

5.1.1 Fixed fire protection

The flight decks are to be protected by a fixed fire protection system for flight decks complying with the provisions of Pt C, Ch 4, Sec 13, [10].

5.1.2 Drainage facilities

In addition to the requirements of Pt C, Ch 1, Sec 10, [8.10.7], drainage facilities from flight decks are to comply with the requirements of Pt C, Ch 4, Sec 10, [3.2], as applicable to helidecks.

6 Well docks

6.1 General

6.1.1 Application

The requirements and the general provisions as defined in Pt C, Ch 4, Sec 12 for any vehicles, rescue boat or operational boats using internal combustion engines also with combustibles having a flash point below 60°C, shall be applied to well docks

6.1.2 Classification

Well docks are to be classified as category (14) "Special purpose spaces".

6.1.3 Portable fire extinguishers

The provisions of Pt C, Ch 4, Sec 12, [4.2.1] are applicable except on the deck in submerged part during the amphibious operations, constituted by the bottom of well dock.

7 Ro-ro spaces

7.1 General

7.1.1 Application

The requirements and the general provisions for a ro-ro space as defined in Pt C, Ch 4, Sec 12 shall also be applied to any vehicles using internal combustion engines having combustibles with a flash point below 60°C.

7.1.2 Classification

Ro-ro spaces to be classified as category (14) "Special purpose spaces".

8 Aircraft hangars

8.1 General

8.1.1 General definition

In addition to Ch 5, Sec 1, [1.2.6], the necessary services such as refuelling, defuelling, ammunition loading, oxygen loading can be handed on the aircrafts inside the aircraft hangar.

8.1.2 Application

a) The requirements and the general provisions for a ro-ro space as defined in Pt C, Ch 4, Sec 1, [2.30.1] are also applicable to an aircraft hangar except for the single requirement of Pt C, Ch 4, Sec 12, [2.1.1] for which the aircraft hangar can be considered as a closed vehicle space and therefore be provided with a ventilation system sufficient to give at least 6 air changes per hour.

b) Permanent openings in the side plating, the ends or deckhead of the space are to be so situated that a fire in the aircraft hangar does not endanger stowage areas and embarkation stations for survival craft and accommodation spaces, service spaces and control stations in superstructures and deckhouses above the aircraft hangar.

8.1.3 Protection of aircraft hangar access doors

Suitable means of fire-protection such as local water spraying systems are to be provided to the doors giving access to aircraft hangars from the open decks in order to withstand any projection of fired fuel oil from the flight decks.

8.1.4 Subdivided aircraft hangars

Where an aircraft hangar is internally divided into several sub-aircraft hangars by means of internal subdividing bulkheads extending across the full breadth of the aircraft hangar, the doors fitted in the subdividing bulkheads need not have A class integrity nor be made of steel, if agreed by the Society. However, when such a door does not have A class integrity or is not of steel construction, a water curtain capable of delivering at least 5 l/min/m² of water is to be provided on both sides of the bulkhead.

Indicators are to be provided at the damage control station showing whether these doors are open or closed.

8.1.5 Drainage facilities

Drainage from aircraft hangars directly to the sea is to be avoided as far as possible. In addition to the requirements of Pt C, Ch 1, Sec 10, [8.10.7], drainage facilities from aircraft hangars are to comply with the requirements of Pt C, Ch 4, Sec 10, [3.2.2].

8.1.6 Aircraft refuelling facilities

In addition to the requirements of Pt C, Ch 1, Sec 10, [11], aircraft refuelling facilities are to comply with the requirements of Pt C, Ch 4, Sec 10, [4.1], Pt C, Ch 4, Sec 10, [4.2] and Pt C, Ch 4, Sec 10, [4.4.1], as applicable, to helicopter facilities.

8.2 Operational

8.2.1 Vehicles

Where vehicles such as cars, fire-fighting trucks (VLIP), trucks using internal combustion engine for their own propulsion are running or stored inside the aircraft hangar, their fuel is not to have a flash point below 60°C. At any time of operation, the total number of such vehicles in the aircraft hangar is to be such that the total power output of these vehicles does not exceed 0,02 kW/m³.

For vehicules using electrical engines, their own propulsion are running or stored inside the aircraft hangar, the provisions in Ch 5, Sec 5, Tab 1Ch 5, Sec 5, Tab 1 are to be applied.

8.2.2 Battery charging

When some vehicle using electrical engines or other batteries are located in the aircraft hangar, the charging of such batteries will not be permitted in the aircraft hangar. The charging of such batteries is to be done in a dedicated spaces considered as a battery room.

8.2.3 Aircraft refuelling

The aircraft refuelling may be permitted inside the aircraft hangar if suitable safety devices are provided and safety procedures are ensured.

In case of aircraft refuelling operation inside the hangar, the dedicated area is to be fitted with a mechanical ventilation system providing at least 10 air changes per hour during the refuelling operations.

Ventilation fans are to be of non-sparking type.

8.3 Fire protection

8.3.1 Fire-fighting system

With regards to the risk analysis proceeded by the Naval Authority, the fire-fighting system required by Pt C, Ch 4, Sec 12, [4.1] may be replaced by a more suitable technical solution on the agreement of the Society.

9 Oxygen production

9.1 Oxygen production and storage installation

9.1.1 Where oxygen for aircraft breathing is produced aboard the ship, special consideration is to be given to the oxygen production and storage installation, with regard to fire prevention, containment of fire, ventilation, fire detection and fire fighting.

Where fitted, such installation is to be to the satisfaction of the Society.

Section 7 Escape

1 General

1.1 Application

1.1.1 The requirements of Pt C, Ch 4, Sec 8 are to be replaced by the applicable requirements of SOLAS, Chapter II-2, Part D, Regulations 12 and 13 as applicable, for Ro-Ro passenger ships carrying more than 36 passengers, and the applicable requirements of the Fire Safety System Code, Chapter 13, and other relevant IMO Resolutions, Circulars, Guidelines and other standards referred therein, except that:

a) regulations 13.3.2.1 and 13.3.2.4.1 are replaced by the following [1.1.2] to [1.1.5]

b) regulation 13.3.2.3 is replaced by the following [1.1.6]

c) regulation 13.3.4 is replaced by Pt C, Ch 4, Sec 8, [3]

d) d)requirement 2.1.1 of FSS Code, Ch 13, is replaced by the following [1.1.9]

e) requirement 2.2.3 of FSS Code, Ch 13, is replaced by the following [1.1.10]

f) requirement 2.1 of FSS Code, Ch 11, is replaced by the following [1.1.11].

1.1.2 Escape from spaces below damage control deck

a) Below the damage control deck, two means of escape are to be provided from each watertight compartment or similarly restricted space or group of spaces.

b) At least one of the means of escape required in item a) above is to consist of a readily accessible enclosed stairway (Category [2]), which is to provide continuous fire shelter from the level of its origin to the appropriate embarkation decks.

c) the continuous fire shelter is also provided on the damage control deck through a route protected as a category [2] space (horizontal stairway).

d) When external escape routes are provided, they are to be provided with emergency lighting in accordance with SOLAS Ch III regulation 11 and slip-free surfaces underfoot. Boundaries facing external open stairways and passage-ways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck are to have fire integrity, including insulation values, in accordance with Ch 5, Sec 6, Tab 1 and Ch 5, Sec 6, Tab 2, as appropriate, for category [4] spaces.

e) The stairway arrangement required by the preceding item b) for below damage control deck compartments of one main vertical zone can be arranged by:

   1) one enclosed stairway which provides a continuous fire shelter from the level of its origin to the embarkation deck in one watertight compartment, and

   2) each of the other watertight compartments of the main vertical zone has an enclosed stairway which provides a continuous fire shelter from the level of its origin to the damage control deck, and

   3) the continuous fire shelter is also provided on the damage control deck through a route protected as a category [2] space (horizontal stairway).

f) In the bottom of the well dock, the means of escape arrangement required by the preceding item a) are to be provided with the length between each ladders not exceeding 80m, in each side of well dock.

1.1.3 Escape from spaces above the damage control deck: fire scenario

Above the damage control deck there is to be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape providing continuous fire shelter to the embarkation deck.

1.1.4 Escape from spaces between damage control deck and bulkhead deck: flooding scenario

a) Between damage control deck and bulkhead deck, at least one means of escape independent from watertight doors and giving access to embarkation deck is to be provided at each deck level from each watertight compartment or similarly restricted space or group of spaces.

b) The means of escape required in item a) above are to be, as far as practicable, a stairway, but where the purpose and forms of the ship make it impracticable, the means of escape may be a ladder or ladders (depending on the number of persons to be evacuated), to the satisfaction of the Society.

1.1.5 Additional requirements

a) When it is not possible to cross from one side to the other of the ship, the requirements [1.1.2] to [1.1.4] are applicable to each side of the ship.

b) The stairways referred to in [1.1.2] and [1.1.3] (fire scenario - continuous fire shelter) are to be sized considering that the total number of persons to be evacuated use those stairways. Other stairways which may be added for compliance with requirement [1.1.4] but do not comply with [1.1.2] are not to be considered as main escape routes for fire scenario evacuation analysis.

1.1.6 Direct access to stairway enclosures

Stairway enclosures in accommodation and service spaces are to have direct access from the corridors and be of a sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency.

Within the perimeter of such stairway enclosures, only public toilets, lockers of non-combustible material providing storage for non-hazardous safety equipment are permitted.

Only public spaces, accommodation spaces of minor fire risk (category 6) as defined in Pt C, Ch 4, Sec 5, [1.2.3], item b), corridors, lifts, public toilets, pantries containing no cooking appliances, special purpose spaces and open ro-ro spaces to which any embarked troops carried can have access, other escape stairways required by provisions [1.1.2] to [1.1.5] and external areas are permitted to have direct access to these stairway enclosures.

Small corridors or “lobbies” used to separate an enclosed stairway from galleys or main laundries may have direct access to the stairway provided they have a minimum deck area of 4,5 m^2, a width of not less than 900 mm and contain a fire hose station

1.1.7 Evacuation analysis

Escape routes are to be evaluated by an evacuation analysis early in the design process.

The analysis is to be used to identify and eliminate, as far as practicable, congestion which may develop during an abandonment, due to normal movement of embarked troops and crew along escape routes, including the possibility that crew may need to move along these routes in a direction opposite to the movement of embarked troops. In addition, the analysis is to be used to demonstrate that escape arrangements are sufficiently flexible to provide for the possibility that certain escape routes, assembly stations, embarkation stations or survival craft may not be available as a result of a casualty.

Note 1: For the application of the IMO Circular MSC.1/Circ.1533, the scenarios and given values such as Response duration (R), Total travel duration (T), Embarkation and launching duration (E+L), counterflow factor, walking speed, etc. may be replaced by more effective scenarios and values given by the Naval Authority.

1.1.8 Around the flight decks, corridors on open deck, giving access to a safe route to the assembly stations, are to be provided. The persons evacuating by these external corridors are to be protected from the liquids falling from the flight decks by a suitable gutter arrangement.

1.1.9 Minimum net width of means escapes

a) Stairways are not to be less than 700mm in net width. The minimum net width of stairways is to increase by 10 mm for every person provided in excess of 70 persons. The total number of persons to be evacuated by such stairways is assumed to be two thirds of the total number of the crew and embarked troops in the areas served by such stairways.

b) Stairways are not to be less than 700mm in net width. The width of the stairways is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13, [2.1.2], considering the distribution of persons given in [1.3] hereafter.

1.1.10 Vertical rise and inclination of stairways

Stairways are not to exceed 3,5 m in vertical rise without the provision of a landing. Their angle of inclination is to be in general 45°, but not greater than 50°, for the stairways used by embarked troops in normal operation.

1.1.11 Low-location Lighting systems

The requirements as defined in Pt C, Ch 4, Sec 8, [2.3.2] in item [g] shall be applied except for the photoluminescent systems exposed to a red lighting during 11 hours. Such photoluminescent equipment are to be also tested and applied with a red lighting. The luminance performance shall be at the satisfaction of the Society with the agreement of the Naval Authority.

1.2 Dispensation and application

1.2.1 When it is not practical to apply one requirement of the mentioned rules above, the arrangement is to be at the satisfaction of the Society with the agreement of the Naval Authority.

At least one assembly station and one embarkation station is to be provided for each vertical safety zone. The assembly stations shall have sufficient clear deck space to accommodate all persons assigned to muster at that station but at least 0,35 m^2 per person.

Note 1: The assembly stations and embarkation stations may include spaces such as corridors, landings of stairway enclosures, accommodation and service spaces but a an assembly station is not to include a control station, a machinery space, an ammunition space or a bottom of well dock. In any case, a space which requires a key for access can not be included in an assembly station or an embarkation station unless the key is enclosed in a beak-glass type enclosure conspicuously located an indicated near the normally locked access door.

1.3 Distribution of persons

1.3.1 For the application of the provision of the Fire Safety System Code, Chapter 13 [2.1.2.2.2.1], cases 1 and 2 are to be replaced by:

a) Case 1 (night time)
   - the total number of the embarked troops in its cabins
   - the total number of the members of crew not operating by watch in its cabins and berthing
   - 2/3 of the members of the crew operating by watch in its cabins and berthing spaces, and service spaces
   - 1/3 of the crew operating by watch in its service space.

b) Case 2 (day time)
   - embarked troops in public space occupied to the maximum capacity
   - 1/3 of the remaining embarked troops in its vehicles and aircrafts maintenance spaces
   - 2/3 of the remaining embarked troops in cabins
   - 1/4 of the members of crew not operating by watch in its public spaces
   - 3/4 of the members of crew not operating by watch in its service spaces
   - 1/3 of the crew operating by watch in its cabins and berthing spaces
   - 1/3 of the crew operating by watch in its service spaces, and
   - 1/3 of the crew operating by watch in its public spaces.

Note 1: For the application of the provision of Fire Safety System Code, Chapter 13 [2.1.2.1.4], the number of persons to be distributed in each public space is to be proportional to the deck area of these public spaces, as per the following formula:

$n = N \cdot a / A$

where:

N : Total number of persons to be distributed in the public spaces

a : Deck area of the selected public space

A : Total deck area of the public spaces available to the total number of persons to be distributed in the public spaces.

Note 2: Other cases of distribution of persons may be considered in replacement of, or in addition to, cases 1 and 2 above by more effective scenarios given by the Naval Authority.

Section 8 Facilities for Flammable Products with Flashpoint ≤ 60 °C

1 General

1.1 Application

1.1.1 Amphibious vessels complying with the requirements of this Section may stored and delivered flammable liquids with flashpoint ≤ 60°C in limited amounts not exceeding the maximum oil product specified in [1.2.1].

1.2 Maximum capacity of flammable liquid with flashpoint ≤ 60°C

1.2.1 The total capacity of tanks designed to store oil product having is to be less than 1000 m^3.

1.3 Definitions

1.3.1 Petrol

The term "Petrol" is to be used to nominate oil products having flammable liquids with a flash point ≤ 60°C. This oil products are exclusively used to be delivered onboard, to tenders, rescue boats, operational boats, landing barges, road vehicules, aircrafts and dedicated carts to supply aircrafts.

1.3.2 Petrol area

With regards to the stowage of flammable liquids with flashpoint ≤ 60°C and corresponding requirements of this Section, the petrol area is that part of the ship where petrol and petrol vapours are likely to be present and includes petrol tanks, petrol slop tanks, petrol pump rooms, petrol delivery station, petrol delivery area, hold spaces in which independent tanks are located, cofferdams or void spaces surrounding integral tanks and the following deck areas:

- within 3 m of a petrol tank installed on deck
- within 3 m of a petrol tank outlet or access, in case of independent tanks installed below deck
- within 3 m of a petrol tank or petrol slop tank outlet or access in case of integral tanks installed below deck and separated from the weather deck by a cofferdam
- the deck area above an integral petrol tank, petrol slop tank without an overlaying cofferdam plus the deck area extending transversely and longitudinally for a distance of 3 m beyond each side of the tank
- within 3 m of any petrol liquid or vent pipe, flange, petrol valve, gas or vapour outlet, or entrance or exhaust to a petrol pump-room.
- within 3 m of any petrol delivery stations, petrol delivery areas with flexible hose under pressure or petrol vapour outlet fitting tanks of trucks, aircrafts, tenders or crafts.

1.3.3 Hazardous ares

The different spaces are to be classified according Tab 1.

1.3.4 Petrol delivery station

Petrol delivery station is a closed space in which the petrol refuelling facilities are fitted.

A petrol delivery station and petrol pump room dedicated to petrol refuelling may be located in the same space.

1.3.5 Petrol delivery area

Petrol delivery area is the area where the delivery of petrol is performed at vehicles, aircrafts or boats.

Petrol delivery area includes 3m around to the vehicle, aircraft or boat in which the petrol is supplied

1.3.6 Petrol pump room

Petrol pump room is a space containing pumps and their accessories for the handling of petrol.

A petrol pump room and petrol delivery station may be located in the same space.

1.3.7 Cofferdam

The cofferdam is a void space surrounding one or several tank, permitting to isolate a tank from adjacent spaces or areas.

Table 1 : Space descriptions and hazardous area zones for vessel using flammable liquids having a flash point not exceeding 60°C

No.	Description of petrol spaces	Hazardous area
1	Interior of petrol tanks, petrol slop tank, any pipework	Zone 0
2	Cofferdams	Zone 1
3	Petrol Pump room, delivery station or compartment for hoses	Zone 1
4	Areas on open deck or semi-enclosed spaces on open deck, within 3 m of any petrol tank outlet, petrol vent outlet, valve, pipe flange, petrol pump room ventilation outlets	Zone 1
5	Areas on open deck or semi-enclosed spaces on open deck, within 1.5 m of pump room entrance, pump room ventilation entrance, openings into cofferdam or other zone 1 spaces.	Zone 1
6	Enclosed or semi-enclosed spaces in which welded pipes containing petrol are located.	Zone 2
7	Petrol delivery areas on open deck or semi-enclosed spaces on open deck or in enclosed spaces, within 3m around the hoses used to filling operations and refueled tanks.	Zone 1
8	Areas of 1.5 surrounding a areas of zone 1	Zone 2
9	Areas on open deck extending to the coaming fitted to keep any spills on deck and away from the accommodation and service space and 3 m beyond these up to a height of 2,4 m above the deck	Zone 2

2 General arrangement

2.1 Compartment arrangement

2.1.1 Length of tanks

The length of each tank may not exceed 10 meters or one of the values of Ch 4, Sec 9, Tab 1, as applicable, whichever is the greater.

2.1.2 Segregation

The petrol tanks are to:

a) be segregated from others spaces no defined as petrol tanks or petrol slop tanks by means of a cofferdam,

b) have separate pumping and piping systems which may not pass through other tanks,

c) have separate tank venting systems.

The associated tanks, slop tanks, pump rooms, delivery stations and areas are to be as remote as is practical from accomodation spaces, escape routes and embarkation stations.

2.1.3 Restricting openings

Access doors, air inlets and openings to accommodation spaces, service spaces and control stations are not to face the petrol area.

2.2 Access arrangement

2.2.1 Tank and cofferdam

Access to cofferdam may be direct by pump-room. Access to tanks may be directly from pump room, through the cofferdam.

Note 1: Safe access to tanks or cofferdam shall be at means tohatches Their dimensions are to be sufficient to allow a person wearing a self-contained air-breathing apparatus and protective equipment. The minimum clear opening is to be not less than 600mm x600mm.

Note 2: Access shall be enable to the evacuation of an injured person from bottom of tanks or cofferdam.

2.2.2 Pump-room and delivery station

Access to pump-room or delivery stations is to be direct from an open deck

2.2.3 Access to the gas-safe spaces

Gas-safe spaces such as accommodation, service space, machinery and other similar spaces shall not have any direct communication with hazardous spaces as defined in [1.3.3].

2.3 Petrol tanks

2.3.1 Tank and associated equipment are to be surrounded by a cofferdam to protected it against physical damage and from a fire in an adjacent space or area.

2.3.2 Where independent tanks are used, special attention shall be given to:

- inspection procedures.
- location of the petrol tank, which are to be fitted on the weather deck or in the well dock, in zone where a suitable possibly removable containment coaming is to be fitted such as to prevent any spillage and/or leakages from flowing to gas-safe areas.
- storage of the tank, which are to be securely fastened to the hull structure.
- a space is to be left between tanks and ship sides sufficient to allow easy passage of ship personnel and transfer of fire-fighting arrangements.
- the petrol handling system serving portable tanks is to be such that liquid heads higher than those allowable for petrol tanks, if any served by the same system cannot occur.
- electric bonding.
- provision are to be made such that any portable tank is easily identifiable by means of markings or suitable plates.

2.4 Cofferdam

2.4.1 The cofferdams around the petrol tanks are to be fitted with:

a) a gas detection system with alarms centralized at the continuously manned damage control station

b) a fixed water-spraying fire-extinguishing system to water the bulkheads and ceiling, complying with the provisions of Pt C, Ch 4, Sec 13, [7], activated at least from the damage control station

c) a fixed means of flooding for submerging totally the space, activated at least from the damage control station

d) an effective power ventilation system, sufficient to give permanently at least 30 air changes per hour, to maintain hydrocarbon concentration below 2% by volume, with arrangement such as to prevent air stratification and formation of air pockets. The cofferdam may be fitted with a refrigerated air ventilation used to maintain the temperature of petrol tank under the 25°C.

e) or/and an inert system controlled from the damage control station. The inert gas system is to comply with the provisions of Ch 4, Sec 9, [4.5.4] or with another standard deemed acceptable by The Society.

The width of the cofferdams is to allow easy passage for inspection purposes.

3 Bilge

3.1 Bilge system

3.1.1 Petrol pump rooms, petrol delivery station and duct keels below or petrol slop tanks, hold spaces in which independent petrol tanks are installed and all hazardous space, dry cofferdams are to be served by an independent bilge pumping system entirely situated within the petrol area as defined in [1.3.2] and fitted with pumps or ejectors. No connection is permitted with the bilge system serving gas-safe spaces of the ship.

4 Petrol system

4.1 Petrol tanks

4.1.1 Level gauging

Each petrol tank or petrol slop tank is to be fitted with a remote level gauging system as defined in Ch 4, Sec 9, [4.5.2].

4.1.2 Overflow protected

Each petrol tank or petrol slop tank is to be fitted with a protection against tank overfilling system as defined in Ch 4, Sec 4, [5.5]

4.1.3 Venting

Petrol tanks and petrol slop tanks are to be provided with gas venting systems entirely separate from any vent pipes serving other compartments.

Such systems are to comply with the requirements of Ch 4, Sec 9, [4.5.3] and Ch 4, Sec 9, [4.5.4] for cargo tanks of auxiliary naval vessels.

4.2 Petrol delivery system

4.2.1 General

The area shall be provided for the petrol facilities and delivery area which shall be away of more than 3m from the accommodation spaces, service spaces, control stations and escape routes and evacuation stations accordance to [1.3.2]

The petrol facilities area shall be provided with arrangement whereby petrol spillage may be provided with collected and drained to a dedicated slop tank and isolated from any source of ignition, except to refuelling operation in well dock or close aboard.

Fixed arrangements are to be provided at the refuelling station for filtering and sampling.

4.2.2 Materials

Materials for construction of tanks, piping, valves fittings and pumps are to be of steel or iron cast.

4.2.3 Petrol piping system

The petrol piping system is to be installed, except as stipulated in [3.3.3], within the petrol tank and petrol independent tank area and is not to run through tanks and other compartments not belonging to the petrol area.

Where necessary, petrol piping is to be provided with joints or expansion bends.

Pipe lengths serving petrol tanks are to be provided with shut-off valves operable from petrol station.

In order to prevent any generation of static electricity, the outlets of filling lines are to be led as low as possible in the tanks. In opposite case, the offloading capacity shall be limited not more than 1m/s.

Inside the ship, pipe lengths serving between petrol pump room and petrol station are to be welding.

4.2.4 Petrol systems safeties

The delivery system is to be fitted with shutdown valve on petrol piping.

The shutdown valve is automatically closed, petrol pump stopped and audible alarm triggered if:

a) manual emergency stop buttons activation

b) refueled tank overflow/overpressure is detected automatically by an integrated system to the refueling installation

c) fire or concentration of gas hazard is detected

d) unusual overheating of the pump or no flow are detected.

The manual emergency stop buttons shall be provided close to each exit from delivery station and delivery area.

Where a gravity fuelling system is installed, equivalent closing arrangement shall be provided to isolate the petrol piping.

The fuel pumping system shall incorporate a device which will prevent over-pressurization of delivering hose.

4.3 Petrol pump room

4.3.1 The pump room is to comply with the applicable requirements for oil tankers. Refer to NR467, Pt D, Ch 7, Sec 4.

For the construction, installation and operation of petrol pumps, the applicable requirements for oil tankers are to be complied with. Refer to NR467, Pt D, Ch 7, Sec 4.

5 Petrol delivery facilities

5.1 General

5.1.1 In general, the actual refuelling operation shall be carried out on an open deck and shall be arranged and treated for fire protection purpose as the ship fuel filling station. In addition, connection to the petrol piping shall be located outside of the close spaces.

If the refuelling is not carried on the open deck or if the connection to the petrol piping is located inside a vehicle hangar, aircraft hangar or well dock, refuelling and maintenance facilities shall be treated as category A machinery spaces with regard to structural fire protection, fixed fire-extinguishing and detection system requirements.

5.1.2 Petrol delivery piping

All equipment used in refuelling operations shall be electrically bonded. Measures related to the limitation of the production of electrostatic energy in petrol spaces shall be taken.

Petrol piping shall not pass through accommodation spaces, service spaces and control stations. When this is not possible, specific arrangement shall be submitted to the Society to avoid the flammable vapours in the concerned spaces.

Means are to be provided in order to purge the piping after use.

5.1.3 Petrol delivery hoses

The length of flexible hoses shall not exceed the surface of delivery area.

The petrol flexible hoses shall be type approved except flexible hoses dedicated to aircrafts submitted if approved according to equivalent standard.

5.2 Arrangement

5.2.1 During the petrol refuelling operations, none vehicle or boat shall be drive along inside the petrol delivery area.

The delivery area shall be contiguous of the delivery station with a directly access into this space.

“No Smoking” signs shall be displayed at appropriate locations.

5.3 Ventilation

5.3.1 The effective power ventilation system shall be sufficient to give at least 20 air changes per hour, during the petrol refuelling operations, inside the petrol delivery station and area, with arrangement such as to prevent air stratification and formation of air pockets.

The ventilator stop failure is to be connected to shutdown valve located before the flexible hose and is ti be fitted with a shutdown alarm centralized in the continuously manned damage control station.

Ventilation fans are to be of non-sparking type.

6 Fire and gas protection

6.1 Fire fighting system

6.1.1 Fixed system

In addition to the requirements of Pt C, Ch 4, Sec 12, [4], at least one foam portable extinguisher and one dry powder portable extinguisher shall be located at each access to delivery station.

6.1.2 Portable system

One foam applicator is to be connected to the hydrant located at least 10 m of each delivery area. This foam applicator shall be capable of delivering foam at a rate not less than 400l/min during at least 5 minutes.

6.2 Fire and gas detection system

6.2.1 General

Petrol areas, such cofferdam, pump room, delivery stations and delivery areas, except into the tanks and on the flight deck, are to be fitted with a fixed fire and gas detection system alarms. This system should be capable of indicating at the continuously manned damage control station and in petrol areas, by audible and visual means the presence and location of a fire and an accumulation of flammable gas.

6.2.2 Fire detection system

The fire detection system are to be compliant with Pt C, Ch 4, Sec 13, [9]. The provisions regarding power supply, such required in Pt C, Ch 4, Sec 13, [9] to fire detection and fire alarm systems, shall be also required to gas detection and gas alarm systems.

A manually operated call points shall be provided close to each exit from delivery station and delivery area.

6.2.3 Gas detection system

The combustible gas detectors are to alarm at not more than 25% and at 60% of the lower explosive limit (LEL).

7 Electrical installations

7.1 Hazardous locations and types of equipment

7.1.1 In addition to the general requirements of Ch 5, Sec 5, electrical equipment and hazardous areas definitions are to comply with requirements of NR467, Pt D, Ch 7, Sec 5, [2].

7.1.2 Static electric discharge risk

To avoid static electric discharge at connection of hose, the metallic tanks of road vehicle, carts, tenders, boats, barges or aircrafts shall be connected to the hull structure of ship. The cable square section is to be minimum $6mm^2$.

7.1.3 Radio electric discharge risk

To avoid fire ignition risk, in addition to the requirement Pt C, Ch 4, Sec 10, [4.2], “No radio” signs shall be displayed at appropriate locations, around the filling points to prohibit to use radio devices.

8 Operation manual

8.1 General

8.1.1 Manual operation

Each petrol facilities shall have an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements. This manual may be part of the ship’s emergency response procedures.

The procedures and precautions to be followed during refueling operations shall be in accordance with recognized safe practices and contained in the operations manual.

CHAPTER 6
MILITARY OFFSHORE PATROL VESSEL

Section 1	General
Section 2	Hull and Stability
Section 3	Machinery and Systems
Section 4	Electrical Installations and automation
Section 5	Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **military OPV**, as defined in Pt A, Ch 1, Sec 2, [4.7].

1.1.2 The applicable set of requirements are governed by the following main characteristics:

- rule length
- high speed criteria, as defined in [1.2.1]
- hull material (steel, aluminium or composites).

1.1.3 Ships dealt with in this Chapter are to comply with:

- Part A
- the applicable requirements according to Tab 1
- NR216 Materials and Welding, as applicable.

Table 1 : Applicable requirements

Item		L ≥ 60 m	L < 60 m
Ship arrangement		• Part B, Chapter 1 Part B • Articles [2] and [3]	• NR566**(1)** • Articles [2] and [3]
Hull**(1)**	Slow speed	• Part B • Ch 6, Sec 2	• Part B • Ch 6, Sec 2
	High speed	• Part B • Ch 3, Sec 2 • Ch 6, Sec 2	• Part B • Ch 3, Sec 2 • Ch 6, Sec 2
Stability		• Part B	• NR 566**(2)**
Machinery and systems		• Ch 3, Sec 3	• NR 566**(2)** • Ch 6, Sec 3
Electrical installations and automation		• Part C • Ch 6, Sec 4	• NR566**(2)**
Fire protection, detection and extinction		• Part C • Ch 3, Sec 5**(1)**	• NR566**(2)** • Ch 6, Sec 5 **(3)**

(1) Case-by-case examination for hull in composites.
(2) Requirements to be applied, except the specific rules for passenger ships not to be taken into account.
(3) Special consideration will be given with regard to escape and circulation for ships carrying more than 60 persons.
Note 1: NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.

1.2 Definitions

1.2.1 High speed criteria

Offshore patrol vessels are considered complying with the high speed criteria when the following condition is fulfilled:

$V \geq 7{,}16\ \Delta^{1/6}$

where

V : Maximum ahead service speed V, in knots, at displacement Δ defined below

Δ : Moulded displacement, in tons, in full load condition “end of life”.

Offshore patrol vessels complying with the above criteria are considered High speed.

Offshore patrol vessels not complying with the above high speed criteria are considered Slow speed.

2 Double bottoms

2.1 General

2.1.1 A double bottom is to be fitted extending from the collision bulkhead to the after peak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

2.1.2 Any part of a naval ship not fitted with a double bottom in accordance with [2.1.1] shall be capable of withstanding bottom damages as specified in [2.1.3].

2.1.3 Compliance with [2.1.2] is to be achieved by demonstrating that, for the loading conditions defined in Pt B, Ch 1, Sec 2, [5.2] to Pt B, Ch 1, Sec 2, [5.4], when the ship is subjected to a bottom damage assumed to be at any position along the bottom with an extent specified in Tab 2 for the affected part of the ship:

- the GZmax is greater than or equal to 0,12m
- the range is greater than or equal to 16°, and
- the heel at the equilibrium is less than or equal to 15°.

Table 2 : Bottom damage extent

Longitudinal extent	1/3 $L^{2/3}$
Transverse extent	B/6
Vertical extent measured from the keel line	B/20 with a minimum of 760 mm

3 Doors in watertight bulkheads

3.1 Application

3.1.1 In case of ships where a single deck acts as watertight deck as defined in Pt B, Ch 1, Sec 2, [6.4] and as bulkhead deck as defined in Pt B, Ch 1, Sec 2, [6.2], the requirements of [3.2] apply.

3.1.2 For ships with a watertight deck and a bulkhead deck, the requirement of Pt B, Ch 2, Sec 1, [6] are applicable.

3.2 Doors below the watertight deck

3.2.1 General

Doors provided to ensure the watertight integrity of internal openings which are normally closed at sea are to be sliding watertight doors capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the control position showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular attention is to be paid to minimise the effect of control system failure. Each power-operated sliding watertight door is to be provided with an individual hand-operated mechanism.

If indicated in the specification, hinged watertight doors may be accepted in lieu of watertight sliding doors. Those hinged watertight doors are to be fitted with open/closed/locked indicators locally and at the wheelhouse and a notice on both sides to indicate that these doors are to be kept closed at sea (open for the passage and immediately closed after).

3.2.2 Openings permanently kept closed at sea

Doors provided to ensure the watertight integrity of internal openings which are kept permanently closed at sea may be hinged watertight doors. They are to be provided with a notice which is to be affixed to each such closing appliance to the effect that it is to be kept closed. Manholes fitted with closely bolted covers need not be so marked.

Section 2 Hull and Stability

Symbols

For symbols not defined in this Section, refer to the list at the beginning of this Chapter.

1 General

1.1 Application

1.1.1 The provisions of this Section apply to the ships having the service notation **military OPV**.

1.1.2 The requirements for structure of ships built in composites are to be defined on a case-by-case basis.

1.1.3 The applicable requirements are given in Ch 6, Sec 1, Tab 1.

1.1.4 If applicable, the additional requirements given in Articles [2] and [3] are also to be complied with.

2 Stability

2.1 General

2.1.1 Offshore patrol vessels may be assigned the service notation **military OPV** only after it has been demonstrated that their stability is adequate.

Adequate stability means compliance with standard laid down by the relevant Naval Authority or with the requirements specified in this Section.

In any case, the level of stability is not to be less than that provided by the Rules.

2.2 Intact stability

2.2.1 Regarding intact stability, ships granted with the service notation **military OPV** are to comply with:

- NR566, Ch 1, Sec 3, [2] for ships with length less than 60 m
- Pt B, Ch 3, Sec 2 for ships with length greater than or equal to 60 m.

2.3 Damage stability

2.3.1 Regarding damage stability, ships granted with the service notation **military OPV** are to comply with:

- NR566, Ch 1, Sec 3, [3] as applicable to cargo ships, for ships with length less than 60 m
- Pt B, Ch 3, Sec 3 for ships with length greater than or equal to 60 m.

3 Structure

3.1 Structure in way of weapons systems - All vessels

3.1.1 The weapons firing dynamic loads are to be taken according to Pt B, Ch 5, Sec 6, [9].

3.1.2 The requirements for plating in way of weapon systems are given in Pt B, Ch 7, Sec 1, [2], Pt B, Ch 7, Sec 1, [3] and Pt B, Ch 7, Sec 1, [5], as applicable.

3.1.3 The requirements for ordinary stiffeners in way of weapon systems are given in Pt B, Ch 7, Sec 1, [2] and Pt B, Ch 7, Sec 1, [4], as applicable.

3.1.4 The requirements for primary supporting members in way of weapon systems are given in Pt B, Ch 7, Sec 3 and Pt B, Ch 7, Sec 1, [2], as applicable.

3.2 Aft ramp - All vessels

3.2.1 Plating of the aft ramp and the lower part of the aft ramp side

The gross thickness of plating of the aft ramp and the lower part of the aft ramp side is to be increased with respect to that calculated according to Ch 6, Sec 1, Tab 1, for side plating with the same plate panel dimensions.

The gross thickness addition is to be taken not less than:

- 1 mm for steel material
- 2 mm for aluminium alloy material.

3.2.2 Plating of the upper part of the aft ramp side

The thickness of plating of the upper part of the aft ramp side is to be not less than the value calculated according to Ch 6, Sec 1, Tab 1 for side plating with the same plate panel dimensions.

3.3 Deck structure in way of launching appliances used for special force craft - All vessels

3.3.1 The scantlings of deck secondary stiffeners and primary supporting members are to be determined by direct calculations.

3.3.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

3.3.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/(2,2\ \varphi)$ and $R_m/(4,5\ \varphi)$,

where:

R_{eH} : Minimum yield stress of the primary supporting member material, in N/mm². For aluminium structure, welded condition has to be considered

R_m : Ultimate minimum tensile strength of the primary supporting member material, in N/mm². For aluminium structure, welded condition has to be considered

φ : Dynamic safety factor, to be taken equal to:

- 1,0 if the special force craft is intended for launching with mother ship ahead speed of 5 knots and in calm water
- the value to be specified by the Designer if the special force craft is intended for launching with mother ship speed more than 5 knots or in severe sea condition. This value is not to be less than 1,1.

3.4 Vessels with length more than 24 m and less than 60 m

3.4.1 Applicable Rules

Unless otherwise specified in this Section, the requirements of Part B are applicable.

In addition, for High speed ships as defined in Ch 6, Sec 1, [1.2.1], the requirements of Ch 3, Sec 2 are applicable.

3.4.2 Hull girders loads

The requirements of Pt B, Ch 5, Sec 2 are to be applied, considering:

$C = (118 - 0{,}36\ L)\ L / 1000$

3.4.3 Flooding loads

The requirements of Pt B, Ch 5, Sec 6 are to be applied, with:

d_0 : Distance, in m, to be taken equal to:

$d_0 = 1{,}3$ m.

3.5 Vessels with length less than or equal to 24 m

3.5.1 Applicable Rules

Unless otherwise specified in this Section, the requirements of Part B are applicable, with the exception of Part B, Chapter 6.

In addition, for High speed ships as defined in Ch 6, Sec 1, [1.2.1], the requirements of Ch 3, Sec 2 are applicable.

3.5.2 Hull girders loads

The requirements of Pt B, Ch 5, Sec 2 are to be applied, considering:

$C = (118 - 0{,}36\ L)\ L / 1000$

3.5.3 Flooding loads

The requirements of Pt B, Ch 5, Sec 6 are to be applied, with:

d_0 : Distance, in m, to be taken equal to:$d_0 = 1{,}3$m.

3.5.4 Hull scantlings

The requirements of Part B, Chapter 7 and Part B, Chapter 8 are to be applied, with:

σ_{x1} : In-plane hull girder normal stress, in N/mm^2:$\sigma_{x1} = 0$

τ_1 : In-plane hull girder shear stress, in N/mm^2:$\tau_1 = 0$

R_y : Minimum yield stress of the material, in N/mm^2, to be taken equal to:

$R_y = \gamma_{x1}\ 235 / k$

with γ_{x1} as defined in Tab 1.

Table 1 : Coefficient γ_{x1}

Element	γ_{x1}
Plates contributing to the hull girder strength	0,95
Secondary stiffeners or primary supporting members contributing to the hull girder strength	0,90
Elements not contributing to the hull girder strength	1,00

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1 The provisions of this Section apply to ships having the service notation **military OPV**.

1.1.2 The applicable requirements are given in Ch 6, Sec 1, Tab 1.

2 Additional requirements for OPV with length less than 60 m

2.1 Prevention of progressive flooding

2.1.1 Requirements of Pt C, Ch 1, Sec 10, [5.5] apply.

2.2 Bilge pumping arrangement

2.2.1 Pt C, Ch 1, Sec 10, [6] is to be applied instead of NR566, Ch 2, Sec 5, [1], unless otherwise specified in [2.2.2] and [2.2.3].

2.2.2 An oily bilge water draining system is not required.
Therefore, offshore patrol vessels of length less than 60 m are not to comply with the following requirements:

- Pt C, Ch 1, Sec 10, [6.2.1], item a)
- Pt C, Ch 1, Sec 10, [6.2.2], item c)
- Pt C, Ch 1, Sec 10, [6.5.4]
- Pt C, Ch 1, Sec 10, [6.6.1], item a)
- Pt C, Ch 1, Sec 10, [6.6.3], item a)
- Pt C, Ch 1, Sec 10, [6.7.1].

2.2.3 At least two bilge suctions are to be provided for draining the propulsion engine room. At least one of the suction is to be connected directly to a bilge pump.

2.3 Capacity of fuel oil service tanks

2.3.1 Pt C, Ch 1, Sec 10, [11.9.2] is to be applied instead of NR566, Ch 2, Sec 6, [4.2.2].

Section 4 Electrical Installations and automation

1 General

1.1 Application

1.1.1 The provisions of this Section apply to ships granted with the service notation **military OPV** and with a length greater than or equal to 60 m. These requirements are additional to those of Part C, Chapter 2 and Part C, Chapter 3.

1.1.2 The text “at every muster station” in Pt C, Ch 2, Sec 3, [3.5.3], item a) is to be replaced by “at main and emergency evacuation stations, as defined in Ch 3, Sec 5, [1.2.1] and Ch 3, Sec 5, [1.2.2]”.

Section 5 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships granted with the service notation **military OPV** and having a length less than 60 m.

1.1.2 Applicable Rules

Ships dealt with in this Section are to comply with the Rules stipulated in Ch 6, Sec 1, Tab 1, according to the length of the ship. The requirements of this Section are to be applied in addition.

1.2 Definitions

1.2.1 Control stations

For the application of this Section, the definition given in NR566, Ch 4, Sec 1, [4.4.8] is to be completed by:

"Rooms containing naval systems, as detection, command or weapon control operating room, except technical spaces not normally manned, are to be categorized as control stations.

Spaces containing network cabinets for computer and control centers, electronic cabinet systems or control computers managing data related to the control of the ship.

Spaces containing the ship's radio equipment for safety or ship navigation communication are to be categorized as control stations. Spaces containing radio equipment for other purposes need not be categorized as control stations."

1.2.2 Open deck

For the application of this Section, the definition of category (10) given in NR566, Ch 4, Sec 4, [2.2.2], item b), 2) is to be completed by:

"Open deck spaces for the stowage of any embarkation such as tender or special force craft".

1.2.3 Evacuation stations

The evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

1.2.4 Machinery spaces

For the application of this Section, the definition given in NR566, Ch 4, Sec 1, [4.4.15] is to be completed by:

"The spaces containing naval systems, not normally manned, are to be considered as machinery spaces".

1.2.5 Ammunition spaces

Ammunition spaces are defined in Pt C, Ch 4, Sec 1, [2.4].

Note 1: The ready for use lockers located on open deck may be not considered as ammunition spaces.

2 Suppression of fire

2.1 Detection and alarm

2.1.1 Protection of ammunition spaces

Ammunition spaces are to be provided with a fixed fire detection and alarm system complying with the requirements of Pt C, Ch 4, Sec 3, [5].

When the required smoke detector cannot be contained into the ammunition lockers, this detector is to be installed into the space where the ammunition lockers are located.

2.2 Fire containment

2.2.1 Space categorisation

When the mast contains one radio or a navigation equipment as required by SOLAS or by the Naval Authority, including the one for flight assistance, it is to be categorized as control station.

2.2.2 Fire integrity of ammunition spaces

The bulkheads and decks of ammunition spaces are to be insulated to A-30 standard. Fire insulation for the boundaries of ammunition spaces is to be installed outside of the ammunition spaces as much as possible.

When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only A-0 standard is required.

2.2.3 Ventilation systems

a) Ventilation systems intended to be used during normal operation are to comply with the requirements of NR566, Ch 4, Sec 4, [5] and with the applicable requirements of the present Sub-Article.

   These requirements are not intended to apply to alternative configurations used solely in casualty situations. In any case, arrangements intended for use solely in casualty situations are not to impair compliance of the ventilation systems intended for normal operation with the requirements of NR566, Ch 4, Sec 4, [5] and with the applicable requirements of the present sub-article.

b) For ships provided with CBRN protection, parts of the ventilation system not fully complying with the requirements NR566, Ch 4, Sec 4, [5] and with those of the present sub-article may be accepted provided that:
   - they are used solely during CBRN operation, and suitably marked to this end, and
   - they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and
   - the ventilation system in use during normal operation is fully compliant with the requirements of the present Article, and
   - suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 3, [2] for ships to be assigned the **CBRN** additional class notation.

2.2.4 Ventilation systems for ammunition spaces

The ventilation systems serving ammunition spaces shall be separated from the ventilation systems serving other types of space. No ventilation duct shall pass through any ammunition space except the ducts provided for the ventilation of this ammunition space. Torpedo magazines shall be provided with a dedicated ventilation system capable of being stopped locally.

Note 1: If a common duct serves several ammunition spaces, this common duct is to be located outside the served spaces.

Ducts provided for the ventilation of ammunition spaces shall not pass through other spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

The capacity of the ventilation systems serving ammunition spaces are to comply with the requirement of Pt C, Ch 4, Sec 5, [6.7.1].

2.2.5 Fuel oil with a flashpoint less than 43°C

Use and storage of fuel oil having a flash point less than 43°C may be accepted only for special force craft or unmanned aircraft, as per arrangement specially reviewed by the Society.

The aggregate quantity on board of such fuel oil is to be as low as possible and properly justified.

2.3 Fire fighting

2.3.1 Fixed fire-extinguishing systems in ammunition spaces

Ammunition spaces are to be provided with a fixed fire-extinguishing system complying with the requirements of Pt C, Ch 4, Sec 6, [6.1.1].

2.3.2 Fire-fighter outfits

The ship is to be provided with at least four fire-fighter outfits with a minimum of two two-way portable radiotelephone apparatuses for communication between fire-fighters. Those two-way portable radiotelephone apparatuses are to be of an explosion proof type and intrinsically safe.

Fire-fighter outfits are to comply with Pt C, Ch 4, Sec 6, [8.1]

Fire-fighter outfits are to be stored so as to be easily accessible and ready for use, in at least two separated locations.

2.3.3 Fire pumps

The requirement of NR566, Ch 4, Sec 5, [2.2.1] and Ch 4, Sec 5, [2.2.3] are to be replaced by the following provisions:

a) The total capacity of the fire pumps is to be sufficient to supply simultaneously two hydrants and the most demanding fire-fighting system using the fire main.

b) At least two independently powered fixed fire pumps are to be provided. The arrangement of sea connections, pumps and their sources of power is to be such as to ensure, in the event of a fire in any one compartment, that all the fire pumps will not be put out of actions.

2.3.4 International shore connection

At least one international shore connection complying with Pt C, Ch 4, Sec 6, [1.2.7] is to be provided.

3 Escape and circulation

3.1 Application

3.1.1 Limitation

The requirements of [3.2] are applicable for the ships with a maximum complement of less than 60 persons.

Special consideration is to be given by the Society to ships carrying more than 60 persons.

3.2 Means of escape from control stations, accommodation spaces and service spaces

3.2.1 Escape from spaces below the bulkhead deck

The requirements of NR566, Ch 4, Sec 6, [4.1.1] are to be completed by the following provisions:

"At least one of the means of escape from accommodations and service spaces below the open deck is to be a stairway sized as per [3.2.2]".

3.2.2 Details of stairways, ladders and deck hatches

The minimum net width of a stairway between its handrails is to be 560 mm and of a ladder between its vertical main frames is to be 300 mm.

Stairways are inclined ladders having an angle not more than 70° from the horizontal.

In addition, consideration is to be given to the minimum net free passage in order that a fire-fighter with his complete equipment or an injured person on a stretcher can easily pass through a deck hatch.

3.2.3 Detail of passageways

The minimum net width (as defined in Pt C, Ch 4, Sec 8, [4.1.1]) of a bulkhead hatch or a doorway is to be 700 mm.

3.2.4 Evacuation station

At least one evacuation station as defined in [1.2.3] is to be provided and have a clear deck of 0,35m^2 per person.

Part D
Service Notations

CHAPTER 7
LANDING CRAFTS

Section 1 General

Section 2 Hull and Stability

Section 3 Machinery and Systems

Section 4 Fire Protection

Section 1 General

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the service notation **landing craft** as defined in Pt A, Ch 1, Sec 2, [4.8].

1.1.2 The applicable set of requirements are governed by each of the following main characteristics:

- ship is able to be docked inside the well dock of a mother ship
- rule length
- high speed criteria
- hull material.

Ships not designed to be berthed aboard a mothership are not covered by the notation **landing craft**.

Ships with rule length equal or more than 60m are not covered by the notation **landing craft**.

1.1.3 Ships dealt with in this Chapter are to comply with:

- Part A
- NR216 Materials and Welding, as applicable.
- the applicable requirements according to Tab 1

Table 1 : Applicable requirements

Item	Reference
Ship arrangement	• Article [2] • NR566 **(1)**
Hull	• Ch 7, Sec 2
Stability	• Ch 7, Sec 2
Machinery and systems	• NR 566, Ch 2 **(1)** • Ch 7, Sec 3
Electrical installations and automation	• NR566, Ch 3 **(1)**
Fire protection, detection and extinction	• NR 566, Ch 4 **(1)** • Ch 7, Sec 4
(1) Relevant requirements to be applied, except the specific requirements for passenger ships not to be taken into account. **Note 1:** NR566: Hull Arrangement, Stability and Systems for Ships less than 500 GT.	

2 Specific characteristics of landing crafts

2.1 Capacity to dock on the well deck of a mother ship

2.1.1 Overall dimensions of ship

Overall dimensions of ship shall be clearly mentioned in the drawings submitted. If the ship is fitted with retractable devices used when moving inside or outside a mothership, overall dimensions in these configurations shall also be clearly mentioned on drawings. When the mothership is already known and the limits for overall dimensions of the landing craft are mentioned inside the request for classification, these values can be compared to those mentioned on drawings and their validity assessed by the optional mention **-MOTHERSHIP(name of mother ship class)**.

2.1.2 Hull and appendices

Geometry of hull and appendices shall enable the docking of the ship on a plane surface without damaging any pieces of equipment or part of the ship structure. When docked, the ship shall be able to stay in a stable position without using any additional artefact.

2.1.3 Lashing

Securing points shall be arranged on the ship structure in order to keep the ship in a steady position thanks to securing devices when berthed inside the mother ship well deck.

2.2 Capacity to operate landing operations

2.2.1 Structure of ship adapted to landing operation

Bottom area is to be reinforced in beaching area according to Ch 7, Sec 2, [3.3].

In addition, the transom area might have to be reinforced against breaking waves in the surf zone, according to Ch 7, Sec 2, [3.3].

2.2.2 Ramp operation

In the present Chapter, it is considered that the bow ramp and the bow door are same equipment.

2.2.3 Capacity of ship to maintain herself in a steady position during landing operation

Means shall be available to keep ship on a steady position during landing operation. One or several of the following technical solutions shall be used:

- stern anchor(s)
- means of propulsion offering possibility to modify quickly direction of thrust when the speed of ship is equal to zero
- other solution with equivalent result.

2.2.4 Capacity to deliver on shore troops and equipment

Scantlings of external ramps are to comply with requirement of Ch 7, Sec 2, [3.2].

2.2.5 Capacity to maintain ship power production during landing operation

Specific requirements of Ch 7, Sec 3 are to be fulfilled.

2.2.6 Capacity to leave the beaching position after landing operation

Leaving beaching position, so-called de-beaching in the present Rules, could be achieved by several means (self-propulsion, push-out from the beach, pull-out from the craft, etc.), that must be formally defined and given as operating procedures, according to [2.3.1].

Specific requirements are to be complied with, according to Ch 7, Sec 2, [3.4].

2.3 Safe operation limits

2.3.1 Operating manual

Operation must be defined in an Operating Manual detailing the operating procedures and the limitations for safe operation.

This Operating Manual must be provided to the Society for information.

This Operating Manual should be also made available on board.

Section 2 Hull and Stability

1 General

1.1 Application

1.1.1 The provisions of this Section apply to the ships having the service notation **landing craft**.

2 Stability

2.1 General

2.1.1 Considered vessels may be assigned the service notation **landing craft** only after it has been demonstrated that their stability is adequate.

Adequate stability means compliance with standard laid down by the relevant Naval Authority or with the requirements specified in this Section.

In any case, the level of stability is not to be less than that provided by the Rules.

2.1.2 High speed criteria

Landing crafts are considered complying with the high speed criteria when the following condition is fulfilled:

$V \geq 7{,}16\ \Delta^{1/6}$

where

V : Maximum ahead service speed V, in knots, at displacement Δ defined below

Δ : Moulded displacement, in tons, in full load condition “end of life”.

Landing crafts complying with the above criteria are considered high speed.

Landing crafts not complying with the above high speed criteria are considered slow speed.

2.2 Intact stability

2.2.1 The intact stability is to comply with the provisions of NR467, Part B, Chapter 3 for the loading conditions mentioned in [2.2.2], except when specified otherwise.

2.2.2 The following loading conditions have to be considered for the purpose of the stability calculations:

- ship in the fully loaded departure condition with the maximum weight of cargo and embarked troops homogeneously distributed on the dedicated spaces, with full fuel
- ship in the light arrival condition without cargo nor embarked troops, with 10% remaining fuel

2.2.3 Ice accretion

For the purpose of calculating the ice accretion, when applicable, the following values are to be used:

- 15 kg/m^2 on exposed weather decks and gangways
- 7,5 kg/m^2 for the projected lateral area on each side of the ship above the waterplane.

2.2.4 Cargo Space

For landing craft with open cargo space, the drainage system has to comply with the applicable requirements of regulation 24, paragraphs 1(b), 1(c), (4) to (6) of the International Load Line Convention, as modified by the Protocol. Alternatively, an additional amount of water equal to 0,10m above the cargo deck is to be considered for the intact stability calculations.

For landing craft with closed cargo space and fitted with a single bow door creating a possible entry of water, the stability of the ship has to be evaluated with an additional amount of seawater on the cargo deck, having a height equal to 0,30m. For this condition, the following stability criteria are to be complied with:

- the positive righting lever curve should have a minimum range of 7° beyond the angle of equilibrium
- the metacentric height (GM) should be positive
- the righting lever (GZ) is to be at least 0.05 m within the positive range.

The results of model tests may be used to determine the quantity of green water to be considered in the above calculations for open or closed cargo space, associated with a quantity of rainfall equal to 100 mm/hour.

2.3 Damage stability

2.3.1 Taking into account as initial conditions before flooding, the loading conditions defined in [2.2.2], the ship is to comply with the damage stability criteria as specified in [2.3.8], for the damage dimensions defined in [2.3.2].

2.3.2 The extent of damage is assumed to occur anywhere:

a) for side damage: on the ship's length between watertight transverse bulkheads spaced at a distance of not less than the longitudinal extent of damage specified in Tab 1

b) for bottom damage: for 0,3L from the forward perpendicular of the ship, between watertight transverse bulkheads spaced at a distance of not less than the longitudinal extent of damage specified in Tab 1.

High speed landing craft (as defined in [2.1.2]) are to consider that the damage occur anywhere along the ship's length.

Table 1 : Extent of damage

	Longitudinal extent	Transverse extent	Vertical extent
Side damage	3 + 3% L	B/5**(1)**	Full depth**(2)**
Bottom damage (For 0,3 L from the forward perpendicular of the ship)	1/3 $L^{2/3}$	B/6	B/12
(1) Measured inboard from the side of the ship perpendicularly to the centerline at the level of the summer waterline. **(2)** From the moulded line of the bottom shell plating at centerline upwards without limit.			

2.3.3 If pipes, ducts trunks or tunnels are situated within the assumed extent of damage, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be floodable for each case of damage.

2.3.4 If damage of a lesser extent than that specified in [2.3.2] results in a more severe condition, such lesser extent is to be assumed.

2.3.5 The permeability of spaces assumed to be damaged is to be as indicated in Tab 2.

Table 2 : Values of permeability

Spaces	Permeabilities
Appropriated to cargo	by calculation but not less than 0,60
Appropriated to stores	0,60
Occupied by accommodation	0,95
Occupied by machinery	0,85
Void spaces, empty tanks	0,95
Intended for liquids	0 to 0,95**(1)**
(1) See [2.3.6].	

2.3.6 The permeability of partially filled compartments shall be consistent with the amount of liquid carried in the compartment. Whenever damage penetrates a tank containing liquids, it shall be assumed that the contents are completely lost from that compartment and replaced by salt water up to the level of the final plane of equilibrium.

2.3.7 Compliance with the requirements of [2.3.8] is to be confirmed by calculations which take into consideration the design characteristics of the ship, the arrangements, configuration and permeability of the damaged compartments and the distribution, specific gravities and free surface effect of liquids.

2.3.8 Ships are to be capable of surviving the assumed damage and the standard specified in [2.3.2], for the loading conditions defined in [2.2.2] in a condition of stable equilibrium and such as to satisfy the following criteria:

a) The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings include air-pipes, ventilators and openings which are closed by means of weathertight doors or hatch covers but may exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors and sidescuttles of the non-opening type.

b) In the final stage of flooding, the angle of heel due to unsymmetrical flooding should not exceed 7° when the cargo is not lashed with arrangements capable of preventing any shifting, and 15° otherwise.

c) The initial metacentric height of the ship in the final stage of flooding for the static equilibrium position in case of symmetrical flooding and for the upright position in case of unsymmetrical flooding as calculated by constant displacement method should not be less than 0,05 m before appropriate measures to increase the metacentric height have been taken.

d) The righting lever curve at the final stage of flooding should have a minimum range of 10° associated with a maximum righting equal or greater to the maximum between:

- 0,05m
- heeling moment / displacement, where heeling moment is the moment due to the crowding of the embarked troops after damage.

  For the purpose of calculating the heeling moment of crowding of embarked troops, the following assumptions shall be made:
  - 4 persons per square meter
  - a mass of 90kg for each person.
  - the persons shall be distributed on the available spaces in such away that they produce the most adverse heeling moment.

Unprotected openings may not become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in item a), and any other openings capable of being closed weathertight may be authorised.

e) The stability is to be sufficient during the intermediate stages of flooding. In this regard the Society applies the same criteria relevant to the final stage of flooding also during the intermediate stages of flooding.

3 Structure

3.1 General

3.1.1 Applicable Rules

Unless otherwise specified in this Section, the landing craft structure is to meet the relevant requirements of NR600, except NR600, Ch 2, Sec 2.

Note 1: NR600 Hull Structure and Arrangement for the Classification of Cargo Ships less than 65 m and Non Cargo Ships less than 90 m.

3.1.2 The navigation coefficient n which appears in the formulae of NR600 are defined in Tab 3 depending on the assigned navigation notation.

Table 3 : Navigation coefficient n

Navigation notation	Navigation coefficient n
unrestricted navigation	1,00
coastal area	0,80
sheltered area	0,65

3.2 Additional requirements for external ramps

3.2.1 General

It is assumed that the ramps are not lifted with vehicles on the ramp.

The external ramps are to be able to operate with a heel angle of 5° and a trim angle of 2°.

The thicknesses of plating and the scantlings of ordinary stiffeners and primary supporting members are to be determined:

- under vehicle loads in harbour condition, at rest, as defined in NR600, Ch 5, Sec 2, Tab 1
- under sea pressure, and slamming pressure if relevant, in lifted position and locked at sea.

The locking of external ramps in lifted position at sea is examined by the Society on a case by case basis.

The ship’s structure under the reactions due to the ramp is examined by the Society on a case by case basis, under vehicle loads and under sea pressure.

Internal loads exerted on ramps in lifted position at sea are to specified by the designer.

3.2.2 Plating

The gross thickness of plate panels subjected to wheeled loads is to be not less than the value obtained from NR600, Ch 4, Sec 3.

However, minimum net thicknesses are to comply with Pt B, Ch 7, Sec 1, [2.2.1].

3.2.3 Ordinary stiffeners

The gross section modulus and the gross shear sectional area of ordinary stiffeners subjected to wheeled loads is to be not less than the value obtained from NR600, Ch 4, Sec 4.

3.2.4 Primary supporting members

The primary supporting structure of external ramps is to be verified through direct calculation, considering the following cases:.

- ramp in sloped position, supported by hinges at one end and by supporting ground or mother ship at the other, under loads defined in NR600, Ch 5, Sec 2, Tab 1, in harbour condition
- ramp in lifted position, loaded by relevant loads and locked, at sea.

It is to be checked that the stresses are in accordance with the criteria defined in NR600, Ch 2, Sec 3.

3.2.5 Locking devices

It is to be checked that the combined stresses σ_{VM} in rigid supports and locking devices are in accordance with the criteria defined in NR600, Chapter 2, Section 3.

3.2.6 Tests and trials

The watertightness / weathertightness is to be tested as per applicable requirements of NR600.

The weathertightness of the bow door is to be confirmed at each renewal survey by a hose test. In addition, for watertight bow door, a specific survey is requested at each annual survey, to confirm that the proper locking and tightness are maintained.

3.3 Additional requirements for landing operations - Beaching

3.3.1 A beaching reinforced area is to be considered at bottom level on a length to be defined by the Designer measured from fore end. In any case, this length should not be less than 0,3 L.

3.3.2 Bottom beaching pressure, in kN/m², is to be calculated as per following formula:

$$P_{beach} = (3,3 \cdot \Delta)/(L \cdot b)$$

with:

Δ : full load displacement, in t, at end of life

b : mean transversal dimension of horizontal bottom, in m, in 0,3L forward area.

3.3.3 Bottom plating t, in mm, in beaching reinforced area is to be calculated as follows:

$$t = \max(1{,}2 \cdot t_1, 8)$$

with:

t_1 : Thickness, in mm, calculated according NR600, Ch 4, Sec 3, with p = P_{beach}

3.3.4 Bottom secondary stiffeners in beaching reinforced area are calculated according to requirements of NR600, Ch 4, Sec 4, with p = P_{beach}

3.3.5 Bottom primary supporting members in beaching reinforced area are calculated according to requirements of NR600, Ch 4, Sec 5, with p = P_{beach}

3.3.6 All fillet welds of bottom structure in beaching area are to be double continuous.

3.3.7 If waves are likely to break on the transom, the structural design of the transom is to be reinforced adequately to support this breaking wave pressure. In such case, the design breaking wave pressure is to be specified by the Designer, without being taken less than 50 kN/m².

3.4 Additional requirements for landing operations - De-beaching

3.4.1 The maximum de-beaching force F_{DB}, in kN, is to be defined according to the Operating Manual mentioned in (Chap 7, Sec 1, [2.3]). In case F_{DB} is not mentioned in the Operating Manual, this force is to be taken equal to 5Δ, with Δ, in t, being the full load displacement at end of life.

3.4.2 When de-beaching is operated by pushing out the landing craft from the beach (e.g. by tractors or bulldozers), the craft structure must be suitably reinforced in way of push-out force application.

The maximum push-out force is to be according to the Operating Manual mentioned in (Ch 7, Sec 1, [2.3]). In case the maximum push-out force is not mentioned in the Operating Manual, this force, in kN, is to be taken as F_{DB}, defined in [3.4.1].

3.4.3 When de-beaching is operated by pulling out the landing craft from aboard (e.g. by pull-out anchors), the craft structure must be suitably reinforced in way of winch foundations and bollards sustaining the pull-out force and the winches must be designed to deliver the pull-out force.

The maximum pull-out force is to be according to the Operating Manual mentioned in (Ch 7, Sec 1, [2.3]). In case the maximum pull-out force is not mentioned in the Operating Manual, this force, in kN, is to be taken as F_{DB}, defined in [3.4.1].

3.5 Anchoring, mooring and towing equipment

3.5.1 The anchoring capability, the mooring capability and the towing capability is left to the decision of the Naval Authority.

3.5.2 If anchors are used to pull-out the craft during de-beaching operation, the complete mooring line should be designed with a safety factor of 6 with respect to F_{DB} as defined in [3.4.1].

3.5.3 If anchoring capability is requested, equipment in anchors and chain cables is to be in compliance with NR600, Ch 5, Sec 5.

3.5.4 If mooring or towing capability is requested, corresponding equipment is to be in compliance with NR600, Ch 5, Sec 5.

3.6 Cargo lashing - securing points

3.6.1 Where cargo is secured by lashing devices, following requirements [3.6.2] to [3.6.6] are applicable.

3.6.2 Securing points are to be listed in the Operating Manual mentioned in Ch 7, Sec 1, [2.3], together with indications of Safe Working Load (SWL) and Maximum Securing Load (MSL).

3.6.3 Design of securing points, integration into craft structure and mini-maxi pulling angles are to be submitted for review.

3.6.4 Strength of lashings is outside scope of Classification.

3.6.5 checking criteria

It is to be checked that the equivalent stress σ_{VM} , in N/mm², induced by the pulling force SWL in the worse possible direction, is in compliance with the following formula:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma_{VM}$$

where:

R_y	:	Minimum yield stress, in N/mm², of the material to be taken equal to 235/k N/mm², unless otherwise specified
k	:	Material factor, defined in Pt B, Ch 4, Sec 1, [2.3] or Pt B, Ch 4, Sec 1, [4.4] as applicable
γ_R	:	1,2
γ_m	:	1,02

3.6.6 It is recommended to:

- avoid out of plane loading on stiffening members
- align welded attachments to decks and bulkheads with stiffeners by using a weld area suitable for load considered
- design eyeplates, lugs, etc. in accordance with recognized national or international standards suitable for considered MSL.

Section 3 Machinery and Systems

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships granted with the service notation **landing craft**.

2 Availability of energy and propulsion power means of production during landing operations

2.1

2.1.1 Protection of equipment against grounding

Equipment like propellers, thrusters involved shall be fitted with physical protection against grounding.

2.1.2 Protection and position of air inlets dedicated to means of propulsion and energy production and ventilation openings for machinery spaces

a) air inlets and ventilation openings dedicated to machinery installations shall be protected against water ingress coming from waves impacting the aft part of the ship

b) air inlets and ventilation openings dedicated to machinery installations should normally not be located on the aft part of the ship.

2.1.3 Availability of means of cooling

Sea inlets and outlets shall not be located on the fore part of the ship.

2.1.4 Availability of exhaust gas piping systems

Accumulation of water through water ingress coming from waves impacting the aft part of the ship should not be possible whenever the engines were in operation or not during landing operations.

Section 4 Fire Protection

1 General

1.1 Application

1.1.1 Unless otherwise specified, the provisions of this Section apply to the ships granted with the service notation **landing craft**.

1.2 Definitions

1.2.1 Control stations

For the application of this Section, the definition given in NR566, Ch 4, Sec 1, [4.4.8] is to be completed by:

"Rooms containing naval systems, as detection, command or weapon control operating room, except technical spaces not normally manned, are to be categorized as control stations".

1.2.2 Open deck

For the application of this Section, the definition of category (10) given in NR566, Ch 4, Sec 4, [2.2.2], item b), 2) is to be completed by:

"Open deck spaces for the stowage of any embarkation such as tender or special force craft".

1.2.3 Evacuation stations

The evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

1.2.4 Machinery spaces

For the application of this Section, the definition given in NR566, Ch 4, Sec 1, [4.4.15] is to be completed by:

"The spaces containing naval systems, not normally manned, are to be considered as machinery spaces".

1.2.5 Ammunition spaces

Ammunition spaces are defined in Pt C, Ch 4, Sec 1, [2.4].

Note 1: The ready for use lockers located on open deck may be not considered as ammunition spaces.

2 Suppression of fire

2.1 Detection and alarm

2.1.1 Protection of ammunition spaces

Ammunition spaces are to be provided with a fixed fire detection and fire alarm system complying with the requirements of Pt C, Ch 4, Sec 3, [5].

When the required smoke detector cannot be contained into the ammunition lockers, this detector is to be installed into the space where the ammunition lockers are located.

2.2 Fire containment

2.2.1 Fire integrity of ammunition spaces

The bulkheads and decks of ammunition spaces are to be insulated to A-30 standard. Fire insulation for the boundaries of ammunition spaces is to be installed outside of the ammunition spaces as much as possible.

When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only A-0 standard is required.

2.2.2 Ventilation systems

a) Ventilation systems intended to be used during normal operation are to comply with the requirements of NR566, Ch 4, Sec 4, [5] and with the applicable requirements of the present sub-article.

   These requirements are not intended to apply to alternative configurations used solely in casualty situations. In any case, arrangements intended for use solely in casualty situations are not to impair compliance of the ventilation systems intended for normal operation with the requirements of NR566, Ch 4, Sec 4, [5] and with the applicable requirements of the present sub-article.

b) For ships provided with CBRN protection, parts of the ventilation system not fully complying with the requirements NR566, Ch 4, Sec 4, [5] and with those of the present sub-article may be accepted provided that:

- they are used solely during CBRN operation, and suitably marked to this end, and
- they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and
- the ventilation system in use during normal operation is fully compliant with the requirements of the present Sub-article, and
- suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 3, [2] for ships to be assigned the **CBRN** additional class notation.

2.2.3 Ventilation systems for ammunition spaces

Ventilation systems of ammunition spaces are to comply with the following provisions:

a) ventilation systems for ammunition spaces are to be independent of the systems serving other categories of spaces

b) no duct is to pass through any ammunition space, except the ducts provided for the ventilation of this ammunition space

c) capacity of the ventilation systems serving ammunition spaces are to comply with the requirement of Pt C, Ch 4, Sec 5, [6.7.1]

d) ducts provided for the ventilation of ammunition spaces, when passing through any other spaces, are to be constructed of steel and arranged to preserve the integrity of the division.

2.3 Fire fighting

2.3.1 Fixed fire-extinguishing systems in ammunition spaces

Ammunition spaces are to be provided with a fixed fire-extinguishing system complying with the requirements of Pt C, Ch 4, Sec 6, [6.1.1].

2.3.2 Fire-fighter outfits

The ship is to be provided with at least four fire-fighter outfits with a minimum of two two-way portable radiotelephone apparatuses for communication between fire-fighters. Those two-way portable radiotelephone apparatuses are to be of an explosion proof type and intrinsically safe.f

Fire-fighter outfits are to comply with Pt C, Ch 4, Sec 6, [8.1].

Fire-fighter outfits are to be stored so as to be easily accessible and ready for use, in at least two separated locations.

2.3.3 Fire pumps

The requirement of NR566, Ch 4, Sec 5, [2.2.1] and Ch 4, Sec 5, [2.2.3] are to be replaced by the following provisions:

a) the total capacity of the fire pumps is to be sufficient to supply simultaneously two hydrants and the most demanding fire-fighting system using the fire main

b) at least two independently powered fixed fire pumps are to be provided. The arrangement of sea connections, pumps and their sources of power is to be such as to ensure, in the event of a fire in any one compartment, that all the fire pumps will not be put out of actions.

2.3.4 International shore connection

At least one international shore connection complying with Pt C, Ch 4, Sec 6, [1.2.7] is to be provided.

3 Escape and circulation

3.1 Application

3.1.1 Limitation

The requirements of Ch 6, Sec 5, [3.2] are applicable for the ships with a maximum complement of less than 60 persons.

Special consideration is to be given by the Society to ships carrying more than 60 persons.

NR483

RULES FOR THE CLASSIFICATION OF THE NAVAL SHIPS

Part E
Additional Class Notations

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Chapter 2	System of Trace and Analysis of Records (STAR)
Chapter 3	Availability of Machinery (AVM)
Chapter 4	Automation Systems (AUT)
Chapter 5	Monitoring Equipment (MON)
Chapter 6	Comfort on Board (COMF)
Chapter 7	Environmental Protection (CLEANSHIP)
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Part E
Additional Class Notations

CHAPTER 1
MILITARY ENVIRONMENT

Section 1	ARMOUR
Section 2	SHOCK
Section 3	Residual Strength
Section 4	FFS

Section 1 ARMOUR

1 General

1.1 Introduction

1.1.1 During their operation, naval ships may be exposed to specific threats induced by weapons shoots. The threats may result from:

- bullets and other high performance projectiles
- splinters from external or internal blasts.

Naval ships are commonly protected from these threats by armour plate, armour compound or other adequate means.

The threats and corresponding levels of protection are defined by the Naval Authority.

1.2 Application

1.2.1 The additional class notation **ARMOUR** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.2.1], to ships fitted with a protection by armour, when the requirements of Articles [2] to [4]of this Section are complied with.

2 Documentation

2.1 Document for information

2.1.1 Confidentiality

The documentation relating to the **ARMOUR** notation is treated as confidential, in accordance with the Society General Conditions (item 11), and any additional confidentiality level defined by Naval Authority, if any.

2.1.2 Armouring table

The following documentation is to be consolidated in an "armouring table" to be submitted to the Society for information:

- list of protected areas / compartments / structural modules. The concerned protected areas should be clearly described, in longitudinal - transverse - vertical location and in extend
- nature of armour components, for each protected area in the above list. In particular, the following information should be documented:
  - armour mechanical properties
  - thickness of different barriers or protective plates
  - armour configuration in simple / double plates, gaps, etc.

The armour components should be duly identified by a reference such as to allow management of information without ambiguity (see Article [3]).

- for each armour component of the above list:
  - description of the connection arrangement and the connection means to the ship structure (welding, bounding, bolting, etc)
  - load-carrying capability for normal loads exerted during navigation or operation in peace-time
  - possible welding restriction on the armour plate after installation on board, if any.

The above armouring table submitted to the Society should evidence formal acceptance by the Naval Authority.

3 Armour requirements

3.1 Strength

3.1.1 Special attention should be given to the connection of the armour components listed in the armouring table with the surrounding ship structural elements.

In particular, the following should be checked:

- the ship structure should be adequately reinforced to support the weight of the armour components
- the details of ship structure reinforcements should be shown on structure drawings submitted to the Society
- the external or internal loads during navigation or operation in peace-time should not be transferred to the armour component, if it is specified as non load-carrying in the armouring table.

3.2 Stability

3.2.1 The stability documentation submitted for the ship should adequately take into account the relevant datas of the amour components (weight, location on board, etc.).

3.3 Fire safety

3.3.1 Armour including combustible materials will be considered on a case by case basis.

4 Surveys

4.1 Construction Surveys

4.1.1 Welding

In case the armour component is welded to the ship structure, the relevant Welding Procedure Specification should be subject to Classification acceptance.

4.1.2 Compliance with armouring table

The presence on board of various armour components is checked during Surveyor's inspection, on basis of the armouring table specified in [2.1.2].

4.1.3 Installation on board

The fitting on board is checked based on the documents mentioned in [3.1].

Section 2 SHOCK

1 General

1.1 Assignment of the additional notation SHOCK

1.1.1 Condition for assignment

The additional class notation **SHOCK** is assigned to a ship which complies with the requirements of both the notations **SHOCK STRENGTH** and **SHOCK EQUIPMENT** described in [1.2] and [1.3] respectively. In this case, the notation **SHOCK** replaces the notations **SHOCK STRENGTH** and **SHOCK EQUIPMENT**.

1.2 Assignment of the additional notation SHOCK STRENGTH

1.2.1 Scope

The additional class notation **SHOCK STRENGTH** is assigned to a ship in order to certify that measures are taken to increase her survivability following threat damage to the structures from an assigned underwater non-contact explosion. This notation considers loads coming from underwater non-contact explosions of either submarine mines or torpedoes.

1.2.2 Condition for the assignment

The assignment of the notation **SHOCK STRENGTH** implies that a detailed structural analysis or a test have been carried out, for compliance with Articles [2], [3] and [4] taking also into account the dynamic vertical bending and vibrations that can be induced by the assigned underwater non-contact explosion. Details of the calculations and testing methods and the structural performance achieved, based on the specified loads, will not be published and will be only disclosed to the Naval Authority.

1.2.3 Documentation to be submitted

The following confidential input data are to be submitted for information:

- the loading scenarios, as defined in [2.2]
- the description of the calculation procedures
- the assumptions made
- the details of the software used and its validation as appropriate
- the summary of the results obtained.

1.2.4 Assignment of the notation

If requested by the Naval Authority or by the Shipyard, the **SHOCK STRENGTH** notation is assigned by the Society if the acceptance criteria specified in this Section are fulfilled.

1.3 Assignment of the additional notation SHOCK EQUIPMENT

1.3.1 Scope

Pieces of equipment which are required to resist, to a certain extent, the shock loads due to an underwater explosion near the ship are to comply with the requirements of Articles [5] and [6].

The notation **SHOCK EQUIPMENT** may be assigned to ships where a list of specified pieces of equipment have been satisfactorily shock tested and subsequently fulfil the shock resilience criteria specified by the Naval Authority for the applicable design shock level.

1.3.2 Conditions for assignment

The assignment of the notation **SHOCK EQUIPMENT** is contingent upon the application of the following steps:

a) the critical pieces of equipment are specified by the Naval Authority
b) miscellaneous shock levels are defined by the Naval Authority
c) miscellaneous performance criteria are defined by the Naval Authority
d) each piece of equipment is associated to one or several shock levels and performance criteria
e) shock testing for the given shock level is performed for each equipment
f) performance criteria for equipment after shock testing is evaluated.

1.3.3 Documents to be submitted

For each piece of equipment required to be assessed under shock conditions, the following documents are to be submitted for review:

a) equipment general arrangement drawing, showing actual possible orientation on board

b) detailed supporting arrangement, including mountings specifications and arrangement

c) design shock level applicable.

2 Principles of the additional notation SHOCK STRENGTH

2.1 Underwater explosions

2.1.1 Non contact underwater explosions

A non contact underwater explosion is an explosion caused by the detonation of either a submarine mine or a torpedo warhead occurring at a distance such that the effects of the gas bubble impinging directly on the ship structures are negligible.

2.1.2 Bubble evolution and loading mechanisms

The evolution of the bubble and the corresponding field pressure, without any obstacle, is schematically shown in Fig 1. This implies two types of loading mechanisms:

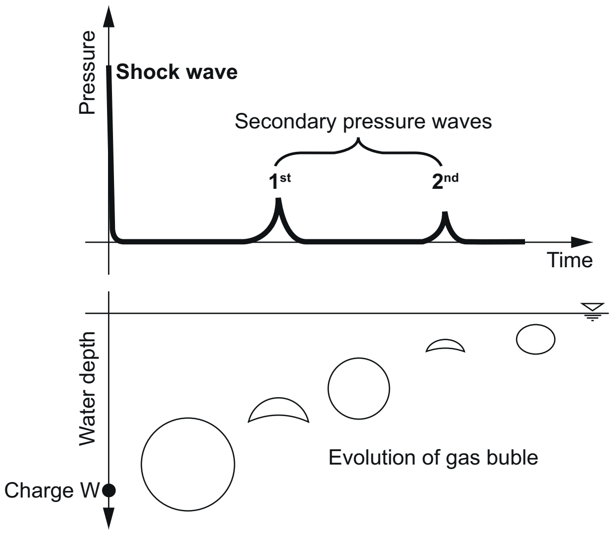
- shock wave
- bubble pulsations.

Two types of loadings have fundamentally different physics and do not have the same consequences on the ship structure. The duration of the shock wave is extremely small (few milliseconds) and it affects the local hull structure as described in Article [3], while the duration of the pressure pulses are much longer and can induce the global hull girder vibrations (whipping) as described in Article [4].

2.1.3 Whipping

Whipping is defined as the transient beam-like, low frequency response of a ship caused by external transient loading.

Figure 1 : Evolution in time of the pressure field and the gas bubble migration process



2.2 Loading scenarios

2.2.1 Description of loading scenarios

A loading scenario is defined by a charge and its location with respect to the ship:

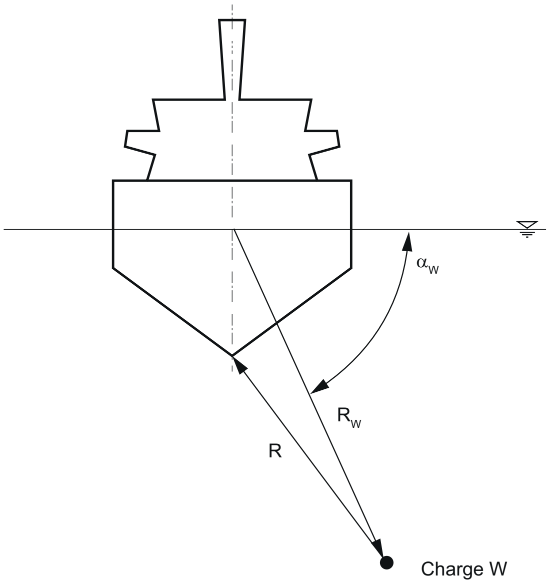
W : Charge mass of TNT equivalent, in kg

Rw : Distance, in m, between the center of the explosion and the point, in the plane of the explosion perpendicular to the longitudinal axis of the ship, defined as the intersection between the waterline and the longitudinal plane of symmetry of the ship

αw : Relative angle of the charge location with respect to the free surface, as shown in Fig 2.

X_W : Longitudinal position of the center of the explosion with respect to the midship section.

Figure 2 : Definition of the charge position



2.2.2 Specification of loading scenarios

The loading scenarios to be used should be specified by the Naval Authority.

2.2.3 Shock factor

A quantity used to characterize the severity of the shock wave is called shock factor and is defined by the following expression:

$$SF = \frac{\sqrt{W}}{R}$$

where:

R : Standoff distance i.e. the distance from the charge to the closest hull point, in m, as shown in Fig 2.

This quantity is often used to specify the loading scenarios. It should however be complemented by the value of the mass W and the depth of the charge (or its relative angle αw).

2.2.4 Remarks

For a given charge W, the worst case for the local structural response to shock wave, is the one corresponding to the smallest distance from the center of explosion to the hull. However for the global whipping response, the worst loading scenario may not be the one with the smallest distance to the hull. Hence, as far as whipping analysis is considered, several distances, higher than the minimum distance specified in the loading scenarios should be considered in the computations.

3 Local structural response to shock wave

3.1 Shock wave modelling

3.1.1 Free field pressure

In the vicinity of the detonation point, the shock wave can be mathematically described as an acoustic pressure field travelling at the speed of sound with the amplitude inversely proportional to the distance and exponentially decaying in time:

$p_0 = p_{max} \exp(-t/\theta)$

p_{max} : Maximum pressure at the distance R from the detonation point, in MPa

$$P_{max} = K_1 \left(\frac{W^{1/3}}{R}\right)^{A_1}$$

t : Time, ms

θ : Decay constant depending on the type of charge, in ms

$$\theta = K_2 W^{1/3} \left(\frac{W^{1/2}}{R}\right)^{A_2}$$

The differents constants depend on the type of charge and their values should be agreed with the Society. In the absence of data the values for TNT can be used (see Tab 1).

Another important quantity is the energy per unit area (in MJ/m²), and is given by:

$$E = \frac{\theta P_{max}^{2}}{2 \cdot \rho \cdot c}$$

where:

ρ : Sea water density to be taken equal to 1025 kg/m^3

c : Speed of sound in sea water to be taken equal to 1500 m/s

This energy per unit area is roughly proportional to the square of the Shock Factor.

Table 1 : Charge dependent constant

K1	A1	K2	A2
52,12	1,18	0,09	–0,185

3.1.2 Loading pressure

The maximum pressure p_{max} can be supposed to occur almost instantly (zero rise time) and the expression (see [3.1.1]) represents the pressure for the field without obstacle. In order to calculate the effective loading pressure p_L to be applied on the hull wetted surface, the diffraction effects are to be taken into account. In the absence of more detailed diffraction analysis, the free field pressure p_0 could be multiplied by 2.

$p_L = 2\ p_0$

3.2 Structural response

3.2.1 General

The structural response to the shock pressure loading defined in [3.1.2], needs to be evaluated by appropriate methods. The type of modelling depends on the complexity of the structural elements.

3.2.2 Plating

In the case of plating a simplified approach may be accepted. This approach might be based on the quasi static assumptions or the simplified dynamic analysis can be employed with the analytical definition of the mode shapes.

3.2.3 Stiffened panels

The structural response of the stiffened panels is to be evaluated using the appropriate nonlinear structural dynamic analysis applying the pressure loading time history defined in [3.1.2]. The strain rate effects should be accounted for in the analysis. Any other alternative numerical method may be accepted on a case-by-case basis.

3.3 Acceptance criteria

3.3.1 Whatever the approach used for the evaluation of the structural response, the calculated strain should not exceed the strain corresponding to the maximum stress in the stress-strain (σ,$\in$) curve of the corresponding material.

4 Global whipping response

4.1 Evaluation of the dynamic response

4.1.1 General

The mathematical model of the hull girder dynamics should combine the following steps:

- pressure bubble dynamics
- ship hull hydrodynamics
- ship structural dynamics
- coupled hydro-structure dynamics.

4.1.2 Gas bubble dynamics

The gas bubble is pulsating in the surrounding water with the motion tendency to approach the free surface (see Fig 1). As a first approximation the presence of the free surface can be ignored. The practical consequence of this assumption is that the gas bubble keeps the spherical shape during the pulsations, which significantly simplifies the analysis.

The basic assumptions of the mathematical model of the bubble dynamics are:

- the fluid is incompressible and inviscid
- the presence of the ship does not affect the bubble evolution.

Based on the above assumptions, the differential equation for the instantaneous radius of the gas bubble, its first and second time derivatives, can be built and is to be solved in time domain using the recognized numerical techniques. The different parameters of the differential equation should be agreed with the Society. Among the acceptable methods the Double Asymptotic Approximation (DAA) is recommended.

When deemed necessary, the presence of the free surface should be accounted for using the appropriate mathematical model which has to be approved by the Society.

4.1.3 Ship hull hydrodynamics

While vibrating, the hull surface in contact with the water will induce the dynamic pressure which should be taken into account in the global interaction model. The final effect of the induced dynamic pressure can be modelled using the concept of the added mass. The pressure is to be calculated using the recognized 2D/3D potential flow numerical approach. The variation in time of the hydrostatic buoyancy forces should also be taken into account.

4.1.4 Ship structural dynamics

The modal approach is recommended to describe the global structural dynamics and a sufficient number of modes needs to be accounted for, typically more than 20.

4.1.5 Coupled hydro-structure dynamics

The coupled hydro-structure interaction motion equation is to be solved. The gas bubble excitation vector is obtained after projecting the gas bubble pressure [4.1.2] into the hull girder modes and integrating it over the wetted hull surface. The dynamic equation is to be integrated in time and the time history of the vertical bending moment along the ship is to be evaluated. The maximum value of the whipping bending moment at each section is denoted by $M_{Whip}(\chi)$ and this value is to be used to check the acceptance criteria.

4.2 Acceptance criteria

4.2.1 The maximum whipping bending moment $M_{Whip}(\chi)$ is to satisfy the following criteria:

$$M_{Whip}(\chi) \le \frac{M_u(\chi)}{\gamma_R \gamma_M}$$

where:

$M_U(\chi)$: Ultimate bending moment capacity, see Pt B, Ch 6, Sec 3, [3.3.1]

γ_R, γ_M : Partial safety factors, see Pt B, Ch 6, Sec 3, [2.2.1].

4.3 Alternative method

4.3.1 Alternative methods may be used if duly justified and adequately documented to the satisfaction of the Society.

5 Principles of the additional notation SHOCK EQUIPMENT

5.1 Schok levels

5.1.1 Stanag 4549

Stanag 4549 refers to NATO standard Stanag 4549 Edition 1 - Testing of surface ship equipment on shock testing machines. The requirements of this section are in line with the principles identified in this standard, which is considered a recognized standard for shock testing.

5.1.2 Shock response spectra (SRS)

A shock response spectrum is the visualization of the maximum responses of an assembly of massless oscillators (fictitious single degree of freedom systems), having a range of natural frequencies (f), to a given shock motion of the base.

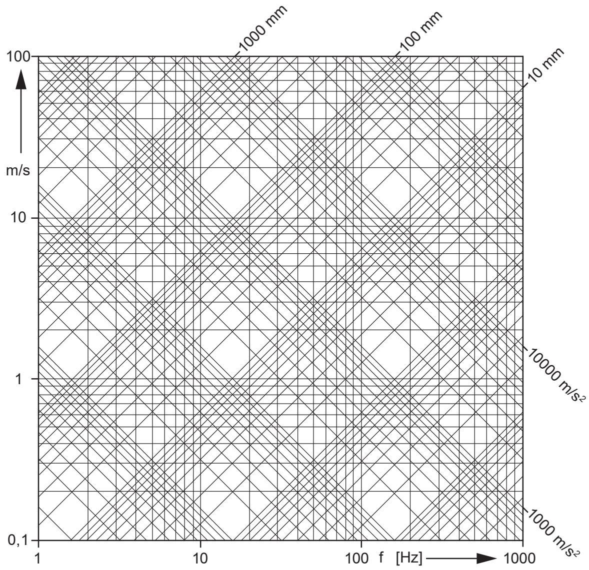
Each shock corresponds to a different time history of acceleration, and reproducing exactly such time series of acceleration is not possible with chock testing machines. This SRS is therefore a way of characterization of a given shock level, which can then be compared to actual shock testing machine motion measurement during the testing phase and ensure that the test is indeed representative of the shock level.

The SRS may be graphically represented on a specific grid shown in Fig 3, and defined as follows:

- Horizontally, the natural frequency is plotted using logarithmic scale.
- Vertically, on a logarithmic scale, there the “pseudo velocity” ω, Z_{max}, where Z_{max} is the absolute value of the maximum relative displacement between the base and the mass of the single degree of freedom system, either occurring during the excitation or thereafter. That is a maximax shock spectrum. The angular natural frequency is:

  $\omega = 2\pi f$
- In the graph, a decade in frequency and a decade in pseudo velocity are to be represented by a same length, preferably 50 mm.
- The graph must show lines rotated 45° anti-clockwise from the horizontal position. These being lines of constant relative displacement Z_{max}.
- The graph must show lines rotated 45° clockwise from the horizontal position. These being lines of constant absolute acceleration, $\omega 2|Z_{max}|$, of the masses.
- The grid as shown in Fig 3 must have 10 equidistant steps on a linear scale for each decade. This applies to f, $|Z_{max}|$, $\omega|Z_{max}|$ and $\omega^2|Z_{max}|$.

Figure 3 : Typical grid for representation of SRS



5.1.3 Design Shock Level

In order to define the design level of shock motion, a number of standardized shock levels may be defined using 3 parameters SRS parameters, each of these parameters corresponding to a straight line on the grid shown in Fig 3:

- the maximum relative displacement d_0, in meters
- the maximum pseudo velocity v_0, in m/s
- the maximum absolute acceleration a_0, in m/s².

It is generally defined in the frequency range from 4 to 400 Hz:

a) In the lower frequency range between 4 Hz and f_i a constant relative displacement.

b) In an intermediate frequency range between f_i and f_s, a constant pseudo velocity ω, in m/s:

$\omega\ |d_0| = v_0$

Occasionally f_i and f_s may coincide.

c) In the higher frequency range between f_s and 400 Hz, a constant absolute acceleration ω^2, in m/s²:

$\omega^2\ |d_0| = a_0$

The actual shock levels required for each project are to be specified by the Naval authority and in order to define the Design Shock Level for each equipment, in one the following formats:

- a full SRS directly derived from a design shock level acceleration history
- a standard shock response spectrum NS(d_0, v_0, a_0).

Note 1: f_i and f_s depend on the values for d_0, in m; v_0 in m/s and a_0 in m/s²:

$f_i = v/2\pi d_0$

$f_s = a_0/2\pi\ v_0$

In order that $f_s \geq f_i$, it is a requirement that $v_0 \leq (a_0 d_0)^{0,5}$. The SRS is then entirely defined by these three numerical values.

Note 2: Use of NATO Standardized Shock Levels: NATO Standardized Shock Levels based on such SRS are defined in Stanag 4549, and is identified in with the following term:

NS (relative displacement ; pseudo velocity ; absolute acceleration)

For instance, NS(0,035 ; 3,5 ; 1250) means a NATO standard level of:

- 35 mm relative displacement between 4,0 and 15,9 Hz
- 3,5 m/s pseudo velocity between 15,9 Hz and 56,8 Hz and
- ~125 g absolute acceleration between 56,8 Hz and 400 Hz.

Applications are foreseen within the following ranges:

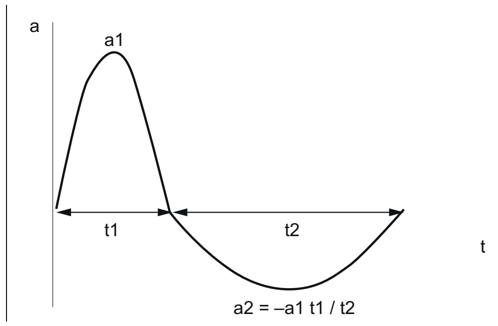
- $0,025 \leq d_0 \leq 0,100$
- $2,5 \leq v_0 \leq 16$
- $250 \leq a_0 \leq 10,000$

5.1.4 Acceleration time history

The shock level can also be specified as an acceleration time history, giving the acceleration (velocity, or displacement) as a function of time. This time history is generally given by the Naval Authority.

In case only a Design Shock Level or a SRS is given, a simple sinusoidal time history, as shown in Fig 4, may be used. The Shock Response Spectrum corresponding to this time history should be computed, and compared to the required Design Shock Level or SRS. The comparison of the spectra is done as specified in [6.1.5]. The various parameters of this simple time history should be tuned until the comparison with the required spectrum is satisfactory.

Figure 4 : Sinusoidal acceleration history



6 Assessment of Equipment

6.1 Assessment by testing

6.1.1 General

Each piece of equipment is to be shock tested in accordance with the requirements of this Section, or following another recognized standard. In particular, these requirements are in line with Stanag 4549.

6.1.2 Arrangement of mountings

The mountings are to be in the same configuration as on board installation during the testing.

When such an arrangement, that is, equipment on mountings, has passed the tests as specified herein, the equipment without mountings or on another type of mountings will not be considered to be in compliance with this Section.

If equipment is on mountings, then other links such as cables and piping may considerably enhance the total stiffness of equipment "suspension". Depending on the actual situation, these additional connections should also be simulated during testing.

The mounting arrangement plan on board and for testing is to be submitted for review.

6.1.3 Shock direction and attachment to the shock testing machine

Shock in three different shipboard directions are to be simulated by three separate tests:

a) vertically (sense upwards)

b) athwartships (sense not specified)

c) fore and aft direction (sense not specified).

During a test as mentioned under test (b) or test (c) it is allowed to apply at the same time an (unspecified) shock as mentioned under test (a). This is usual practice for some testing machines during so called inclined testing.

Depending on the foreseen orientation of each type of equipment on board, the relevant testing configurations are

required with reference to the equipment local axis (X, Y and Z).

The equipment including its mounting system (if any; see [6.1.2]) is attached through its normal attachment points to the shock testing machine, either directly or by means of fixtures. The attachment and the fixtures are to be such that the measured results are reproducible and that no plastic deformation occur other than in the mountings.

6.1.4 Required test verification

For a given design shock level, the actual shock testing is different according to the testing directions defined in [6.1.3] and applicable depending on the testing cases according to Tab 2.

The tests are to be carried out according to the following requirements:

a) for the test in the upward vertical direction the design shock level as defined in [5.1.3]is to be applied

b) for the test in the athwartships direction a similar spectrum should be used having as a minimum 50% of the d_0, v_0, a_0 values for the vertical test

c) for the test in the fore and aft direction a similar spectrum should be used having as a minimum 25% of the d_0, v_0, a_0 values for the vertical test.

A test for a given equipment comprises at a minimum 3 shocks.

The shock the equipment is subjected is to be measured in accordance with Stanag 4549 or another recognized standard.

Table 2 : Applicable test case depending on equipment orientation on board

	Case 1	Case 2	Case 3
	Only one single possible orientation on board for the equipment **(1)**	Only the vertical axis of the equipment is known, with one single face point upwards **(2)**	The equipment may be mounted in any orientation
Equipment local X axis	test (c) fore and aft direction (sense not specified)	test (b) athwartships (sense not specified)	test (a) vertically (sense upwards)
Equipment local Y axis	test (b) athwartships (sense not specified)	test (b) athwartships (sense not specified)	test (a) vertically (sense upwards)
Equipment local Z axis	test (a) vertically (sense upwards)	test (a) vertically (sense upwards)	test (a) vertically (sense upwards)

(1) In that case, Z is considered as the vertical axis, and X is considered oriented in the longitudinal direction of the ship
(2) In that case, Z is considered as the vertical axis, X and Y axis may be either in the longitudinal or transversal direction of the ship

6.1.5 Comparison of spectra

The acceleration measured during the test is to be converted in a Shock Response Spectrum. The required design shock level is considered to have been met during testing if all measured SRS exceed the required spectra, with the exception of minor excursions.

A measured response spectrum is to exceed the required three-line spectrum, with the exception of frequency ranges where minor excursions occur below the required spectrum.

Further definitions of tolerances, with examples can be found in Appendix 3 to Annex A of Stanag 4549.

6.1.6 Shock testing report

A shock testing report is to be submitted to the Society for review for each equipment, detailing at least the following information:

a) Equipment description:
   1) The name and address of the supplier or manufacturer
   2) References to drawings and full description of equipment as accepted. If modifications during shock testing were introduced and found appropriate during successive testing, such modifications are to be fully documented
   3) The weight and general overall dimensions of the equipment as tested
   4) Description of any mounting system used to support the equipment during the test including the number of mountings fitted, their load range, their location, the type number and the name of the manufacturer of the mountings.

b) Description of actual shock testing:
   1) reference to testing standard
   2) reference to the project applicable design shock level
   3) description of the testing machine
   4) identification of testing authority
   5) detailed installation of the equipment during the test, including mountings
   6) description of each test
   7) description of the instrumentation
   8) for each test, measured velocity signals and maximal shock response spectra.

c) Description of the performance test:
   1) definition of the acceptance criteria for equipment function after shock, according to specified shock resilience criteria
   2) description of any damage
   3) functional performance tests results.

d) General conclusion with acceptable status from the testing authority.

6.2 Assessment by computations

6.2.1 General

As an alternative to the testing, the assessment of large and heavy mechanical components (such as shaft lines, reduction gears, main engines foundations, diesel generators foundations) may be performed based on computations for which the applied methodology is accepted by the Naval Authority.

6.2.2 Type of computations

Dynamic structural analysis should be used based on a structural model of the equipment.

6.2.3 Loading

The structural model is to be loaded by an imposed acceleration time history, as defined in [5.1.4].

6.3 Acceptance Criteria

6.3.1 An equipment is deemed to be qualified for a given design shock level after satisfactory review of an approved test report in accordance with Stanag 4549 and [6.1.6]. For components for which the assessment is based on dynamic structural analysis, the acceptance criteria is to be defined by the Naval Authority.

6.4 Alternative Methods

6.4.1 Any other alternative methods or reference standards that are used to assess the pieces of equipment to be covered by the additional class notation **SHOCK EQUIPMENT** may be considered on a case-by-case basis.

Section 3 Residual Strength

1 General

1.1 Application

1.1.1 This Section applies to ships for which the residual hull girder ultimate strength under damage condition is evaluated according to minimum hull damage scenarios and rule wave hull girder loads defined in Article [2].

Ships complying with the requirements of this Section may be granted with the additional class notation **RS-P**.

2 Design requirements

2.1 Minimum damage scenarios

2.1.1 The two following damage scenarios are to be considered independently between 0,2 L and 0,8 L:

- in-air damages as defined in [2.1.2]
- under-water damages as defined in [2.1.3].

The damage extents defined in [2.1.2] and [2.1.3] are to be measured from the moulded lines of the ship.

Stiffeners are to be considered intact unless the connection of stiffener with attached plate is included in the damage extent.

2.1.2 Transverse extent for in-air damage

The damage extends from the point of intersection of the side shell and the uppermost continuous deck:

- vertically downward for a distance D/4
- transversally inboard for a distance B/2

where B and D are defined in Pt B, Ch 1, Sec 2.

2.1.3 Transverse extent for under-water damage

The damage extends from the point of intersection of the keel line and the side shell:

- vertically upward for a distance D/5
- transversally outboard in one direction for a distance B/3.

where B and D are defined in Pt B, Ch 1, Sec 2.

2.2 Hull girder residual strength check

2.2.1 Hull girder loads

The vertical bending moment M_D, in kN.m, to be considered for the check of ultimate hull girder strength in damaged condition, is to be obtained from the following formula:

- in hogging condition:

  $M_{D,H} = M_{SW,H} + 0,825\ M_{WV,H}$
- in sagging condition:

  $M_{D,S} = M_{SW,S} + 0,825\ M_{WV,S}$

where:

$M_{SW,H}$: Maximum still water bending moments calculated in hogging condition, as defined, in Pt B, Ch 5, Sec 2, [2.2]

$M_{SW,S}$: Maximum still water bending moments calculated, in sagging condition, as defined, in Pt B, Ch 5, Sec 2, [2.2]

$M_{WV,H}$: Vertical wave bending moments calculated in hogging condition, as defined, in Pt B, Ch 5, Sec 2, [3.1]

$M_{WV,S}$: Vertical wave bending moments calculated in sagging condition, as defined, in Pt B, Ch 5, Sec 2, [3.1]

2.2.2 Hull girder ultimate bending capacity in the damaged condition

The hull girder ultimate bending capacity in damaged condition M_{UD}, in kN.m, is to be calculated in hogging and sagging conditions according to Pt B, Ch 6, App 1, with the damaged parts assumed not to contribute to the hull girder strength.

When assessing the ultimate bending capacity of the damaged hull transverse sections:

- damaged area as defined in [2.1] is to be removed from the capacity model
- the hull girder longitudinal members are to be considered with their net scantlings according to Pt B, Ch 6, Sec 1, [2].

2.2.3 Checking criteria

The vertical hull girder ultimate bending capacity in the damaged condition at any hull transverse section located between 0,2 L and 0,8 L is to satisfy the following criteria:

$$\frac{M_{UD}}{\gamma_R \gamma_m} \geq M_D$$

where:

M_{UD} : Ultimate bending moment capacity of the hull transverse section considered, in kN.m:

- In hogging condition:
  $M_{UD} = M_{UD,\,H}$
- In sagging condition:
  $M_{UD} = M_{UD,\,S}$

M_D : Vertical bending moment, in kN.m, defined in [2.2.1]

γ_m : Partial safety factor for material defined in Pt B, Ch 6, Sec 3

γ_R : Partial safety factor for resistance defined in Pt B, Ch 6, Sec 3.

Section 4 FFS

1 General

1.1 Scope

1.1.1 The additional class notation **FFS** is assigned in accordance wit Pt A, Ch 1, Sec 2, [6.2.4] to ships provided with flooding fighting systems allowing to cope with the ingress of great amount of water resulting from a hull damage, or a sea water pipe breaking, by maintaining ship functions totally or partially as considered by the Naval Authority and by maintaining at a limited level the flooding of the compartment suffering a water ingress

1.2 Application

1.2.1 Compartments to be covered

Flooding fighting systems are to be provided, covering, as a minimum, the largest machinery compartment and the compartments containing the main propulsion prime movers and associated main energy sources.

1.3 Definitions

1.3.1 Clean bilge system

Clean bilge system, also called bilge system in this section, means the bilge system required by Pt C, Ch 1, Sec 10, [6] in any watertight compartment other than spaces permanently dedicated to the carriage of fresh water, ballast water, fuel oil or JP5-NATO (F44) and for which other efficient means of pumping are provided, under all practical conditions.

1.3.2 Flooding fighting system

A Flooding Fighting System (FFS) includes suction and overboard discharge piping, pumps, ejectors, and associated instrumentation and control system.

1.4 Documents to be submitted

1.4.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documentation to be submitted

No.	I/A**(1)**	Documents
1	A	Diagram of the flooding fighting piping systems
2	A	Capacity, prime mover and location of the pumps and ejectors
3	I	Overboard discharges of FFS piping systems showing positions related to the deepest subdivision waterline
4	I	Pressure loss calculations in case of a FFS serving several compartments
5	A	Material, external diameter and wall thickness of the pipes
6	A	Material, type and size of the accessories
7	I	Nature, service temperature and pressure of the fluids used for the operation of the FFS
8	A	Type of connections between pipe lengths, including details of weldings, where provided
9	A	Location of the controls of the flooding fighting systems
10	I	Pump approval certificates
11	I	Drawings showing the design of the on-board testing devices if any
12	I	List of compartments protected by a FFS approved by the Naval Authority
13	A	Construction drawing of the pumps and ejectors
14	I	Characteristics of the means of pumping, flow versus ΔP
15	I	Drawings of the priming devices and related operation instructions
16	I	Material characteristics of pumps and ejectors
17	I	Workshop test results for the means of pumping
(1) A: for approval; I: for information		

2 Design of flooding fighting systems

2.1 General

2.1.1 Segregation by compartment

An FFS is normally to serve a single watertight compartment.

Several compartments may however be served by the same FFS provided:

a) they are located in the same safety zone.

b) the FFS can manage one single damage for the most demanding compartment. When required by the Naval Authority, the FFS may be required to cope with damages on several compartments. Calculations showing possibility of operating such common piping systems and pumps taking into account the pressure losses are to be provided.

c) the branch of the flooding fighting system serving one compartment can be isolated from the rest of the system by a valve able to be maneuvered locally and remotely from a position located on or above the damage control deck.

d) the risk of progressive flooding and the risk of flooding a healthy compartment when pumping water from a damaged compartment are avoided.

2.1.2 Location

a) Location of pipes and pumps with respect to the ship side: flooding fighting means of pumping and piping system are not to be situated at a distance less than B/5 from the ship side, where B is the ship's width. This does not apply to the portion of piping leading the water to the overboard discharge at the ship side.

b) Compartment completely located inside the B/5 area: in case this kind of design has been chosen:

   1) means of pumping are to be installed outside the compartment

   2) the associated piping system inside the compartment is to be installed as far away as possible from the side of the ship

   3) a valve able to isolate the portion of the piping system located inside the flooded compartment from the rest of the flooding fighting system is to be installed. This valve is to be able to be manoeuvred locally and remotely from a position located on or above the damage control deck and an indication is to be provided at the damage control station showing the actual position of the valve or whether the valve is fully closed or fully open.

c) location of the flooding fighting system controls : the controls of each FFS are to be grouped at one location per system on or above the damage control deck. An instruction notice is to be displayed close to the controls.

d) the overboard discharges of the flooding piping systems are to be located above the deepest subdivision waterline unless a calculation is provided assessing the ability of the system to operate with overboard discharges below the deepest subdivision waterline. In any case, the overboard discharge is to be fitted with a valve operable from a position on or above the damage control deck and an indication is to be provided at the damage control station showing the actual position of the valve or whether the valve is fully closed or fully open.

2.1.3 Pooling clean bilge system

Pooling the clean bilge system and flooding fighting system together may be considered by the Society if agreed by the Naval Authority and provided:

a) the clean bilge system is serving only the compartments considered for the flooding fighting system

b) requirements for both the clean bilge system and the flooding fighting system are applied.

When the compartment or group of compartments is also served by a bilge system and by an emergency bilge system, as required by NR467 Pt C, Ch 1, Sec 10, [6], pooling the emergency bilge system and flooding fighting system together may be considered by the Society if agreed by the Naval Authority and provided:

a) the emergency bilge system is serving only the compartments considered for the flooding fighting system

b) requirements for both the emergency bilge system and the flooding fighting system are applied.

2.2 Design requirements

2.2.1 Unless otherwise mentioned in this section, rules for piping systems mentioned in Pt C, Ch 1, Sec 10, [1] to Pt C, Ch 1, Sec 10, [5] and Pt C, Ch 1, Sec 10, [19] are to be complied with. The FFS is to be considered as a bilge system for the purpose of applying material-related requirements.

2.3 Means of pumping

2.3.1 Arrangement of the means of pumping

For each flooding fighting system, at least two fixed means of pumping are to be provided including at least one power pump.

2.3.2 Capacity of the means of pumping

The pumping capacity for the flooding fighting system in each compartment referred to in [1.2] is to be not less than the capacity determined by the following formula:

$$Q = 0,36W^{2/3}\sqrt{2gh}$$

where:

Q : Total capacity of pumps serving the compartment(s), in m^3/h

W : Volume of the compartment(s), in m^3. In case the compartment(s) extends above the margin line, W is to be taken as the volume of the compartment(s) located below the margin line.

g : Gravity constant (9,81 m/s^2)

h : Vertical distance between the waterline at full displacement of the ship and the maximum level L which may be reached in the compartment, in m, see Fig 1.

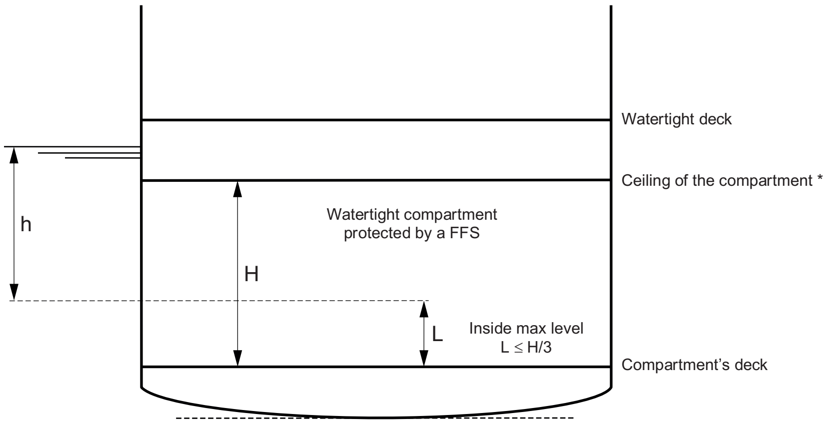
The maximum level L is to be taken as:

- the lowest location of sensitive equipment of which failure means partial unavailability of a primary essential service (see Pt C, Ch 2, Sec 1, [3.3]), electric switchboard, cabinet or junction box
- H/3, where H is the height of the compartment(s). If the compartment(s) extends above the margin line, determination of H should stop at the margin line

whichever is the smaller.

In case the FFS is serving several compartments, the requirements of [2.1.1], item b) are to be complied with.

Figure 1 :



* if higher than the margin line, determination of H and W should stop at the margin line

2.3.3 Type of pumps

a) Flooding fighting pumps are to be of the self-priming type. Centrifugal pumps are to be fitted with efficient priming means, unless an approved priming system is provided to ensure the priming of pumps under normal operating conditions.

b) Flooding fighting power pumps are to be suitable to operate when submersed in seawater.

c) Arrangements are to be provided to start the motor of dedicated flooding power pumps from the damage control station and locally.

2.3.4 Power supply for the power pumps

The means of pumping powered by electricity are to be able to be fed by two different parts of the main switchboard supplied by different generating sets.

2.4 Piping

2.4.1 Size of flooding fighting pipes

The actual internal diameter of flooding fighting system pipes is to be calculated assuming a water velocity less than 5 m/s. It is in any case not to be less than 125 mm.

2.4.2 Distribution of suctions

One direct suction per compartment covered is to be fitted for each pump or ejector, located at a low point well below maximum level L commensurate with a reasonably short length of suction pipe.

2.4.3 Discharge of the means of pumping

In case the discharge of several means of pumping inside a single compartment is common, the design of the piping system is to allow to pump the water out of the compartment when only one means of pumping is used.

If located inside the compartment protected by the FFS, the isolating valves provided for this purpose are to be operable from a position on or above the damage control deck and an indication is to be provided at the damage control station, showing the actual position of the valve or whether the valve is fully closed or fully open.

3 Certification and testing

3.1 Certification of pumps

3.1.1 General

The means of pumping are to:

- have their design approved according to [3.1.2]
- be able to work in immersed conditions
- have the materials and casing tested according to Pt C, Ch 1, Sec 10, [19] as bilge pumps
- be able to run on a limited time without pumping water, to be demonstrated by testing

Individual certifications or type approval schemes might be used.

3.1.2 Design approval

Documentation as included in Tab 1 is to be submitted to the Society in order to check compliance with the design requirements given in [2.3.3].

3.1.3 Test at the workshop

Immersed conditions test is to be undertaken in the presence of a Surveyor according to a standard approved by the Society.

Additional tests as mentioned in Pt C, Ch 1, Sec 10, [19] for bilge pumps are to be undertaken in the presence of a surveyor for the pressure test for the casing and the performance test. The performance test is to reflect at minima the conditions encountered onboard, especially those related to counterpressure. Results of the other mentioned tests are to be provided to the Surveyor.

3.1.4 Certificates

Class certificate is to be issued after the completion of tests mentioned in [3.1.3] and approval of drawings.

Work certificates are to be provided to the Society related to materials, balancing and vibration tests.

In case of a type approval, scheme I or II is to be applied according to NR320.

3.2 Tests on board

3.2.1 Proper operation of each FFS is to be tested after the installation onboard by starting the pumps during a limited time.

Part E
Additional Class Notations

CHAPTER 2
SYSTEM OF TRACE AND ANALYSIS OF RECORDS (STAR)

Section 1	Star-Hull
Section 2	Star-Mach
Appendix 1	Acceptance Criteria for Isolated Areas of Items
Appendix 2	Acceptance Criteria for Isolated Items
Appendix 3	Acceptance Criteria for Zones
Appendix 4	Pitting Intensity Diagrams
Appendix 5	Naval Authority's Hull Inspection Reports
Appendix 6	Risk Analyses for Star-Mach
Appendix 7	Planned Maintenance Scheme

Section 1 Star-Hull

1 General

1.1 Principles

1.1.1 Application

The additional class notation **STAR-HULL** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.3.2], to ships complying with the requirements of this Section.

1.1.2 Scope

The additional class notation **STAR-HULL** is assigned to a ship in order to reflect the fact that a procedure including periodical and corrective maintenance, as well as periodical and occasional inspections of hull structures and equipment, (hereafter referred to as the Inspection and Maintenance Plan) are dealt with on board by the crew and at the Naval Authority's offices according to approved procedures.

The assignment of the notation implies that a structural tridimensional analysis has been performed for the hull structures, as defined in Pt B, Ch 7, App 1 or Pt B, Ch 7, App 2 or Pt B, Ch 7, App 3, as applicable.

The implementation of the Inspection and Maintenance Plan is surveyed by the Society through:

- periodical audits carried out at the Naval Authority's offices and on board
- examination of the data recorded by the Naval Authority and made available to the Society through an electronic ship database suitable for consultation and analysis
- periodical check of the hull structure, normally at the class renewal survey, against defined acceptance criteria and based on:
  - the collected data from actual implementation of the Inspection and Maintenance Plan
  - the results of the inspections and other checks carried out during the class renewal survey (see [5]).

1.2 Conditions for the assignment and maintenance of the notation

1.2.1 Assignment of the notation

The procedure for the assignment of the **STAR-HULL** notation is the following:

- a request for the notation is to be sent to the Society:
  - signed by the Interested Party applying for the classification, in the case of new ships
  - signed by the Naval Authority, in the case of existing ships
- the following documents are to be submitted to the Society by the Interested Party:
  - plans and documents necessary to carry out the structural analysis, and information on coatings and on cathodic protection (see [2.1])
  - the hot spot map of the structure identified by the FEM analysis (see [2.2])
  - the Inspection and Maintenance Plan to be implemented by the Naval Authority (see [2.3])
  - information concerning the ship database and relevant electronic support to be implemented by the Naval Authority (see [1.3.1])
- the Society reviews and approves the initial Inspection and Maintenance Plan, taking into account the results of the structural analysis, as well as the information concerning the ship database
- the Society carries out an initial shipboard audit to verify the compliance of the procedures on board with respect to the submitted documentation.

1.2.2 Maintenance of the notation

The maintenance of the **STAR-HULL** notation is based on the following surveys and checks, whose scope and periodicity are specified in [5], to be carried out by the Society:

- annual audits at the Naval Authority's offices (see [5.1])
- annual shipboard audits (see [5.2])
- class renewal surveys (see [5.3]).

1.3 Ship database

1.3.1 The ship database, to be available on board and at the Naval Authority's offices, using an electronic support suitable for consultation and analysis, is to provide at least the following information:

- the hot spot map, as indicated in [2.2]
- the documents required for the Inspection and Maintenance Plan, as indicated in [2.3], and the corresponding reports during the ship operation, as indicated in [3.5].

The ship database is to include a backup system in order for the data to be readily restored, if needed.

1.3.2 The ship database is to be:

- updated by the Naval Authority each time new inspection and maintenance data from the ship are available
- kept by the Naval Authority.

Access to the databases is to be logged, controlled and secured.

1.3.3 The ship database is to be made available to the Society. This ship database is to be transmitted to the Society at least every six months. It may be agreed between the Naval Authority and the Society that the required data are automatically downloaded into the Society's ship database after they are collected.

2 Documentation to be submitted

2.1 Plans and documents to be submitted

2.1.1 Structural analysis

The plans and documents necessary to support and/or perform the structural analysis covering hull structures are:

- those submitted for class as listed in Pt B, Ch 1, Sec 3, for new ships
- those listed in Tab 1, for existing ships or after major repair or renewal for these ships. However, depending on the service and specific features of the ship, the Society reserves the right to request to the Naval Authority additional or different plans and documents from those in Tab 1.

Table 1 : Existing ships - Plans and documents to be submitted to perform the structural analysis

Plans and documents
Midship section
Transverse sections
Shell expansion
Longitudinal sections and decks
Double bottom
Pillar arrangements
Framing plan
Deep tank and ballast tank bulkheads
Watertight subdivision decks and bulkheads
Watertight tunnels
Fore part structure
Aft part structure
Last thickness measurement report

2.1.2 Coatings

The following information on coatings is to be submitted:

- list of all structural items which are effectively coated
- characteristics of the coating system.

2.1.3 Cathodic protection

The following information on sacrificial anodes is to be submitted:

- localisation of anodes in spaces, on bottom plating and sea chests
- dimensions and weight of anodes in new condition.

When the protection against corrosion is achieved by means of impressed currents, the description of the system and the operating manual are to be provided to the Society.

2.2 Hot spot map

2.2.1 The items to be included in the hot spot map are, in general, the following:

- items (such as a plating panels, ordinary stiffeners or primary supporting members) for which the structural analysis carried out at the classification phase for new ships showed that the ratio between the applied loads and the allowable limits exceeded 0,975
- items identified as "hot spot item" during the structural reassessment according to Ch 2, App 2, or after repair or renewal for these ships under the Naval Authority responsibility
- structural details subjected to fatigue, based on the list defined in Pt B, Ch 11, App 1
- other items depending on the results of structural FEM analyses and/or on experience.

2.2.2 The updated hot spot map may indicate which items are to be inspected periodically under the Naval Authority's responsibility.

2.3 Inspection and Maintenance Plan (IMP)

2.3.1 The Inspection and Maintenance Plan is to be based on the Naval Authority's experience and on the results of the structural analyses including the hot spot map.

The Inspection and Maintenance Plan is to include:

- the list of areas, spaces and hull equipment to be subjected to inspection
- the periodicity of inspections
- the elements to be assessed during the visual examination for each area or space, as applicable:
  - coating
  - anodes (if any)
  - pitting
  - fractures
  - deformations
- the elements to be assessed during the inspection of hull equipment.

2.3.2 As regards the maintenance plan, the following information is to be given by the Naval Authority:

- maintenance scope
- maintenance type (inspection, reconditioning)
- maintenance frequency (periodicity value unit is to be clearly specified, i.e. hours, week, month, year)
- place of maintenance (port, sea, etc.)
- manufacturer's maintenance and repair specifications, as applicable
- procedures contemplated for repairs or renewal of structure or equipment.

3 Inspection and Maintenance Plan (IMP)

3.1 Minimum requirements

3.1.1 The minimum requirements on the scope of the Inspection and Maintenance Plan (IMP), the periodicity of inspections, the extent of inspection and maintenance to be scheduled for each area, space or equipment concerned, and the minimum content of the report to be submitted to the Society after the inspection are given hereafter.

3.1.2 At the Naval Authority's request, the scope and periodicity may be other than those specified below, provided that this is agreed with the Society.

3.1.3 The IMP performed at periodical intervals does not prevent the Naval Authority from carrying out occasional inspections and maintenance as a result of an unexpected failure or event which may affect the hull or hull equipment condition.

Interested parties are also reminded that any damage to the ship which may affect the class is to be reported to the Society.

3.2 General scope of IMP

3.2.1 The IMP is to cover at least the following areas/items:

- deck area structure
- access hatches
- deck fittings
- steering gear
- superstructures
- shell plating
- tanks, including peaks,
- rudders
- sea connections and overboard discharges
- sea chests
- propellers.

3.3 Periodicity of inspections

3.3.1 Inspections are to be carried out at least with the following periodicity:

- Type 1: two inspections every year, with the following principles:
  - one inspection is to be carried out outside the window provided for the execution of the annual class survey, in the vicinity of the halfway date of the anniversary date interval
  - the other inspection is to be carried out preferably not more than two months before the annual class survey is conducted
  - the minimum interval between any two consecutive inspections of the same item is to be not less than four months.
- Type 2: inspection at annual intervals, preferably not more than four months before the annual class survey is carried out.
- Type 3: inspection at bottom surveys.

3.3.2 The following areas/items are to be inspected with a periodicity of Type 1:

- deck area structure
- shell plating above waterline
- hatches
- deck equipment
- superstructures
- ballast tanks, including peaks
- dry holds and spaces
- other accessible spaces
- sea connections and overboard discharges.

For ships less than 6 years old, 25% in number of ballast tanks (with a minimum of one) are to be inspected annually, in rotation, so that all ballast tanks are inspected at least once during the 6-year class period.

For ships 6 years old or more, all ballast tanks are to be inspected annually.

3.3.3 The following areas are to be inspected with a periodicity of Type 2:

- bunker and double bottom fuel oil tanks
- fresh water tanks
- cargo tanks, if any.

3.3.4 Whenever the outside of the ship's bottom is examined in drydock or on a slipway, inspections are to be carried out on the following items:

- rudders
- propellers
- bottom plating
- sea chests and anodes.

In addition, the requirement under Pt A, Ch 2, Sec 2, [5.4.2] is to be complied with.

3.4 Extent of inspections

3.4.1 Deck area structure

The deck plating and structures over deck, as applicable, are to be visually examined for assessment of the coating, and detection of fractures, deformations and corrosion.

When structural defects affecting the class (such as fractures or deformations) are found, the Society is to be called by the Naval Authority for occasional survey attendance. If such structural defects are repetitive in similar areas of the deck, a program of additional close-up surveys may be planned at the Society's discretion for the next inspections.

In other cases, such as coating found in poor condition, repairs or renewal are to be dealt with, or a program of maintenance is to be set by the Naval Authority in agreement with the Society, at a suitable time, but at the latest at the next intermediate or class renewal survey, whichever comes first.

3.4.2 Hatches

Hatches are to be visually examined, in particular tightness devices, locking arrangements and coating condition, as well as signs of corrosion.

Any defective tightness device or securing/locking arrangement is to be dealt with. Operating devices of hatch covers are to be maintained according to the manufacturer's requirements and/or when found defective.

For structural defects or coating found in poor condition, refer to [3.4.1].

3.4.3 Deck fittings

The inspection of deck fittings is to cover at least the following items:

- Piping on deck

  A visual examination of piping is to be carried out, with particular attention to coating, external corrosion, tightness of pipes and joints (examination under pressure), valves and piping supports. Operation of valves is to be checked.

  Any defective tightness, supporting device or valve is to be dealt with.

- Vent system

  A visual examination of the vent system is to be carried out. Dismantling is to be carried out as necessary for checking the condition of closure (flaps, balls) and clamping devices and of screens.

  Any defective item is to be dealt with.

- Ladders, guard rails, bulwarks, walkways

  A visual examination is to be carried out with attention to the coating condition (as applicable), corrosion, deformation or missing elements.

  Any defective item is to be dealt with.

- Anchoring and mooring equipment

  A visual examination of the windlass, winches, capstans, anchor and visible part of the anchor chain is to be carried out. A working test is to be effected by lowering a sufficient length of chain on each side and the chain lengths thus ranged out are to be examined (shackles, studs, wastage).

  Any defective item is to be dealt with. For replacement of chains or anchors, the Society is to be requested for attendance.

  The manufacturer's maintenance requirements, if any, are to be complied with.

- Other deck fittings

  Other deck fittings are to be visually examined and dealt with under the same principles as those detailed in the items above according to the type of fitting.

3.4.4 Steering gear

The inspection of the installation is to cover:

- examination of the installation
- test with main and emergency systems
- changeover test of working rams.

3.4.5 Superstructures

The structural part of superstructures is to be visually examined and checked under the same scope as that required for deck structure.

The closing devices (doors, windows, ventilation system, skylights) are to be visually examined with attention to tightness devices and checked for their proper operation.

Any defective item is to be dealt with.

3.4.6 Shell plating

The shell plating, sides and bottom, are to be visually examined for assessment of the coating, and detection of fractures, deformations and corrosion.

When structural defects affecting the class (such as fractures or deformations) are found, the Society is to be called for occasional survey attendance. If such structural defects are repetitive in similar areas of the shell plating, a program of additional close-up surveys may be planned at the Society's discretion for the next inspections.

In other cases, such as coating found in poor condition, repairs or renewal are to be dealt with, or a program of maintenance is to be set by the Naval Authority in agreement with the Society, at a suitable time, but at the latest at the next intermediate or class renewal survey, whichever comes first.

3.4.7 Ballast tanks

Ballast tanks, including peaks, are to be overall surveyed with regards to:

- structural condition (fractures, deformations, corrosion)
- condition of coating and anodes, if any
- fittings such as piping, valves.

A program of close-up survey may also be required, depending on the results of the structural analyses and the hot spot map.

When structural defects affecting the class are found, the Society is to be called for occasional survey attendance. If such structural defects (such as fractures or deformations) are repetitive in similar structures in the same ballast tanks or in other ballast tanks, a program of additional close-up survey may be planned at the Society's discretion for the next inspections.

In other cases, such as coating found in poor condition or anodes depleted, repairs or renewal are to be dealt with, or a program of maintenance is to be set by the Naval Authority in agreement with the Society, at a suitable time, but at the latest at the next intermediate or class renewal survey, whichever comes first.

3.4.8 Dry holds and spaces

Dry holds and other spaces such as vehicle decks are to be subjected to overall examination and dealt with in the case of defects, under the same scope as that required for ballast tanks. Attention is also to be given to other fittings, such as bilge wells (cleanliness and working test) and ladders.

A program of close-up survey may also be required, depending on the results of the structural analyses and the hot spot map.

When structural defects affecting the class are found, the Society is to be called for occasional survey attendance. If such structural defects (such as fractures or deformations) are repetitive in similar structures, a program of additional close-up survey may be planned at the Society's discretion for the next inspections.

3.4.9 Other accessible spaces

Other spaces accessible during normal operation of the ship or port operations, such as cofferdams, void spaces, pipe tunnels and machinery spaces are to be examined and dealt with under the same scope as that required for dry holds and spaces.

Consideration is also to be given to the cleanliness of spaces where machinery and/or other equivalent equipment exist which may give rise to leakage of oil, fuel water or other leakage (such as main and auxiliary machinery spaces and steering gear space).

3.4.10 Rudder(s)

A visual examination of rudder blade(s) is to be carried out to detect fractures, deformations and corrosion. Plugs, if any, have to be removed for verification of tightness of the rudder blade(s). Thickness measurements of plating are to be carried out in case of doubt. Access doors to pintles (if any) have to be removed. Condition of pintle(s) has to be verified. Clearances have to be taken.

Condition of connection with rudder stock is to be verified.

Tightening of both pintles and connecting bolts is to be checked.

3.4.11 Sea connections and overboard discharges

A visual external examination of sea inlets, outlet corresponding valves and piping is to be carried out in order to check tightness. An operation test of the valves and manoeuvring devices is to be performed.

Any defective tightness and/or operability is to be dealt with.

3.4.12 Sea chests

Sea chests have to be examined with regards to:

- structural condition (fractures, deformations, corrosion)
- condition of cleanliness, coating and anodes
- visual examination of accessible part of piping or valve.

3.4.13 Propellers

A visual examination of propeller blades, propeller boss and propeller cap is to be carried out as regards fractures, deformations and corrosion. For variable pitch propellers, absence of leakage at the connection between the blades and the hub is to be also ascertained.

Absence of leakage of the aft tailshaft sealing arrangement is to be ascertained.

3.4.14 Cargo tanks, bunker and double bottom fuel oil tanks, fresh water tanks, as applicable

Bunker and double bottom fuel oil tanks are to be overall surveyed with regards to:

- structural condition (fractures, deformations, corrosion)
- condition of coating and anodes, if any
- fittings such as piping, valves.

Cargo tanks, if any, are to be overall surveyed with regards to:

- structural condition (fractures, deformations, corrosion)
- condition of coating and anodes, if any
- fittings such as piping, valves.

A program of close-up survey may also be required, depending on the results of the structural analyses and the hot spot map.

When structural defects affecting the class are found, the Society is to be called for occasional survey attendance. If such structural defects (such as fractures or deformations) are repetitive in similar structures in the same tank or in other tank, a program of additional close-up survey may be planned at the Society's discretion for the next inspections.

In other cases, such as coating found in poor condition, repairs or renewal are to be dealt with, or a program of maintenance is to be set by the Naval Authority in agreement with the Society, at a suitable time, but at the latest at the next intermediate or class renewal survey, whichever comes first.

3.5 Inspection reports

3.5.1 Inspection reports are to be prepared by the person responsible after each survey. They are to be kept on board and made available to the Surveyor at his request. An electronic form is to be used for this purpose (see [1.3]).

A copy of these reports is to be transmitted to the Naval Authority's offices, for the records and updating of the ship database.

3.5.2 The inspection reports are to include the following.

- General information such as date of inspection/maintenance, identification of the person performing the inspection with his signature, identification of the area/space/equipment inspected.
- For inspection of structural elements (deck area, hatches, superstructures, ballast tanks, dry holds and spaces, other spaces), the report is to indicate:
  - coating condition of the different boundaries and internal structures and, if any, coating repairs
  - structural defects, such as fractures, corrosion (including pitting), deformations, with the identification of their location, recurrent defects
  - condition of fittings related to the space inspected, with description as necessary of checks, working tests, dismantling, overhaul
- For inspection of equipment (deck equipment, sea connections and overboard discharges), the report is to indicate the results of visual examination, working tests, dismantling, repairs, renewal or overhaul performed.

3.5.3 When deemed necessary or appropriate, the report is to be supplemented by documents, sketches or photographs, showing for example:

- location and dimension of fractures, pitting, deformations
- condition of equipment before repairs
- measurements taken if required by the Society.

3.5.4 Models of inspection reports for structural elements and equipment are given in Ch 2, App 5.

These models are to be used as a guide for entering the collected data into the ship database, in an electronic form.

3.6 Changes to Inspection and Maintenance Plan

3.6.1 Changes to ship operation, review of the inspection and maintenance reports, possible subsequent changes to the hot spot map and corrosion rates different than those expected may show that the extent of the maintenance performed needs to be adjusted if any by the Naval Authority to improve its efficiency.

Where more defects are found than would be expected, it may be necessary to increase the extent and/or the frequency of the maintenance program. Alternatively, the extent and/or the frequency of the maintenance may be reduced subject to documented justification.

4 Acceptance criteria

4.1 Coating assessment

4.1.1 Criteria

The acceptance criteria for the coating condition of each coated space is indicated in Tab 2.

Where acceptance criteria are not fulfilled, coating is to be repaired.

4.1.2 Repairs

The procedures for repairs of coatings are to follow the coating manufacturer's specification for repairs, under the Naval Authority's responsibility.

Table 2 : Acceptance criteria for coatings

Condition	Acceptance criteria
Ships less than 12 years old	Coatings in GOOD condition
Ships 12 years old or more	Coatings in GOOD or FAIR condition
Note 1: GOOD : Only minor spot rusting FAIR : Local breakdown at edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition POOR : General breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration.	

4.2 Sacrificial anode condition (as applicable)

4.2.1 Criteria

The acceptance criteria for sacrificial anodes in each coated space fitted with anodes is indicated in Tab 3 in terms of percentage of losses in weight.

Where acceptance criteria are not fulfilled, sacrificial anodes are to be renewed.

Table 3 : Acceptance criteria for sacrificial anodes

Condition	Percentage of loss in weight
Ships less than 12 years old	less than 25
Ships 12 years old or more	less than 50

4.3 Thickness measurements (applicable only if required by the Society on case by case basis)

4.3.1 General

The acceptance criteria for measured thicknesses are indicated in:

- Ch 2, App 1 for isolated areas of items (for example a localized area of a plate)
- Ch 2, App 2 for items (for example a plating panel or an ordinary stiffener)
- Ch 2, App 3 for zones (for example the bottom zone).

When the acceptance criteria are not fulfilled, actions according to [4.3.2] to [4.3.4] are to be taken.

4.3.2 Isolated area

The thickness diminution of an isolated area of an item is the localized diminution of the thickness of that item such as, for example, the grooving of a plate or a web or a local severe corrosion. It is expressed as a percentage of the relevant as built thickness.

It is not to be confused with pitting (see [4.4]).

If the criteria of acceptable diminution are not fulfilled for an isolated area, then this isolated area is to be repaired or replaced. In any case, the criteria of thickness diminution are to be considered for the corresponding item (see [4.3.3]).

4.3.3 Item

For each item, thicknesses are measured at several points and the average value of these thicknesses is to satisfy the acceptance criteria for the relevant item.

If the criteria of measured thicknesses are not fulfilled for an item, then this item is to be repaired or replaced. Where the criteria are fulfilled but substantial corrosion as defined in Pt A, Ch 2, Sec 2, [3.2.7] is found, the IMP is to be adjusted to increase the frequency and/or extent of the maintenance program. In any case, for the items which contribute to the hull girder longitudinal strength, the criteria in [4.3.4] are to be considered.

4.3.4 Zone

For consideration of the hull girder longitudinal strength, the transverse section of the ship is divided into three zones:

- deck zone
- neutral axis zone
- bottom zone.

The sectional area diminution of a zone, expressed as a percentage of the relevant as built sectional area, is to fulfil the criteria of acceptable diminution for that zone.

If the criteria of acceptable diminution are not fulfilled for a zone, then some items belonging to that zone are to be replaced (in principle, those which are most worn) in order to obtain after their replacement an increased sectional area of the zone fulfilling the relevant criteria.

4.4 Pitting

4.4.1 Pitting intensity

The pitting intensity is defined by the percentage of area affected by pitting.

The diagrams in Ch 2, App 4 are to be used to identify the percentage of area affected by pitting and thus the pitting intensity.

4.4.2 Acceptable wastage

The acceptable wastage for a localised pit (intensity ≤ 3%) is 23% of the average residual thickness.

For areas having a pitting density of 50% or more, the acceptable wastage in pits is 13% of the average residual thickness.

For intermediate values (between localised pit and 50% of affected area), the acceptable wastage in pits is to be obtained by interpolation between 23% and 13% of the average residual thicknesses (see Tab 4).

Table 4 : Pitting intensity and corresponding acceptable wastage in pits

Pitting intensity, in % (see Ch 2, App 4)	Acceptable wastage in pits, in percentage of the average residual thickness
≤ 3	23
5	22
10	21
15	20
20	19
25	18
30	17
40	15
50	13

4.4.3 Repairs

Application of filler material (plastic or epoxy compounds) is recommended as a mean for stopping/reducing the corrosion process but this is not an acceptable repair for pitting exceeding the maximum permissible wastage limits.

Welding repairs may be accepted when performed in accordance with agreed procedures.

4.5 Fractures

4.5.1 General

Fractures are found, in general, at locations where stress concentrations occur.

In particular, fractures occur at the following locations:

- beginning or end of a run of welding
- rounded corners at the end of a stiffener
- traces of lifting fittings used during the construction of the ship
- weld anomalies
- welding at toes of brackets
- welding at cut-outs
- intersections of welds
- intermittent welding at the ends of each length of weld.

The structure under examination is to be cleaned and provided with adequate lighting and means of access to facilitate the detection of fractures.

If the initiation points of the fractures are not apparent, the structure on the other side of the plating is to be examined.

4.5.2 Criteria

Where fractures are detected, the Society’s Surveyor is always to be called by the Naval Authority for attendance.

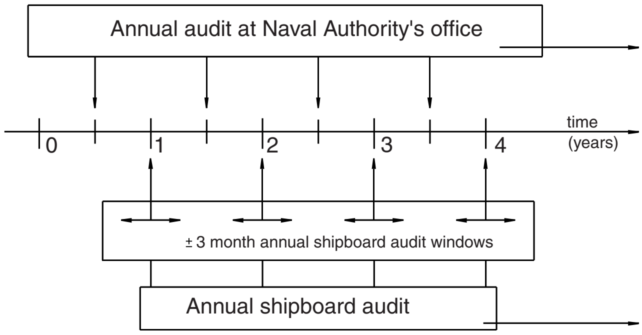
5 Maintenance of the notation

5.1 Annual audit at the Naval Authority's offices

5.1.1 The audit is to be carried out annually preferably within the prescribed six-month window as shown in Fig 1.

If two or more ships belonging to the same Naval Authority are assigned the **STAR-HULL** notation, this annual audit may be performed for all ships at the same time in a suitable period agreed between the Naval Authority and the Society.

Figure 1 : Audit periodicity



5.1.2 The Surveyor checks that the ship database held at the Naval Authority's offices is kept updated, in particular with the inspection and maintenance reports of the IMP.

A preliminary evaluation on how the IMP is applied may be done on the basis of the data and information collected during this audit and the data received from the ship.

Depending on this evaluation, the Society may call for:

- an occasional survey on board the ship by a Surveyor of the Society to be carried out as soon as possible
- corrective actions to be taken by the Naval Authority in applying the IMP.

5.1.3 The annual audit at the Naval Authority's offices performed before the commencement of the class renewal survey is to include the planning required for this survey (see [5.2.2]).

5.2 Annual shipboard audit

5.2.1 The annual shipboard audit is to be carried out concurrently with the annual survey.

5.2.2 During this audit the Surveyor:

- verifies that the ship database is kept updated and transmitted to the Naval Authority's offices
- verifies the consistency and implementation of the IMP
- carries out additional inspections relevant to hull (structure and equipment), if required as a result of the audit at the Naval Authority's offices.

5.3 Class renewal survey

5.3.1 The survey for the renewal of the **STAR-HULL** notation is to be carried out concurrently with the class renewal survey.

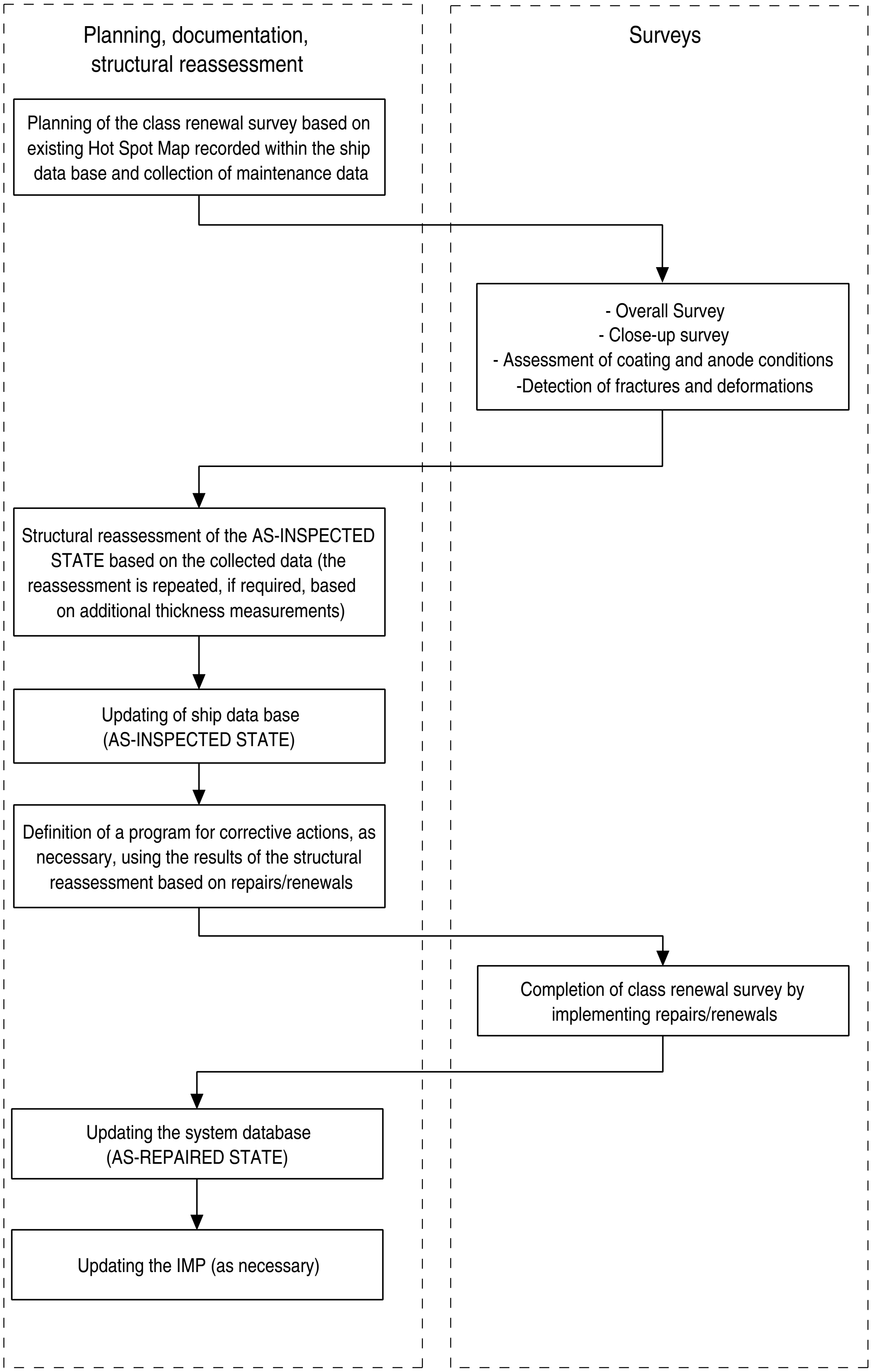
The documentation to be prepared, the surveys to be carried out and the structural reassessment to be done in connection with the class renewal survey are summarised in the flowchart shown in Fig 2.

5.3.2 The planning of the class renewal survey is to be prepared in advance of the survey by the Naval Authority in cooperation with the Society. This planning is preferably to be agreed during the annual audit at the Naval Authority's offices performed approximately eighteen months before the due date of the class renewal survey (see [5.1.3]).

The planning is to include the following information:

- conditions for survey
- provisions and methods for access to structures
- equipment for survey
- indication of spaces and areas for internal examination, overall survey and close-up survey
- indication of tanks to be tested
- indication of areas to be checked for fatigue fracture detection (see [5.3.3]).

Figure 2 : Actions to be taken in connection with the Class Renewal Survey



It is to take account of:

- the results of the IMP held by the Naval Authority during the current class period, as well as the class surveys carried out during the same period
- the scope of the class renewal survey as required in Pt A, Ch 3, Sec 3 and Part A, Chapter 4, as applicable to the ship concerned
- the additional requirements related to the **STAR-HULL** notation as indicated in [5.3.3].

5.3.3 In addition to the scope of the class renewal survey as required for the ship concerned, the following is to be carried out:

- an annual shipboard audit as detailed in [5.2]
- the assessment of the condition of coating and anodes if any
- the close-up survey as required in the survey planning as a result of the previous structural assessment required by the Society on case by case basis
- a specific survey for fatigue fracture detection in accordance with the planning as a result of the previous hot spot map.

5.3.4 On the basis of the results of the surveys, additional visual examination and fatigue fracture detection carried out as indicated in [5.3.3], the "as-inspected state" of the ship is established. A structural reassessment of the "as-inspected state" is performed according to the criteria in Ch 2, App 2. This state may be progressively updated based on the results of additional inspections and/or thickness measurements required on the basis of the first "running" of the analysis.

Once the final "as-inspected state" is established, a program of corrective actions is defined and planned, which may consist of:

- structural renewals
- repairs of structural defects (fractures, deformations, etc.)
- repairs/renewals of coating and/or anodes, if any.

in order to ensure that the ship continues to comply with the acceptance criteria given in Article [4]. In addition, the IMP may be modified if needed.

5.3.5 The corrective actions are to be surveyed by a Surveyor of the Society. Subsequently a new "as-repaired state" of the ship is obtained, including an updated hot spot map.

5.4 Suspension and withdrawal of the notation

5.4.1 The maintenance of the **STAR-HULL** notation is subject to the same principles as those for the maintenance of class: surveys are to be carried out by their limit dates and possible recommendations (related to the notation) are to be dealt with by their limit dates.

The suspension of class automatically causes the suspension of the **STAR-HULL** notation.

5.4.2 Various events may lead either to imposition of a recommendation related to the **STAR-HULL** notation or to suspension of the notation itself. Some cases are given below.

- The condition of the ship is below the minimum level required for class (e.g. scantling of a hull structure below the corrosion margin acceptable for the class around hot spot areas). The action to be taken is either the immediate repair or the imposition of a recommendation for the class (if acceptable) and suspension of the **STAR-HULL** notation. However, in cases where the recommendation is of a minor nature, the notation may not be suspended.
- The Inspection and Maintenance Plan is not complied with (e.g. delays in performing the operations programmed according to the plan or the scope of inspection and/or maintenance not completely fulfilled), and/or the maintenance of the database is not fulfilled.

  The action to be taken is:

  - either the immediate compliance with the requirements or the imposition of a recommendation if the non-conformity is of a minor nature or is an exceptional occurrence
  - or the suspension of the **STAR-HULL** notation if the non-conformity is of a major nature or a recurrence.
- A defect or a deficiency is found in applying the IMP. The actions to be taken are the same as stated both for repair of structure/coating/equipment (first two cases above) and for the application of the IMP (third case above).
- An unexpected defect or deficiency is found or an accident occurs, i.e. not as a result of lack of maintenance or failure in the application of the IMP. The actions to be taken are the same as stated for repair of structure/coating/equipment (first two cases above).

5.4.3 The withdrawal of the **STAR-HULL** notation may be decided in different cases, such as:

- recurrent suspension of the **STAR-HULL** notation
- suspension of the **STAR-HULL** notation for more than a given period (i.e. 3 months)
- expiry or withdrawal of class.

Section 2 Star-Mach

1 General

1.1 Principles

1.1.1 Application

The additional class notations **STAR-MACH** and **STAR-MACH-PMS** are assigned, in accordance with Pt A, Ch 1, Sec 2, [6.3.3] to ships complying with the requirements of this Section.

1.1.2 Inspection and Maintenance Plan

The **STAR-MACH** notation reflects the fact that a procedure including periodic and corrective maintenance, condition-monitoring as well as periodic and occasional inspections of machinery installations and equipment (hereinafter referred to as the Inspection and Maintenance Plan) is operated on board and at the Naval Authority's offices.

The implementation of the Inspection and Maintenance Plan is verified by the Society through:

- a risk analysis, initially performed by the Society in order to identify tentatively critical machinery and equipment items covered in the Inspection and Maintenance Plan, and periodically updated to analyse the performance of these items on the basis of the information stored in the ship database, requiring suitable modifications of the inspection and maintenance intervals, if needed
- periodic examination of the data recorded by the Naval Authority and made available to the Society through an electronic ship database suitable for consultation and analysis; and
- periodic audits carried out by the Society at Naval Authority's offices and on board.

1.1.3 Risk analysis

The purpose of the risk analysis is to assess the inspection and maintenance process taking into account the consequences if a system fails.

The risk analysis is to include at least the machinery and equipment which are identified in [2.1]. The Society, in consultation with the Naval Authority, may extend the scope of the risk analysis to other equipment or systems which are considered critical, depending on the ship's characteristics.

For the purpose of the risk analysis, instruction manuals, spare parts and tools are assumed to be available, when needed.

1.1.4 Class renewal survey

The assignment of the **STAR-MACH** and **STAR-MACH-PMS** notations imply that the class renewal surveys of machinery are carried out by applying the planned maintenance scheme (PMS) described in Pt A, Ch 2, Sec 2. The procedure of recognizing surveys carried out by the Chief Engineer, as indicated in Pt A, Ch 2, Sec 2 when CMS or PMS schemes are adopted, is also applied.

The combination of the Inspection and Maintenance Plan implemented by the Naval Authority and the risk analysis carried out by the Society enables to improve the planned maintenance scheme (PMS), as described in Pt A, Ch 2, Sec 2. For instance, it is possible to allow the inspection of a machinery item based on running hours to be performed at intervals exceeding five years, based on its actual conditions and performances on board.

1.1.5 Manufacturer's recommendations

The **STAR-MACH** notation has by no means to be considered a relapsation or a variation of the type and timing of maintenance recommended by the Manufacturer.

Any possible change or optimization of the original maintenance scheme may be considered only after the expiry of the Manufacturers' warranty period, once that all involved machinery and equipment are set in service and the information relative to the maintenance and performance of various machinery and equipment are collected and elaborated, as necessary, in consultation with the Manufacturer, at Naval Authority's request.

1.2 Conditions for the assignment and maintenance of the notation

1.2.1 Assignment of the notation

The procedure for the assignment of the **STAR-MACH** notation is the following:

- a request for the notation is to be sent to the Society

- the following documentation is to be submitted to the Society by the Interested Party:
  - plans and documents of machinery and equipment (see [2.1])
  - the Inspection and Maintenance Plan to be implemented by the Naval Authority during the ship life (see [2.2]), and
  - information concerning the ship database and relevant electronic support to be implemented by the Naval Authority during the ship life (see [1.3.1])
- the Society performs the risk analysis for the ship and its plants, based on the documentation submitted
- the Society reviews and approves the Inspection and Maintenance Plan, taking into account the results of the above-mentioned risk analysis as well as the information concerning the ship database
- the Society carries out an initial shipboard audit to verify the compliance of the procedures on board with respect to the submitted documentation.

1.2.2 Maintenance of the notation

The maintenance of the **STAR-MACH** notation is based on a risk analysis review (see [3.2]) and the following surveys to be carried out by the Society, according to the scope and periodicity given in [5]:

- annual audit at the Naval Authority's offices (see [5.1])
- annual shipboard audit (see [5.2])
- occasional shipboard audits/surveys (see [5.3]) triggered by:
  - risk analysis results
  - changes to ship operations
  - non-conformities.

1.3 Ship database

1.3.1 The ship database, to be available on board and at the Naval Authority's offices, using an electronic support suitable for consultation and analysis, is to include at least the following information:

- the documents required for the Inspection and Maintenance Plan, as indicated in [2.2], and the corresponding reports during the ship operation, as indicated in [4.2]
- the results of the risk analysis.

1.3.2 The ship database is to be:

- updated by the Naval Authority each time new inspection and maintenance data from the ship are available
- kept by the Naval Authority.

Access to the database is to be logged, controlled and secured.

The ship database is to include a back up system in order that the data can be readily restored, if needed.

1.3.3 The ship database is to be made available to the Society.

The ship database is to be transmitted to the Society at least every six months. When agreed between the Naval Authority and the Society, the required data may be automatically discharged into a Society's database.

1.3.4 The data provided in accordance with [1.3.3] will be used to carry out the risk analysis.

1.3.5 As the risk analysis is subject to be reviewed and updated by the Society during the ship's life, the software used by the Naval Authority is to be compatible with the one used by the Society, in order to make possible the review and updating of the risk analysis results.

2 Documentation to be submitted

2.1 Plans, documents and specifications

2.1.1

a) The plans and documents necessary to assign the **STAR-MACH** notation are to include at least the machinery and equipment listed in Tab 1.

b) For a new ship, the plans and documents listed in Tab 1 do not need to be duplicated with respect to the documents requested for the purpose of classification in Part C.

c) The plans are to be supplemented by Manufacturer's specifications, including the list of relevant equipment and accessories and instructions for their use.

d) The Society may request additional documents or information, when needed.

2.2 Inspection and Maintenance Plan (IMP)

2.2.1 The Inspection and Maintenance Plan is to include at least the following information:

- the list of machinery and equipment covered, including at least the ones listed in Tab 1
- for each item of machinery and equipment:
  - Manufacturer's maintenance instruction book, taking into consideration the scheme recommended by the Manufacturer (see [1.1.5])
  - details relevant to the type of maintenance (e.g. inspection, reconditioning, overhauls, spare parts)
  - maintenance frequency (i.e. running hours, calendar days, weeks, months, years)
  - condition monitoring scheme, where applied
  - place of maintenance execution (e.g. in port, at sea)
  - utilisation rate, running hours and type of service (e.g. heavy, light)
  - procedures foreseen for repairs, overhauling or substitution
- names and qualification of personnel authorized to carry out the duties foreseen by the Inspection and Maintenance Plan (see [4.4])
- procedures for the storage and backup of records and any other relevant information (see [1.3])
- procedure for modification and approval of the plan based on feedback experience and Manufacturer's consultation, as necessary.

Table 1 : List of machinery and equipment for which plans and documents are requested

No.	ITEM
1	General arrangement plan
2	Propulsion plant, including (if applicable): • diesel engines • steam or gas turbines • electric motors for propulsion • gearing • shafting, including bearings and accessories • propellers
3	Steam production and distribution, including (if applicable): • main propulsion boilers and related accessories • main condenser for propulsion boiler • main propulsion steam system including pumps, pipes, valves, filters, etc.
4	Fuel oil heating system, if essential for propulsion, including (if applicable): • steam heaters, including their accessories • thermal oil heaters, including their accessories • electrical plant supplying the electrical heaters
5	Fuel oil system, including: • purifiers • piping system
6	Lubricating oil system, including: • purifiers • coolers (if applicable) • piping system
7	Cooling water system, including: • sea water system • low and high temperature fresh water system • piping system
8	Compressed air system, including compressors and their prime movers and related piping
9	Steering gear, including all equipment and systems necessary for its control
10	Bilge system
11	Ballast system
12	Electricity production and distribution system, including prime movers, generators, cables protections and main switchboard
13	Air ventilation system serving the machinery spaces
14	Fire prevention, detection and fighting system
15	Exhaust gas system
16	Automation and control systems, including information on the possibility for the system to be disconnected in case failure allowing the manual control
17	Any other system or equipment connected in such a way that any single failure of it or part of it might affect the functionality of one of the system, machinery or equipment covered by the risk analysis

3 Risk analysis

3.1 Initial risk analysis

3.1.1 Scope

The scope of the initial risk analysis, to be carried out by the Society in order to assign the **STAR-MACH** notation, is:

- identify critical systems and/or components
- assess the Inspection and Maintenance Plan with regards to currently accepted levels of risk
- recommend measures to improve the type and/or periodicity of inspection and maintenance, when deemed necessary.

3.1.2 Process

The overall process followed by the risk analysis is described in Ch 2, App 6.

3.2 Risk analysis review

3.2.1 Scope

The initial risk analysis carried out in accordance with [3.1] will be kept up-to-date by the Society, on the basis of the information and data gathered from the ship database (see [2.2]), for instance relevant to the actual inspection and maintenance, including failures and repairs, if any.

Where deemed necessary, the updated data will be introduced in the logic probabilistic model for a re-evaluation of the critical systems and components.

When the reviewed risks show a significant deviation from those identified by the initial risk analysis, the Society will recommend modification of the Inspection and Maintenance Plan, for instance in terms of type and periodicity of maintenance (see [2.2]).

3.2.2 Major alterations

In the case of major alterations of the machinery and equipment covered by the **STAR-MACH** notation, the logic probabilistic model defined in accordance with [3.1] will be updated to suit the new arrangements on board.

4 Inspection and Maintenance Plan

4.1 General

4.1.1 The Inspection and Maintenance Plan (e.g. type and frequency of maintenance) is based on the Manufacturer's recommendations, documented experience, condition monitoring and results of the risk analysis (see [3]).

4.2 Inspection and maintenance reports

4.2.1 Inspection and maintenance reports are to be done by the responsible person after each inspection/maintenance operation. They are to be kept on board and made available to the Surveyor on his request. An electronic form is to be used for that purpose (see [1.3]).

A copy of these reports is to be transmitted to the Naval Authority's Office, for their records and updating of the ship data base.

4.2.2 The inspection/maintenance reports are to include:

- running hours and type of service, as applicable (heavy, light)
- frequency of maintenance, timing, time spent for the preventative maintenance
- details relative to the corrective maintenance (overhauls, spare parts, idle time, time between two different stops for maintenance, parts changed and parts reconditioned)
- trend of condition monitoring parameters, where applied
- in case of failure:
  - information on mode and reason of failure
  - time out of service
  - type of repair carried out.

4.3 Changes to the Inspection and Maintenance Plan

4.3.1 Changes to ship operation, condition monitoring, risk analysis review, or any other documented justification may demonstrate that the Inspection and Maintenance Plan needs to be adjusted to improve its efficiency. Where more defects are found than it would be expected, it may be necessary to increase the extent and/or the frequency of the maintenance programme. Alternatively, the extent and/or the frequency of the maintenance may be subject to documented justification and Manufacturer's consultation.

4.4 Responsible persons

4.4.1 The person on board responsible for the collection and process of maintenance data within the scope of the Inspection and Maintenance Plan is to be authorized by the Society in accordance with the procedure established for the recognition of machinery surveys carried out by Chief Engineers (see Part A).

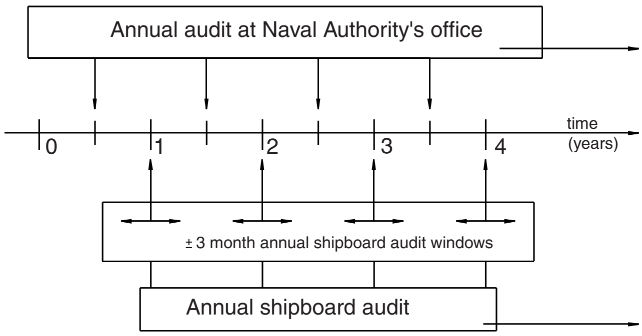
5 Maintenance of the notation

5.1 Annual audit at the Naval Authority's offices

5.1.1 The audit is to be carried out annually preferably within the prescribed six-month window as shown in Fig 1.

If more than one ship belonging to the same Owner are assigned the **STAR-MACH** notation, this annual audit may be performed for all ships at the same time at a suitable period agreed between the Owner and the Society.

Figure 1 : Audit periodicity



5.1.2 The Surveyor checks that the ship data base held at Owner's office is kept updated, in particular with the inspection and maintenance reports of the Inspection and Maintenance Plan.

From the data collected during this audit and data received from the ship, a preliminary review is done. This review may lead to extending the scope of the audit and/or an occasional machinery survey on board the ship, specifically for machinery the performance of which is deteriorating. The audit includes the examination of:

- preventive maintenance records
- corrective maintenance records
- predictive maintenance records, that is, planning records about outstanding inspections or other actions for the forthcoming period.

5.2 Annual shipboard audit

5.2.1 The annual shipboard audit is to be carried out concurrently with the annual survey.

5.2.2 During this audit the Surveyor:

- verifies that the ship data base is kept updated and transmitted to the Owner's office
- verifies the consistency and implementation of the Inspection and Maintenance Plan
- carries out additional inspections and/or tests relevant to machinery, if required as a result of the audit at the Owner's office.

5.3 Occasional onboard audits and/or surveys

5.3.1 Occasional audits may be required after audits at the Owner's offices that showed the Inspection and Maintenance Plan has not been applied or working in the manner intended, or that particular equipment showed abnormal behaviour.

5.3.2 The Society is to be notified when an item is due to be repaired on a non-scheduled basis because of failure. The notification is to include the place, time and specification of the corrective action which has to be executed. The Society will decide whether to carry out an occasional on board survey.

5.3.3 Changes to the operation of the ship and/or modifications to machinery and/or equipment are to be notified to the Society, so that:

- a survey onboard the ship may be carried out to verify the changes and modifications
- the effects of the changes and modifications could be taken into consideration, if deemed necessary, during the next risk analysis
- an immediate revision of the Inspection and Maintenance Plan is conducted, if deemed necessary.

The effects of any changes in relation to the Inspection and Maintenance Plan are monitored during the next annual shipboard audit.

5.4 Suspension and withdrawal of the notation

5.4.1 The maintenance of the **STAR-MACH** notation is subject to the same principles as those for the maintenance of class: surveys are to be carried out by their limit dates, possible recommendations (related to the notation) are to be dealt with by their limit dates.

The suspension of class automatically causes the suspension of the **STAR-MACH** notation.

5.4.2 Different events may lead either to imposition of a recommendation related to the **STAR-MACH** notation or to suspension of the notation itself. Some cases are given below:

a) The condition of the machinery installations is below the minimum level required for class. The action to be taken is either the immediate repair or the imposition of a recommendation for class (if acceptable) and suspension of the **STAR-MACH** notation. However, in cases where the recommendation is of a minor nature, the notation may not be suspended.

b) The Inspection and Maintenance Plan is not complied with (e.g. delays in performing the operations programmed according to the plan or the scope of inspection and/or maintenance not completely fulfilled), and/or the maintenance of the data base is not fulfilled.

   The action to be taken is:

   - either the immediate compliance with the requirements or the imposition of a recommendation, if the non-conformity is of a minor nature or is an exceptional occurrence, or
   - the suspension of the **STAR-MACH** notation, if the non-conformity is of a major nature or a recurrence.

c) A defect or a deficiency is found in applying the Inspection and Maintenance Plan. The actions to be taken are the same as stated above both for repair of machinery installations (case a) above) and for the application of the Inspection and Maintenance Plan (case b)).

d) An unexpected defect or deficiency is found or a casualty occurs, i.e. not as a result of lack of maintenance or failure in the application of the Inspection and Maintenance Plan. The actions to be taken are the same as stated in the case a) above.

5.4.3 The withdrawal of the **STAR-MACH** notation may be decided in different cases, such as:

- recurrent suspension of the **STAR-MACH** notation
- suspension of the **STAR-MACH** notation for more than a given period (i.e. 3 months)
- expiry or withdrawal of class.

Appendix 1 Acceptance Criteria for Isolated Areas of Items

1 General

1.1 Application

1.1.1 The acceptance criteria consist in checking that the thickness diminution of an isolated area of an item (measured according to Ch 2, Sec 1, [4.3.2]) is less than the acceptable limits specified in [1.1.2]. Otherwise, actions according to Ch 2, Sec 1, [4.3.2] are to be taken.

1.1.2 The acceptable limits for the thickness diminution of isolated areas of items contributing to the hull girder longitudinal strength are specified in:

- Tab 1 for the bottom zone items
- Tab 2 for the neutral axis zone items
- Tab 3 for the deck zone items.

The acceptable limits for the thickness diminution of isolated areas of items not contributing to the hull girder longitudinal strength are specified in Tab 4.

Table 1 : Acceptable limits for the thickness diminution of isolated areas of items
Items contributing to the hull girder longitudinal strength and located in the bottom zone

Item			Acceptance limit
Plating of:	• keel, bottom and bilge • inner bottom • lower strake of longitudinal bulkheads		18%
Longitudinal ordinary stiffeners of:	• keel, bottom and bilge • inner bottom • lower strake of longitudinal bulkheads	web	18%
		flange	15%
Longitudinal primary supporting members		web	18%
		flange	15%

Table 2 : Acceptable limits for the thickness diminution of isolated areas of items
Items contributing to the hull girder longitudinal strength and located in the neutral axis zone

Item			Acceptance limit
Plating of:	• side • longitudinal bulkheads • decks		18%
Longitudinals ordinary stiffeners of:	• side • longitudinal bulkheads • decks	web	18%
		flange	15%
Longitudinal primary supporting members		web	18%
		flange	15%

Table 3 : Acceptable limits for the thickness diminution of isolated areas of items
Items contributing to the hull girder longitudinal strength and located in the deck zone

Item			Acceptance limit
Plating of:	• upper deck, stringer plate and sheerstrake • upper strake of longitudinal bulkheads		18%
Longitudinal ordinary stiffeners of:	• upper deck, stringer plate and sheerstrake • upper strake of longitudinal bulkheads	web	18%
		flange	15%
Longitudinal primary supporting members		web	18%
		flange	15%

Table 4 : Acceptable limits for the thickness diminution of isolated areas of items Items not contributing to the hull girder longitudinal strength

Item		Acceptance limit
Hatch coamings	plating	18%
	brackets	22%
Hatch covers	top plating	18%
	side and end plating	18%
	ordinary stiffeners	18%
Plating of transverse bulkheads		18%
Ordinary stiffeners of transverse bulkheads	web	22%
	flange	18%
	brackets	22%
Vertical primary supporting members and horizontal girders of bulkheads	web	18%
	flange	15%
	brackets /stiffeners	18%
Side frames	web	18%
	flange	15%
	brackets / stiffeners	18%
Deck and bottom transverse primary supporting members	web	18%
	flange	15%
	brackets	18%
Plating of the forward and aft peak bulkheads		18%
Ordinary stiffeners of the forward and aft peak bulkheads	web	22%
	flange	18%

Appendix 2 Acceptance Criteria for Isolated Items

Symbols

t_A : As-built thickness of plating, in mm

t_M : Measured thickness of plating, in mm

t_C : Corrosion additions, in mm, defined in Pt B, Ch 4, Sec 2, [3]

t_{C1}, t_{C2} : Corrosion additions, in mm, defined in Pt B, Ch 4, Sec 2, [3] for the two compartments separated by the plating under consideration. For plating internal to a compartment, $t_{C1} = t_{C2} = t_C$

t_R : Overall renewal thickness, in mm, of plating, in mm, defined in:

- [2.2.1] in general
- [4.3.1] for the plating which constitutes primary supporting members

t_{R1} : Minimum renewal thickness, in mm, of plating defined in [2.2.2]

t_{R2} : Renewal thickness, in mm, of plating subjected to lateral pressure or wheeled loads, i.e. the thickness that the plating of a ship in service is to have in order to fulfil the strength check. This thickness is to be calculated as specified in [2.2.3]

t_{R3} : Compression buckling renewal thickness, in mm, i.e. the thickness that the plating of a ship in service is to have in order to fulfil the compression buckling check. This thickness is to be calculated as specified in [2.2.4]

t_{R4} : Shear buckling renewal thickness, in mm, i.e. the thickness that the plating of a ship in service is to have in order to fulfil the shear buckling check. This thickness is to be considered only for ships equal to or greater than 90 m in length and is to be calculated as specified in [2.2.5]

t_G : Rule gross thickness, in mm, of plating, defined in [2.2.6]

$t_{A,W}$: As built thickness of ordinary stiffener web, in mm

$t_{A,F}$: As built thickness of ordinary stiffener face plate, in mm

$t_{M,W}$: Measured thickness of ordinary stiffener web, in mm

$t_{M,F}$: Measured thickness of ordinary stiffener face plate, in mm

w_M : Section modulus, in cm^3, of ordinary stiffeners, to be calculated on the basis of the measured thicknesses of web, face plate and attached plating

w_R : Renewal section modulus, in cm^3, of ordinary stiffeners i.e. the section modulus that an ordinary stiffener of a ship in service is to have to fulfil the yielding check.

$t_{R,W}$: Renewal thickness, in mm, of ordinary stiffener web, i.e. the web thickness that an ordinary stiffener of a ship in service is to have in order to fulfil the buckling check. This thickness is to be calculated as specified in [3.2.2]

$t_{R,F}$: Renewal thickness, in mm, of ordinary stiffener face plate, i.e. the face plate thickness that an ordinary stiffener of a ship in service is to have in order to fulfil the buckling check. This thickness is to be calculated as specified in [3.2.2]

w_G : Rule gross section modulus, in cm^3, of ordinary stiffeners, defined in [3.2.3]

WR_R : Re-assessment work ratio, defined in [4.2.1]

WR_A : As-built work ratio, defined in [4.2.2]

t_{RY} : Yielding renewal thickness, in mm, of primary supporting members, i.e. the thickness that the plating which constitutes primary supporting members of a ship in service is to have in order to fulfil the yielding check. This thickness is to be calculated as specified in [4.3.2]

t_{RB} : Buckling renewal thickness, in mm, of primary supporting members, i.e. the thickness that the plating which constitutes primary supporting members of a ship in service is to have in order to fulfil the buckling check. This thickness is to be calculated as specified in [4.3.3]

E : Young's modulus, in N/mm^2, to be taken equal to:

- for steels in general: $E = 2{,}06.10^5$ N/mm^2
- for stainless steels: $E = 1{,}93.10^5$ N/mm^2

ν : Poisson's ratio. Unless otherwise specified, a value of 0,3 is to be taken into account

R_{eH} : Minimum yield stress, in N/mm^2, of the material, defined in Pt B, Ch 4, Sec 1, [2]

γ_m, γ_R, γ_{K1}, ... , γ_{K9} : Partial safety factors, defined in [1].

1 Partial safety factors

1.1 General

1.1.1 The partial safety factors γ_m and γ_R are defined in:

- Pt B, Ch 7, Sec 1, [1.2] for plating
- Pt B, Ch 7, Sec 2, [1.2] for ordinary stiffeners
- Pt B, Ch 7, Sec 3, [1.3] for primary supporting members.

1.2 Partial safety factors based on the increased knowledge of the structure

1.2.1 General

The partial safety factors γ_{K1}, γ_{K2}, το γ_{K9} take into account the increased knowledge of the structural behaviour obtained through the surveys carried out on in-service ship structures and verification of their performances. Therefore, they have values equal to or less than 1,0 and apply to reduce the partial safety factor on resistance, γ_R, adopted in the strength checks of new ships (see Part B, Chapter 7.

1.2.2 Partial safety factors γ_{K1}, γ_{K2}, γ_{K3} and γ_{K4} for plating

These partial safety factors are to be calculated as specified in:

- [2.2.2] for minimum thicknesses (γ_{K1})
- [2.2.3] for the strength checks of plate panels subjected to lateral pressure or wheeled loads (γ_{K2})
- [2.2.4] for the compression buckling strength checks (γ_{K3})
- [2.2.5] for the shear buckling strength checks (γ_{K4}).

1.2.3 Partial safety factor γ_{K5} for ordinary stiffeners

The partial safety factor for yielding checks of ordinary stiffeners (γ_{K5}) is to be calculated as specified in [3.2.1].

1.2.4 Partial safety factors γ_{K6}, γ_{K7}, γ_{K8} and γ_{K9} for primary supporting members

These partial safety factors are to be calculated as specified in:

- [4.2.1] for reassessment structural analyses (γ_{K6}, γ_{K7})
- [4.3.2] for yielding strength checks (γ_{K8})
- [4.3.3] for buckling strength checks (γ_{K9}).

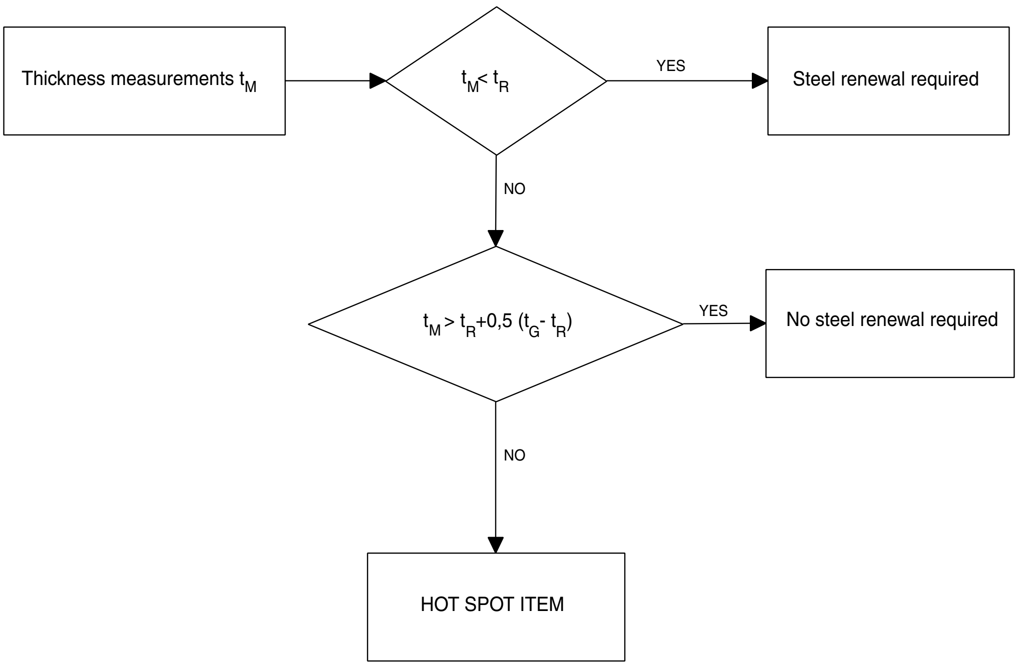
2 Acceptance criteria for plating

2.1 Application

2.1.1 General

The acceptance criteria for measured thicknesses of plating, together with the application procedure to be adopted during the reassessment of hull structures, are indicated in Fig 1.

Figure 1 : Acceptance criteria for measured thicknesses of plating and application procedure



2.2 Renewal thicknesses

2.2.1 Overall renewal thickness

The overall renewal thickness is to be obtained, in mm, from the following formula:

$t_R = \max(t_{R1}, t_{R2}, t_{R3}, t_{R4})$

2.2.2 Minimum renewal thickness

The minimum renewal thickness is to be obtained, in mm, from the following formula:

$t_{R1} = t_1 \gamma_{K1}$

where:

t_1 : Minimum net thickness, in mm, to be calculated as specified in Pt B, Ch 7, Sec 1, [2.2]

γ_{K1} : Partial safety factor: $\gamma_{K1} = N_P \Psi_1$ without being taken greater than 1,0

N_p : Coefficient defined in Tab 1

$$\Psi_1 = 1 + \frac{t_{C1} + t_{C2}}{t_1}$$

Table 1 : Coefficient N_P

Plating	Coefficient N_P
In general, including that which constitutes web of primary supporting members	0,85
Plating which constitutes face plate of primary supporting members	0,89

2.2.3 Renewal thickness of plating subjected to lateral pressure or wheeled loads

The renewal thickness of plating subjected to lateral pressure or wheeled loads is to be obtained, in mm, from the following formula:

$t_{R2} = t_2 \gamma_{K2}$

where:

t_2 : Net thickness, in mm, to be calculated as specified in:

- Pt B, Ch 7, Sec 1, [3], as applicable, for plating subjected to lateral pressure
- Pt B, Ch 7, Sec 1, [4], as applicable, for plating subjected to wheeled loads

where the hull girder stresses are to be calculated considering the hull girder transverse sections constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings

γ_{K2} : Partial safety factor: $\gamma_{K2} = N_P \Psi_2$ without being taken greater than 1,0

N_p : Coefficient defined in Tab 1

$$\Psi_2 = 1 + \frac{t_{C1} + t_{C2}}{t_2}$$

2.2.4 Compression buckling renewal thickness

The compression buckling renewal thickness is to be obtained, in mm, from the following formula:

$t_{R3} = t_3 \gamma_{K3}$

where:

t_3 : Net thickness to be obtained, in mm, from the following formulae:

$$t_3 = \frac{b}{\pi}\sqrt{\frac{\sigma_{x1}\gamma_R\gamma_m 12(1-\nu^2)}{EK_1\varepsilon}}10^3 \quad \text{for} \quad \gamma_m\gamma_R\sigma_{x1} \le \frac{R_{eH}}{2}$$

$$t_3 = \frac{b}{\pi}\sqrt{\frac{3(1-\nu^2)R_{eH}^2}{EK_1\varepsilon(R_{eH}-\sigma_{x1}\gamma_R\gamma_m)}}10^3 \quad \text{for} \quad \gamma_m\gamma_R\sigma_{x1} > \frac{R_{eH}}{2}$$

b : Length, in m, of the plate panel side, defined in Pt B, Ch 7, Sec 1, [5.1.2]

σ_{x1} : In plane hull girder normal stress, in N/mm² to be calculated as specified in Pt B, Ch 7, Sec 1, [5.2.2], considering the hull girder transverse sections as being constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings

ε, K_1 : Coefficients defined in Pt B, Ch 7, Sec 1, [5.3.1]

γ_{K3} : Partial safety factor: $\gamma_{K3} = N_P \Psi_3$ without being taken greater than 1,0

N_p : Coefficient defined in Tab 1

$$\Psi_3 = 1 + \frac{t_{C1} + t_{C2}}{t_3}$$

2.2.5 Shear buckling renewal thickness

The shear buckling renewal thickness is to be obtained, in mm, from the following formula:

$t_{R4} = t_4 \gamma_{K4}$

where:

t_4 : Net thickness to be obtained, in mm, from the following formulae:

$$t_4 = \frac{b}{\pi}\sqrt{\frac{\tau_1 \gamma_R \gamma_m 12(1-\nu^2)}{EK_2}}10^3 \quad \text{for} \quad \gamma_m \gamma_R \tau_1 \le \frac{R_{eH}}{2\sqrt{3}}$$

$$t_4 = \frac{b}{\pi}\sqrt{\frac{\sqrt{3}(1-\nu^2)R_{eH}^2}{EK_2(R_{eH}-\sqrt{3}\tau_1\gamma_R\gamma_m)}}10^3 \quad \text{for} \quad \gamma_m \gamma_R \tau_1 > \frac{R_{eH}}{2\sqrt{3}}$$

b : Length, in m, of the plate panel side, defined in Pt B, Ch 7, Sec 1, [5.1.3]

τ_1 : In plane hull girder shear stress, in N/mm², to be calculated as specified in Pt B, Ch 7, Sec 1, [5.2.3], considering the hull girder transverse sections as being constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings

K_2 : Coefficient defined in Pt B, Ch 7, Sec 1, [5.3.2]

γ_{K4} : Partial safety factor: $\gamma_{K4} = N_P \Psi_4$ without being taken greater than 1,0

N_p : Coefficient defined in Tab 1

$$\Psi_4 = 1 + \frac{t_{C1} + t_{C2}}{t_4}$$

2.2.6 Rule gross thickness

The rule gross thickness is to be obtained, in mm, from the following formula:

$t_G = \max(t_1, t_2, t_3, t_4) + t_{c1} + t_{c2}$

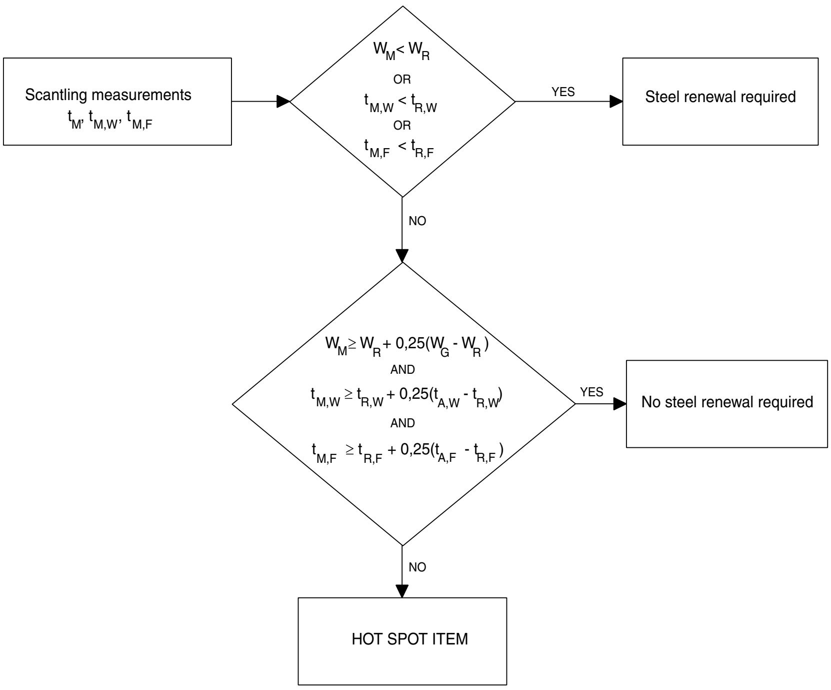
where t_1, t_2, t_3 and t_4 are the net thicknesses defined in [2.2.2], [2.2.3], [2.2.4] and [2.2.5], respectively.

3 Acceptance criteria for ordinary stiffeners

3.1 Application

3.1.1 The acceptance criteria for measured scantlings of ordinary stiffeners, together with the application procedure to be adopted during the reassessment of hull structures, are indicated in Fig 2.

Figure 2 : Acceptance criteria for measured scantlings of ordinary stiffeners and application procedure



3.2 Renewal scantlings

3.2.1 Renewal section modulus

The renewal section modulus is to be obtained, in cm³, from the following formula:

$w_R = w_Y \gamma_{K5}$

where:

w_Y : Net section modulus, in cm³, to be calculated as specified in Pt B, Ch 7, Sec 2, [3], where the hull girder stresses are to be calculated considering the hull girder transverse sections constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings

γ_{K5} : Partial safety factor: $\gamma_{K5} = N_S \Psi_5$ without being taken greater than 1,0

N_S : Coefficient defined in Tab 2

$$\Psi_5 = \frac{1 + \frac{\beta t_C}{w_Y}}{1 - \alpha t_C}$$

α, β : Parameters, depending on the type of ordinary stiffener, defined in Pt B, Ch 4, Sec 2, Tab 1.

Table 2 : Coefficient N_S

Ordinary stiffeners	N_S
Flat bars and bulb profiles	0,85
Flanged profiles	0,81

3.2.2 Renewal web and face plate thicknesses

The renewal web and face plate thicknesses are to be obtained, in mm, from the following formulae:

$t_{R,W} = h_W / C_W$

$t_{R,F} = b_F / C_F$

where:

h_w : Web height, in mm

b_f : Face plate breadth, in mm

C_W, C_F : Coefficients depending on the type and material of ordinary stiffeners, defined in Tab 3.

In any case, the renewal web and face plate thicknesses are to be not less than those obtained according to Pt A, Ch 2, App 3, [4], considering a maximum percentage of wastage equal to 0,75 times the relevant values there specified.

3.2.3 Rule gross section modulus

The rule gross section modulus is to be obtained, in cm³, from the following formula:

$$w_G = \frac{w_Y + \beta t_C}{1 - \alpha t_C}$$

where:

α, β : Parameters, depending on the type of ordinary stiffener, defined in Pt B, Ch 4, Sec 2, Tab 1

w_Y : Net section modulus, in cm³, defined in [3.2.1].

Table 3 : Coefficients C_W and C_F

Type of ordinary stiffeners	C_W			C_F		
	R_{eH} = 235 N/mm²	R_{eH} = 315 N/mm²	R_{eH} = 355 N/mm²	R_{eH} = 235 N/mm²	R_{eH} = 315 N/mm²	R_{eH} = 355 N/mm²
Flat bar	20	18	17,5	Not applicable		
Bulb	56	51	49	Not applicable		
With symmetrical face plate	56	51	49	34	30	29
With non-symmetrical face plate	56	51	49	17	15	14,5

4 Acceptance criteria for primary supporting members

4.1 Application

4.1.1 The acceptance criteria for measured scantlings of primary supporting members, together with the application procedure to be adopted during the reassessment of hull structures, are indicated in Fig 3.

4.2 Work ratios

4.2.1 Reassessment work ratio

The reassessment work ratio is to be obtained from the following formula:

$WR_R = \max(\gamma_{K6} WR_Y, \gamma_{K7} WR_B)$

where:

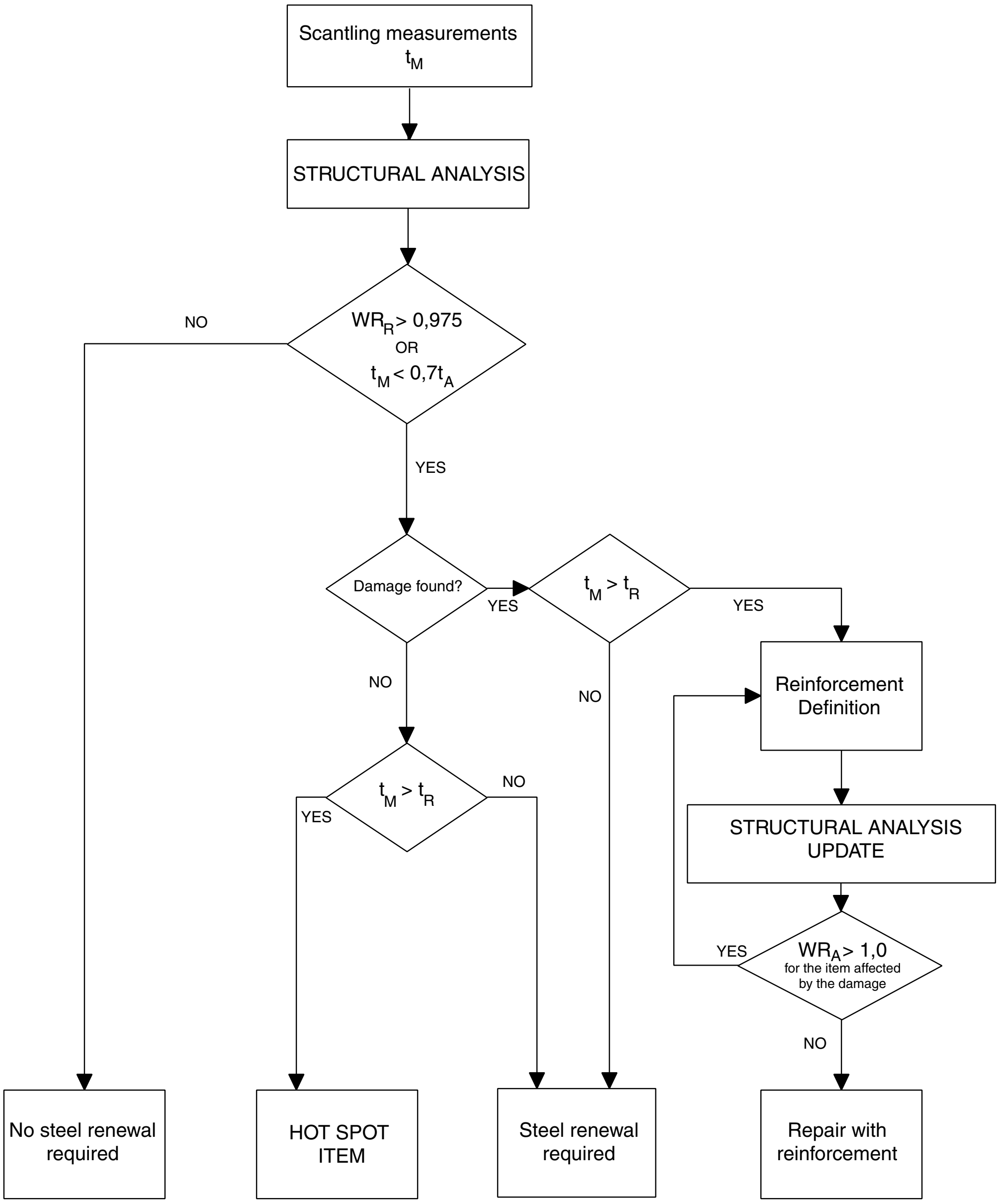
γ_{K6} : Partial safety factor: $\gamma_{K6} = 0,85$

γ_{K7} : Partial safety factor: $\gamma_{K7} = 1,00$

WR_Y : Yielding work ratio, defined in [4.2.3]

WR_B : Buckling work ratio, defined in [4.2.4].

Figure 3 : Acceptance criteria for measured scantlings of primary supporting members and application procedure



4.2.2 As-built work ratio

The as-built work ratio is to be obtained from the following formula:

$WR_A = \max (WR_Y, WR_B)$

where:

WR_Y : Yielding work ratio, defined in [4.2.3]

WR_B : Buckling work ratio, defined in [4.2.4].

4.2.3 Yielding work ratio

The yielding work ratio is to be obtained from the following formula:

$$WR_Y = \frac{\gamma_R \gamma_m \sigma_{VM}}{R_y}$$

where:

σ_{VM} : Equivalent stress, in N/mm², to be calculated as specified in Pt B, Ch 7, App 1, [5.1.2], considering the hull structure as being constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings

R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm²

k : Material factor, defined in Pt B, Ch 4, Sec 1, [2.3].

4.2.4 Buckling work ratio

The buckling element work ratio is to be obtained from the following formula:

$WR_B = \max (WR_{B1}, WR_{B2}, WR_{B3}, WR_{B4})$

where:

WR_{B1} : Compression buckling work ratio:

$$WR_{B1} = \frac{\gamma_R \gamma_m \sigma_b}{\sigma_c}$$

WR_{B2} : Shear buckling work ratio:

$$WR_{B2} = \frac{\gamma_R \gamma_m \tau_b}{\tau_c}$$

WR_{B3} : Compression, bending and shear buckling work ratio:

$$WR_{B3} = \frac{F}{F_c}$$

WR_{B4} : Bi-axial compression and shear buckling work ratio:

$$WR_{B4} = \gamma_R \gamma_m \left(\left(\frac{\sigma_a}{R_a \sigma_{c,a}} \right)^n + \left(\frac{\sigma_b}{R_b \sigma_{c,b}} \right)^n \right)^{\frac{1}{n}}$$

σ_a, σ_b, τ_b : Normal and shear stresses, in N/mm², defined in Pt B, Ch 7, Sec 1, [5.4]

σ_c, τ_c : Critical buckling stresses, in N/mm², defined in Pt B, Ch 7, Sec 1, [5.3]

F : Coefficient defined in Pt B, Ch 7, Sec 1, [5.4.4]

F_c : Coefficient to be obtained from the following formulae:

for $\frac{\sigma_{comb}}{F} \le \frac{R_{eH}}{2\gamma_R \gamma_m}$:

$$F_c = 1$$

for $\frac{\sigma_{comb}}{F} > \frac{R_{eH}}{2\gamma_R \gamma_m}$:

$$F_c = \frac{4\sigma_{comb}}{R_{eH}/\gamma_R \gamma_m} \left(1 - \frac{\sigma_{comb}}{R_{eH}/\gamma_R \gamma_m} \right)$$

σ_{comb} : Combined stress in N/mm², defined in Pt B, Ch 7, Sec 1, [5.4.4]

$\sigma_{c,a}$, $\sigma_{c,b}$: Critical buckling stresses, in N/mm², defined in Pt B, Ch 7, Sec 1, [5.4.5]

n, R_a, R_b : Coefficients defined in Pt B, Ch 7, Sec 1, [5.4.5].

The above quantities are to be calculated considering the hull structure as being constituted by elements (plating, ordinary stiffeners, primary supporting members) having their measured thicknesses and scantlings.

4.3 Renewal scantlings

4.3.1 Overall renewal thickness

The overall renewal thickness is to be obtained, in mm, from the following formula:

$t_R = \max (t_{RY}, t_{RB}, 0{,}75 t_A)$

4.3.2 Yielding renewal thickness

The yielding renewal thickness is to be obtained, in mm, from the following formula:

$t_{RY} = t_Y \gamma_{K8}$

where:

t_Y : Net thickness to be obtained, in mm, from the following formula: $t_Y = [t_A - 0,5\ (t_{C1} + t_{C2})]\ WR_Y$

WR_Y : Yielding work ratio, defined in [4.2.3]

γ_{K8} : Partial safety factor: $\gamma_{K8} = N_P\ \Psi_Y$

N_p : Coefficient defined in Tab 1

$$\Psi_Y = 1 + \frac{0,25(t_{C1} + t_{C2})}{t_Y}$$

4.3.3 Buckling renewal thickness

The buckling renewal thickness is to be obtained, in mm, from the following formula:

$t_{RB} = t_B \gamma_{K9}$

where:

t_B : Net thickness to be obtained, in mm, from the following formula:

$$t_B = [t_A - 0,5(t_{C1} + t_{C2})]\sqrt[3]{WR_B}$$

WR_B : Buckling work ratio, defined in [4.2.4]

γ_{K9} : Partial safety factor: $\gamma_{K9} = N_P\ \Psi_B$

N_p : Coefficient defined in Tab 1

$$\Psi_B = 1 + \frac{0,25(t_{C1} + t_{C2})}{t_B}$$

Appendix 3 Acceptance Criteria for Zones

1 General

1.1 Application

1.1.1 The acceptance criteria consist in checking that the sectional area diminution of a zone (measured according to Ch 2, Sec 1, [4.3.4]) is less than the acceptable limits specified in [1.1.2]. Otherwise, actions according to Ch 2, Sec 1, [4.3.4] are to be taken.

1.1.2 The acceptable limits for the sectional area diminution of zones are specified in Tab 1.

Table 1 : Acceptable limits for the sectional area diminution of zones

Zone		Acceptable limit
Bottom zone		7%
Neutral axis zone	Side	11%
	Inner side and longitudinal bulkheads	11%
Deck zone		7%

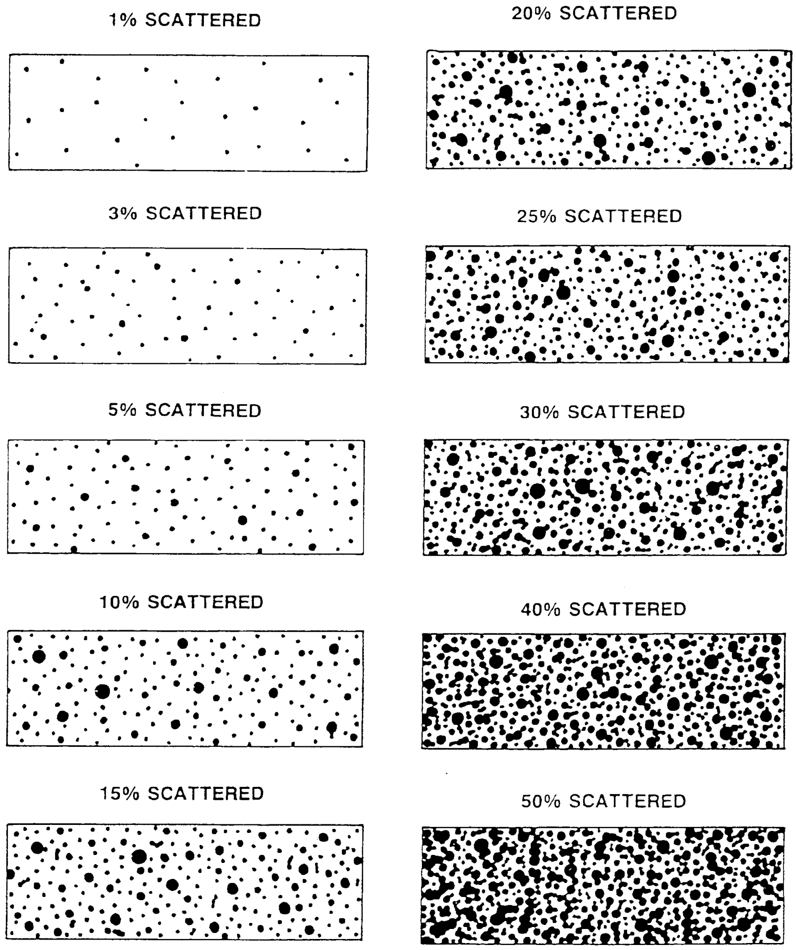
Appendix 4 Pitting Intensity Diagrams

1 General

1.1 Diagrams

1.1.1 As specified in Ch 2, Sec 1, [4.4.1], the pitting intensity is defined by the percentage of area affected by pitting. In order to define the area affected by pitting, and thus the pitting intensity, the diagrams in Fig 1 are to be used.

Figure 1 : Pitting intensity diagrams (from 1% to 50% intensity)



Appendix 5 Naval Authority's Hull Inspection Reports

1 General

1.1

1.1.1 Application

As stated in Ch 2, Sec 1, [3.5], inspection reports are to be prepared by the Naval Authority's person responsible each time an inspection is carried out within the scope of the Inspection and Maintenance Plan. Two models of inspection report are provided for this purpose:

- one model for inspection of spaces (applicable to inspection of deck area structure, ballast tanks, dry holds and spaces, superstructures and other accessible compartments)
- one model for inspection of hull equipment (applicable to hatches, deck equipment, sea connections and overboard discharges).

One separate inspection report is to be issued for each different space or equipment inspected.

1.1.2 Use of models

The Naval Authority is to adapt these models, so far as practicable and appropriate, to the ship concerned, the spaces to be inspected and the existing equipment. However, the general content of the report and its layout are to comply with the models.

1.1.3 Ship database

Interested parties are reminded that, as stated in Ch 2, Sec 1, [1.3], the inspection reports are to be processed and recorded in the ship database which is to be installed on board ship and at the Naval Authority's offices. Therefore, these models are to be used as a guide for entering the collected data into the ship database, in an electronic form.

The recording in the ship database is to be such as to easily retrieve the different reports pertaining the same spaces and equipment during the lifetime of the ship, or the reports of inspections performed during a given period, or the reports related to the same type of space or equipment.

The attached documentation referred to in [2.5] and [3.4] may be either kept in a separate paper file or electronically processed in the ship database through appropriate means.

2 Report for inspection of spaces

2.1 General

2.1.1 The model of Naval Authority's report for space inspection is given in Tab 1.

2.1.2 The report is divided into four parts:

- general identification data
- summary of findings and repairs for the different areas of the space and for the fittings in this space
- details of findings and repairs, as applicable
- additional documentation attached to the report.

2.2 Identification data

2.2.1 The identification data are to give the information about the space inspected, date and place of inspection and name of the person under whose responsibility the inspection has been carried out.

2.2.2 The identification of the space is to be such that:

- it is easy to trace the space concerned, in particular in cases where several identical spaces exist on the ship
- the same identification is used for the subsequent inspection reports pertaining to the same space.

Table 1 : Naval Authority's report for space inspection

Person responsible:	
Date of inspection:	Place of inspection:
Name of ship:	Register number:
Name and type of space:	Location (port/stbd, from frame... to frame...):

Structure area, fittings	Items in the area	Coating / anode condition	Fractures	General corrosion	Pitting or grooving	Deformations	Repairs	Other
Top								
Bottom								
Port side								
Stbd side								
Forward bulkhead								
Aft bulkhead								
Internal structure								
Fittings								

Findings during inspection: (location, type, details)	Action taken: required repair, temporary repair, permanent repair (location, type and extent)
Other documentation attached to the report: sketches [ ] , photos [ ] , thickness measurement report [ ] , other [ ]	

2.3 Summary of findings and repairs

2.3.1 Each space inspected is divided into items corresponding to:

- the different boundaries of the space
- the internal structure of the space
- the fittings of the space.

For better understanding, the second column of the table may be used to clarify which elements belong to each item or which fittings are concerned.

2.3.2 For each item, as applicable, the summary table is to give a general answer to the findings and to the possible repairs made.

- When coating condition is concerned, the answer is to be either “no coating”, or “good”, or “fair”, or “poor”, as per the definition of such conditions given in Pt A, Ch 2, Sec 2.
- Anode condition is to be answered by giving an estimated average loss of weight as a percentage, bearing in mind the acceptance criteria given in Ch 2, Sec 1, [4].
- The other columns (fractures, general corrosion, pitting/grooving, deformations, repairs) are to be answered “yes” or “no”, depending on whether or not such defect/repair has been found/performed.
- The column “other” is to be used to indicate whether another type of inspection has been carried out, such as thickness measurement, pressure test or working test.

2.4 Details of findings and repairs

2.4.1 Each time the answer in the summary table is “poor” for coating, or “yes” for other topics, this part of the report is to be used to give details on the findings, defects or repairs concerned.

2.4.2 As guidance, the following details are to be given:

- for coating found in poor condition: structural elements concerned, type of coating defect (breakdown, hard scale)
- for fractures: location of fractures, dimension, number of identical fractures
- for general corrosion: structural elements concerned, extent of wastage on these elements, estimation of wastage (if thickness measurements have been taken)
- for pitting/grooving: structural elements concerned and location, depth of pitting/grooving, percentage of affected surface using diagrams in Ch 2, App 4, length of grooving
- for deformations: type of deformation (buckling, external cause), location of the deformation and structural elements concerned, estimation of size
- for repairs (if performed without the attendance of a Surveyor, when this is possible or acceptable): type of repairs, elements or areas concerned.

2.5 Attached documentation

2.5.1 It is recommended that the report is supported by attaching sketches, photos, the thickness measurement report or other documentation, when this is deemed necessary to clarify the findings and/or repairs given in the detailed part.

For example:

- photos may be used to show the condition of the coating and anodes, the extent of general corrosion, pitting and grooving, or the appearance and extent of fractures
- sketches may be used to indicate fractures, deformations and repairs, especially when a photo cannot encompass the whole image and give a complete representation.

3 Report for inspection of equipment

3.1 General

3.1.1 The model of Naval Authority’s report for equipment inspection is given in Tab 2.

3.1.2 The report is divided into three parts:

- general identification data
- detailed report of findings and repairs
- additional documentation attached to the report.

Table 2 : Naval Authority's report for equipment inspection

Person responsible:	
Date of inspection:	Place of inspection:
Name of ship:	Register number:
Name and type of equipment:	Location (port/stbd, at frame ..., ...):

Type of inspection, findings and readings:
Repairs, maintenance, pieces renewed:
Working tests, pressure test, trials,...:
Other documentation attached to the report: sketches [ ] , photos [ ] , thickness measurement report [ ] , other [ ]

3.2 Identification data

3.2.1 The identification data are to give the information about the equipment inspected, date and place of inspection and name of the person under whose responsibility the inspection has been carried out.

3.2.2 The identification of the equipment is to be such that:

- it is easy to trace the item of equipment concerned, in particular in cases where several identical items of equipment exist on the ship
- the same identification is used for the subsequent inspection reports pertaining to the same item of equipment.

3.3 Detailed report

3.3.1 The detailed report of inspection is divided into three parts:

- inspection done:
  - the type of inspection carried out: visual external examination, internal examination after dismantling, overhaul
  - readings performed, when applicable: clearances, thickness measurements, working pressure, or other working parameters of the equipment
  - findings during the inspection: corrosion, fractures, pieces of equipment worn out, broken or missing
- maintenance done, repairs carried out and pieces renewed
- results of tests performed after the inspection, such as working test, pressure test, hose test or equivalent for hatch covers or other weathertight fittings, sea trials.

3.4 Attached documentation

3.4.1 It is recommended that the report is supported by attaching sketches, photos, the thickness measurement report or other documentation, when this is deemed necessary to clarify the findings and/or repairs given in the detailed part.

For example:

- photos may be used to show the condition of the pieces of equipment before their overhaul or renewal, the coating condition of piping, or the extent of corrosion
- sketches may be used to indicate fractures and deformations, clearances taken, or other measurements performed.

Appendix 6 Risk Analyses for Star-Mach

1 General

1.1 Application

1.1.1 Scope

The scope of this appendix is to describe the procedure foreseen in order to carry out the risk analysis for the purpose of assigning and maintaining the **STAR-MACH** notation, as given in Ch 2, Sec 2.

The scope of the risk analysis is to identify critical systems and/or components, assess the Inspection and Maintenance Plan with regards to acceptable levels of risk and recommend measures to improve the type and/or periodicity of inspection and maintenance, when deemed necessary.

1.2 Carrying out of risk analysis

1.2.1 Initial risk analysis

An initial risk analysis is to be carried out by the Society, in accordance with Ch 2, Sec 2, [3.1.1].

1.2.2 Risk analysis review

The results of the initial risk analysis will be updated by the Society on the basis of the information and data gathered from the ship database, in accordance with Ch 2, Sec 2, [3.2.1].

1.3 Procedure

1.3.1 Definitions

a) Accident is defined as an event or a series of events whose consequence is loss of life, injury, ship loss or damage, or environmental damage.

b) Risk is defined as the combination of the probability and consequence of an accident.

c) Top event is defined as the final outcome of an event or a series of events (e.g. loss of propulsion).

d) Critical is a system and/or component whose failure may result in the loss of an essential ship's function (e.g. main propulsion system).

e) Fault Tree Analysis (FTA) is a logic diagram showing the causal relationship between events which singly or in combination may cause the occurrence of a top event. If two or more events need to occur to cause the next higher event, this is shown by a logic "and" gate. If any one of two or more events can cause the next higher event, this is shown by a logic "or" gate.

f) Event Tree Analysis (ETA) is a logic diagram used to analyse the effects of an accident, failure or unintended event, taking into account those actions which may mitigate or prevent their escalation. The probabilities of success or failure of each action, multiplied by the likelihood of the accident, gives the likelihood of each consequence.

g) Failure Mode and Effect Analysis (FMEA) is a technique to analyse the modes and consequences of a single failure of a component in a system. The effects of each single failure are analysed to determine their severity and possible mitigation with respect to the loss of the system as a whole.

h) Montecarlo simulation is a technique used to obtain statistical results about the outcome of a system, by means of random extractions of samples in a statistical population.

1.3.2 Flow-chart

Each step of the procedure is indicated in Fig 1 and described in the following paragraphs.

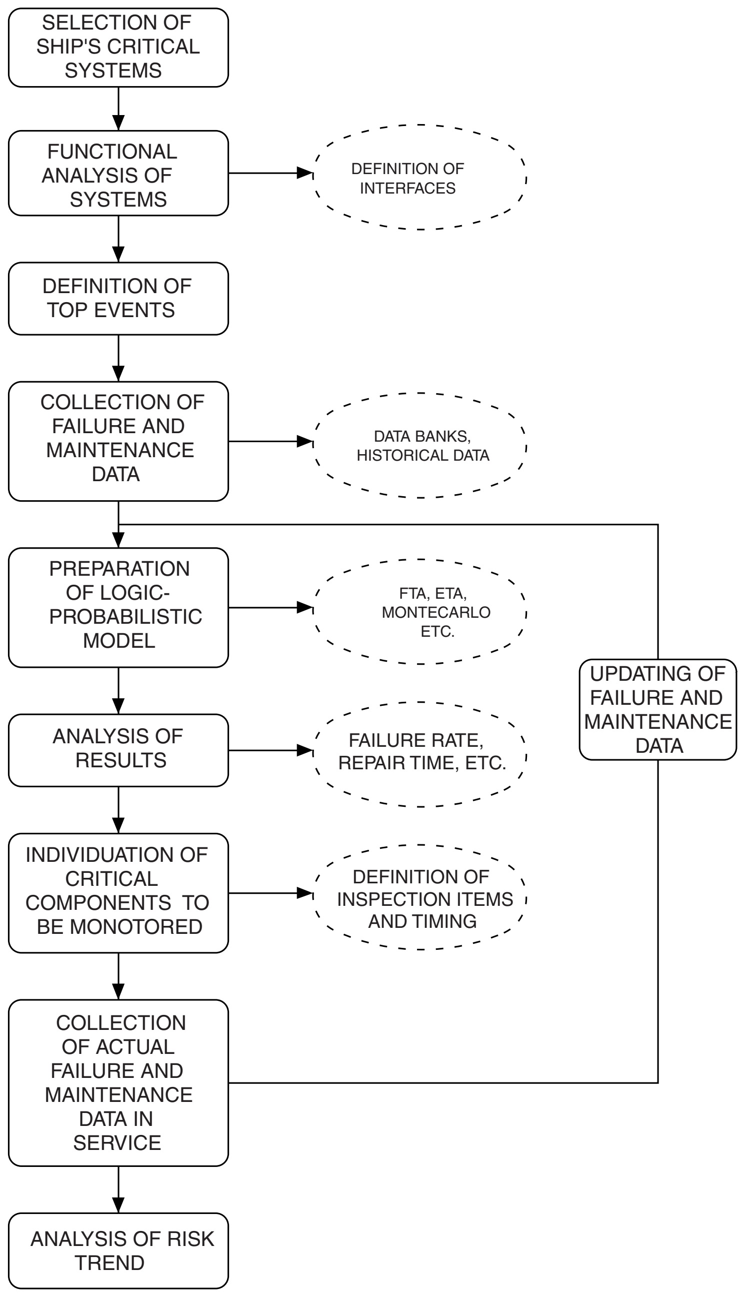
2 Overall process

2.1 Selection of the ship's critical systems

2.1.1 The first step of the risk analysis is to pre-select a list of systems and/or components which may become critical for the safety and operation of the ship.

The selected systems and components are to include at least the ones listed in Ch 2, Sec 2, Tab 1.

Figure 1 : Risk analysis overall process



2.1.2 The risk analysis is extended to other systems and/or components which are deemed critical from the point of view of safety and operation of the ship, depending on her declared mission.

2.2 Functional analysis of the systems

2.2.1 The selected critical systems and components are analysed in order to identify the functions performed by each of them during normal operations and in the case of emergency. For instance, the functions include propulsion, manoeuvrability, fire prevention, detection and alarm, etc.

The functions and systems are broken down to a level of detail which is appropriate for the results to be expected from the risk analysis. Aspects relevant to the interaction of the functions and systems are taken into particular consideration, in order to identify possible weak points, e.g. functions carried out by a single component whose failure may impair the availability of the whole system.

2.3 Definition of top events

2.3.1 This step is relevant to the definition of the top events which may lead to an accident. Examples of top events are:

- loss of propulsion
- loss of electric generation
- loss of steering capability, etc.

2.4 Collection of failure and maintenance data

2.4.1 The availability of failure and maintenance data relevant to the functions and systems under consideration is an important step of the risk analysis. Examples of useful statistical data are the mean time between failures (MTBF) and the mean time to repair (MTTR).

Such statistical data can be obtained from:

- the ship database (see Ch 2, Sec 2, [1.3]) with data recorded from the ship under consideration or similar ships of the same Naval Authority, when available
- historical data on similar installations
- data released by the Manufacturer
- data banks.

2.5 Preparation of the logic-probabilistic model

2.5.1 A logic-probabilistic model is defined for each selected system in order to establish the relationship between parts, sub-systems and/or components, whose failure would impair an essential function of the ship.

The objective of the logic-probabilistic model is to quantify the likelihood, or probability of occurrence, and the consequences of a top event, i.e. the risks against the safety and/or operation of the ship.

The model is developed by means of suitable techniques, such as Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Failure Mode and Effect Analysis (FMEA), Montecarlo simulations, depending on the top events under consideration.

This model is based on the statistical data available, such as the mean time between failures (MTBF) and the mean time to repair (MTTR) of the selected components (see [2.4]).

2.5.2 The fault tree analysis will take into account the duplication required in the Rules for some components (e.g. pumps).

2.6 Analysis of the results

2.6.1 The results from the previous steps are analysed for the identified critical components or systems in order to improve the Inspection and Maintenance Plan, for instance recommending actions concerning:

- preventive maintenance (e.g. inspection intervals)
- corrective maintenance (e.g. procedures for repairs).

2.7 Individuation of the critical components to be monitored

2.7.1 The critical components to be monitored during the ship life are those which result from the risk analysis to have the largest influence on the risks, e.g. the failure of which significantly increases the probability of occurrence of a top event.

2.8 Collection of actual failure and maintenance data

2.8.1 The actual information and data relative to preventive and corrective maintenance and inspection on board are downloaded from the ship database (see Ch 2, Sec 2, [1.3]). In particular, the following data are needed:

- working hours of each component
- mode, cause and time of failure
- down time induced by the failure
- schedule, timing and resources (manpower and consumables) foreseen for the preventive maintenance
- datails on corrective maintenance (spare parts used, tasks carried out, mean time between two corrective actions)
- date when the component has been replaced or re-conditioned.

The actual information and data mentioned above are transformed into statistical parameters, such as the mean time between failure (MTBF) and mean time to repair (MTTB) of each component.

2.9 Updating of failure and maintenance data

2.9.1

a) The actual information and data relative to preventive and corrective maintenance and inspection on board are compared with the ones which were initially assumed to prepare the model. Where necessary, the updated data are introduced in the logic-probabilistic model for a new evaluation of the results and possible re-analysis of the risks.

b) In the case of substantial alterations of the ship machinery and/or equipment, the logic-probabilistic model is modified as far as necessary, using the information available.

c) The modified logic-probabilistic model is used for optimising the maintenance scheme, according to the steps above.

2.10 Analysis of the risk trend

2.10.1 The data relevant to the critical systems and components are gathered during the ship life in order to verify, through the risk analysis, whether a modification of the periodicity of Inspection and Maintenance Plan is necessary.

Appendix 7 Planned Maintenance Scheme

1 General

1.1

1.1.1 A Planned Maintenance Scheme (hereafter referred to as PMS) is a survey system for machinery items which may be considered as an alternative to the Continuous Machinery Survey system (hereafter referred to as CMS), as described in Pt A, Ch 2, Sec 2, [5.4].

This scheme is limited to components and systems covered by CMS.

Any items not covered by the PMS are to be surveyed and credited in the usual way.

1.1.2 This survey scheme is to be approved by the Society before being implemented. When the PMS system is applied, the scope and periodicity of the class renewal survey are tailored for each individual item of machinery and determined on the basis of recommended overhauls stipulated by the manufacturers, documented experience of the operators and, where applicable and fitted, condition monitoring. For instance, within the scope of a PMS system the following cases may occur:

- switchboard A is surveyed based on the regular expiry date of the class renewal survey
- lubricating oil pump B is surveyed based on CMS
- diesel engine C is surveyed based on running hours
- turbo pump D is surveyed based on condition monitoring.

1.1.3 In general, the intervals for the PMS are not to exceed those specified for CMS. However, for components where the maintenance is based on running hours longer intervals may be accepted as long as the intervals are based on the Manufacturer's recommendations.

However, if an approved condition monitoring system is in effect, the machinery survey intervals based on the CMS cycle period may be extended.

1.1.4 When the condition monitoring of machinery and components included in the approved PMS shows that their condition and performance are within the allowable limits, no overhaul is necessary, unless specified by the Manufacturer.

1.1.5 On board the ship there is to be a person responsible for the management of the PMS for the purpose of which he is to possess the appropriate professional qualifications. This person is usually the Chief Engineer; however, another person designated by the Owner may be accepted by the Society provided that his qualifications are considered equivalent to those of the Chief Engineer.

The surveys of machinery items and components covered by the PMS may be carried out by personnel on board who have been issued a statement of authorization, under the conditions and limits given in Pt A, Ch 2, App 1.

Items surveyed by the authorised person will be subject to the confirmatory survey as detailed in Pt A, Ch 2, App 1.

1.1.6 The conditions and procedures for the approval of a PMS are indicated in [2].

2 Conditions and procedures for the approval of the system

2.1 General

2.1.1 The PMS is to be approved by the Society. To this end the Owner is to make a formal request to the Society and provide the documentation and information specified in [2.2], combined in a manual describing the proposed scheme and including sample copies of the different documents to be used during the implementation of the scheme.

2.1.2 The PMS is to be programmed and maintained by a computerised system. However, this may not be applied to the current already approved schemes.

When using computerised systems, access for the purpose of updating the maintenance documentation and the maintenance programmes is only granted to the person responsible for the PMS or another person authorised by him.

Computerised systems are to include back-up devices, such as disks/tapes, CDs, which are to be updated at regular intervals.

The functional application of these systems is to be approved by the Society.

2.2 Documentation

2.2.1 The documentation to be submitted is the manual mentioned above, which is to include:

a) a description of the scheme and its application on board as well as the proposed organisation chart identifying the areas of responsibility and the people responsible for the PMS on board

b) the list of items of machinery and components to be considered for classification in the PMS, distinguishing for each the principle of survey periodicity used as indicated in [1.1.2]

c) the procedure for the identification of the items listed in b), which is to be compatible with the identification system adopted by the Society

d) the scope and time schedule of the maintenance procedures for each item listed in b), including acceptable limit conditions of the parameters to be monitored based on the manufacturers' recommendations or recognised standards and laid down in appropriate preventive maintenance sheets

e) the original reference data, monitored on board, for machinery undergoing maintenance based on condition monitoring

f) the list and specifications of the condition monitoring equipment, including the maintenance and condition monitoring methods to be used, the time intervals for maintenance and monitoring of each item and acceptable limit conditions

g) the document flow and pertinent filing procedure.

2.3 Information on board

2.3.1 The following information is to be available on board:

a) all the documentation listed in [2.2], duly updated

b) the maintenance instructions for each item of machinery, as applicable (supplied by the manufacturer or by the shipyard)

c) the condition monitoring data of the machinery, including all data since the last dismantling and the original reference data

d) reference documentation (trend investigation procedures etc.)

e) the records of maintenance performed, including conditions found, repairs carried out, spare parts fitted

f) the list of personnel on board in charge of the PMS management.

2.4 Annual report

2.4.1 An annual report covering the year's service is to be supplied to the Society. It is to include the following information:

- the list of items of machinery and components (item b) in [2.2.1]) and the procedure for their identification
- the preventive maintenance sheets
- the condition monitoring data, including all data since the last dismantling and the original reference data of the machinery checked through condition monitoring
- any changes to the other documentation in [2.2].
- full trend analysis (including spectrum analysis for vibrations) of machinery displaying operating parameters exceeding acceptable tolerances. In such cases, the actions taken to restore the values of the parameters within the acceptable tolerances are also to be reported.

All the documentation is to be signed by the person responsible mentioned in [1.1.5].

3 Implementation of the system

3.1

3.1.1 When the documentation submitted has been approved and the PMS system has been implemented on board and used for a sufficient period (which is not to exceed one year) so that all personnel become familiar with it, a survey is to be carried out in order to start the system and make it officially operational. The scope of this survey, referred to as Implementation Survey, is given in [5.1.1].

3.1.2 Upon the successful outcome of the Implementation Survey, the PMS is considered approved. The relevant annex to the Certificate of Classification of the ship is updated.

4 Retention and withdrawal of the system

4.1

4.1.1 The PMS system is retained throughout the class period provided that:

- an annual report covering the year's service is supplied to the Society in accordance with [2.4]
- an annual audit in accordance with [5.2] is satisfactorily completed
- any change to the approved PMS is submitted to the Society for agreement and approval.

4.1.2 The survey arrangement for machinery according to the PMS may be withdrawn by the Society if the PMS is not satisfactorily operated on account of either the maintenance records or the general condition of the machinery or the failure to observe the agreed intervals between overhauls.

4.1.3 The Owner may discontinue the PMS at any time by informing the Society in writing. In this case, the items which have been inspected under the PMS since the last annual audit will be credited for class at the discretion of the attending Surveyor.

4.1.4 In the case of sale or change of management of the ship or transfer of class, the approval of the PMS will be reconsidered.

5 Surveys

5.1 Implementation survey

5.1.1 The implementation survey is to be carried out by a Surveyor of the Society, as stated in [3.1.1], within one year from the date of the documentation approval.

5.1.2 The scope of this survey is to verify that:

- the PMS is implemented in accordance with the approved documentation and is suitable for the type and complexity of the components and systems on board
- the documentation required for the annual audit is produced by the PMS
- the requirements of surveys and testing for retention of class are complied with
- the shipboard personnel are familiar with the PMS procedures.

Upon the successful outcome of the survey confirming the proper implementation of the PMS, the system is considered operational subject to the submission to the Society of a report describing the system.

5.2 Annual audit

5.2.1 Once the PMS system is implemented, the continued compliance with the requirements for checks, overhauls and repairs, where needed, indicated in Article [2] is to be verified by means of annual audits in order to confirm the validity of the approved survey scheme system.

5.2.2 The annual audit is to be carried out in conjunction with the annual class surveys.

5.2.3 The purpose of this audit is to verify that the scheme is being correctly operated, in particular that all items (to be surveyed in the relevant period) have actually been surveyed in due time. A general examination of the items concerned is carried out.

5.2.4 The maintenance and performance records are examined to verify that the machinery has been functioning satisfactorily since the previous survey or audit or, if necessary, that the necessary measures have been taken in response to machinery operating parameters exceeding acceptable tolerances, and that the overhaul intervals have been observed.

5.2.5 Written reports of breakdown or malfunction are to be made available.

5.2.6 The description of the repairs, if any, carried out is to be examined. Any machinery part or component which has been replaced by a spare due to damage is to be retained on board, where possible. On this occasion such replaced parts are to be submitted to the examination of the Surveyor.

5.2.7 Where condition monitoring equipment is in use, functions tests, confirmatory inspections and random check readings are to be carried out as far as practicable and reasonable at the discretion of the Surveyor.

5.2.8 The Surveyor also checks that the personnel on board in charge of the PMS have the appropriate authorisation (see Pt A, Ch 2, App 1).

5.2.9 The Surveyor is to review the annual report or verify that it has been reviewed by the Society.

5.2.10 If the Surveyor is not satisfied with the results the PMS is achieving, i.e. with the degree of accuracy as regards the maintenance records and/or the general condition of the machinery, he forwards the Society a report recommending the changes to the survey scheme and explaining the reasons for his suggestions.

5.2.11 Upon the satisfactory outcome of this audit, the Surveyor confirms the validity of the PMS, endorses the Certificate of Classification in accordance with Pt A, Ch 2, Sec 2, [3.3] and decides which items can be credited for class.

5.3 Damage and repairs

5.3.1 Damage to components or items of machinery is to be reported to the Society. The repairs of such damaged components or items of machinery are to be carried out to the satisfaction of the Surveyor.

5.3.2 Any repair and corrective action regarding machinery under the PMS system is to be recorded in the PMS logbook and repair verified by the Surveyor at the Annual Audit.

5.3.3 In the case of outstanding recommendations or records of unrepaired damage which may affect the PMS, the relevant items are to be taken out of the PMS until the recommendations have been fulfilled or the repairs carried out.

6 Machinery items surveyed on the basis of condition monitoring

6.1

6.1.1 The extent of condition-based maintenance and associated monitoring equipment to be included in the maintenance scheme is decided by the Owner. The minimum parameters to be checked in order to monitor the condition of the various machinery for which this type of maintenance is accepted are indicated in [6.1.2] to [6.1.5].

6.1.2 For the main diesel engine the parameters to be checked are the following:

- power output
- rotational speed
- indicator diagram (where possible)
- fuel oil temperature and/or viscosity
- charge air pressure
- exhaust gas temperature for each cylinder
- exhaust gas temperature before and after the turbochargers
- temperatures and pressure of engine cooling systems
- temperatures and pressure of engine lubricating oil system
- rotational speed of turbochargers
- vibrations of turbochargers
- results of lubricating oil analysis
- crankshaft deflection readings
- temperature of main bearings.

6.1.3 For the main and auxiliary steam turbines the parameters to be checked are the following:

- turbine bearing vibrations
- power output
- rotational speed
- plant performance data, i.e. steam conditions at the inlet and outlet of each turbine, saturated, superheated and desuperheated steam conditions at the outlet of boilers, condenser vacuum, sea temperature.

6.1.4 For the auxiliary diesel engines the parameters to be checked are the following:

- exhaust gas temperature before and after the turbochargers
- temperatures and pressure of engine cooling systems
- temperatures and pressure of engine lubricating oil system
- rotational speed of turbochargers
- crankshaft deflection readings.

6.1.5 For other auxiliary machinery the parameters to be checked are the following, as applicable:

- inlet and outlet temperatures of cooling systems
- inlet and outlet temperatures of heating systems
- vibrations and performance data of pumps and fans
- differential pressure at filters.

Part E
Additional Class Notations

CHAPTER 3
AVAILABILITY OF MACHINERY (AVM)

Section	1	Alternative Propulsion Mode (AVM-APM)
Section	2	Duplicated Propulsion System (AVM-DPS)
Section	3	Independent Propulsion System (AVM-IPSx-(V))
Appendix	1	Procedures for Failure Modes and Effect Analysis

Section 1 Alternative Propulsion Mode (AVM-APM)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-APM** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.2] to self propelled ships arranged with means for alternative propulsion mode complying with the requirements of this Section. Where several alternative propulsion modes are available, a suffix, according to the number of such modes, is to be added to the notation.

1.2 Principle

1.2.1 The alternative propulsion system is to be capable of maintaining the ship in operating conditions without any restriction of duration. In particular, it should allow the ship to reach the first suitable port or place of refuge, escape from severe environment or other operational hazards. However the limitations specified in [2.1.1] apply.

1.2.2 The alternative propulsion system is to be so designed as to be available in the following cases:

- failure of any component of the main propulsion system or power generation system (see [2.1.3])
- maintenance operations to be carried out on any part of the main propulsion system.

Note 1: Failures of the alternative propulsion system components are not to be considered.

1.3 Definitions

1.3.1 Main propulsion system

Main propulsion system is the machinery installation which allows the ship to reach its full speed capability. It may consist of:

- two or more independent propulsion sets
- two or more propulsion sets having common auxiliaries, or
- one single propulsion set.

1.3.2 Alternative propulsion system

Alternative propulsion system is the machinery installation which allows the ship to reach the performance indicated in [1.2.1] and [2.1.1]. It may be:

- a propulsion set part of the main propulsion system defined in [1.3.1]
- a propulsion system sharing some components with the main propulsion system (e.g. a generator driven by the main propulsion system and used as electric motor, together with its electrical supply system), or
- an independent propulsion set located in the main propulsion compartment or in a separate compartment.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Machinery spaces general arrangement
2	A	Description of the alternative propulsion system
3	A	A risk analysis demonstrating the availability of the alternative propulsion system in case of a single failure as per [2.1.3] **(2)**
4	A	Calculation note for the fuel capacity necessary to satisfy the range criterion specified in [2.1.1]
5	I	An operating manual with the description of the operations necessary to put the alternative propulsion system into operation when a failure occurs, as listed in [2.1.3]
6	A	Test procedures, including factory acceptance tests and sea trials
7	A	Electrical load balance in APM mode

(1) A : to be submitted for approval
I : to be submitted for information.

(2) This analysis may be in the form of a Failure Mode and Effect Analysis (FMEA), unless the actual arrangement of the machinery and equipment is quite simple and sufficient operating experience can be demonstrated such as to make unlike the possibility of consequence failure in the case of a single failure. In such a case, the Society may consider to accept a functional description of system in lieu of the requested analysis.

1.3.3 Alternative propulsion mode

The alternative propulsion mode (APM) means the operation of the alternative propulsion system alone, without:

- the main propulsion system when both systems are independent
- the rest of the main propulsion system when both systems are combined.

1.4 Documentation to be submitted

1.4.1 The documents listed in Tab 1 are to be submitted.

2 Design requirements

2.1 Availability of the alternative propulsion mode and other ship services

2.1.1 Operating conditions to be achieved when the alternative propulsion mode is activated

Where the alternative propulsion mode is activated, the following operating conditions are to be achieved (calm sea, no current and no wind condition):

- full load speed not less than 7 knots
- operating range of 150 hours, ensured by the provisions detailed in [2.2.1]

Note 1: Fuel oil tanks capacity is to take into account all services necessary for APM operation, including the following systems:

- safety systems, including fire fighting systems, bilge system, navigating lights, communication apparatus, life-saving appliances
- minimum habitability services, including minimum lighting (50%), ventilation (50%), air conditioning (≥ 50%), hospital (100%), galleys (75%), refrigerated stores (100%), drinking water production (100%)
- ship autodefense system.

2.1.2 Services not required during operation of the alternative propulsion mode

Services not required during APM operation are all non essential services not listed in [2.1.1].

2.1.3 Single failures to be considered

a) The alternative propulsion mode is to be available when any of the following single failures occurs:
   - loss of a main propulsion prime mover
   - any failure of a non-static component of systems which are necessary for the operation of the main propulsion system (i.e. prime movers control and monitoring systems, fuel oil systems, lubricating oil systems, cooling system, compressed air system)
   - any failure of tube heat exchangers, necessary for main propulsion system
   - any failure of any non-static component of fuel oil and lubricating oil transfer system
   - any single failure of any electric apparatus, including total failure of one of the main switchboards, electric motors, transformers, distribution switchboards, panels.

b) The following items do not need to be considered for the purpose of granting the **AVM-APM** notation:
   - rigidly coupled shafting components (i.e. propeller, propeller shaft, intermediate shafts, bearings, couplings, pinions and wheels of reduction gears)
   - static components of the systems which are necessary for the operation of the main propulsion system (i.e. pipes, valves, pipe fittings, pipe supports, tanks, cables)
   - loss of one compartment due to fire or flooding
   - plate type heat exchangers.

c) Consequence failures, i.e. any failure of any component directly caused by a single failure of another component, are also to be considered.

2.2 Machinery systems

2.2.1 Fuel oil tanks

An alarm is to be activated when the level in the fuel oil service tank is below the calculated value necessary to achieve the range indicated in [2.1.1]. As an alternative, a dedicated tank of an appropriate capacity is to be made available.

2.2.2 Steering gear

a) In addition to the redundancies (main and auxiliary steering gears or duplication of the power units) required by SOLAS Regulation II-1/29 and 30), the steering gear is to be so designed as to remain available in case of single failure affecting any other active component, such as a rudder actuator.

b) Performance of the steering gear in case of single failure is to be in compliance with the criteria stated in Resolution MSC.137(76) "Standards for ship manoeuvrability" and in IMO Circular MSC/Circ.1053 "Explanatory notes to the standards for ship manoeuvrability".

2.2.3 Activation of the alternative propulsion mode

When the alternative propulsion system shares some components with the main propulsion system, it is to be capable of being activated with an effective, readily usable system, in a time not exceeding half an hour.

2.3 Electrical systems

2.3.1 Main switchboard

In case of loss of one main switchboard, the alternative propulsion system is to remain available.

2.3.2 Emergency generator

The emergency generator is not to be considered in the electrical load balance when the alternative propulsion mode is active.

3 Tests on board

3.1 Factory acceptance tests

3.1.1 The components of the alternative propulsion system are to be subjected to the running tests required by the Rules.

3.1.2 Where the alternative electrical propulsion system is provided, the integration tests of the alternative propulsion system are to be carried out in factory prior to installation.

3.2 Sea trials

3.2.1 Alternative propulsion system

The alternative propulsion system is to undergo the following tests during the sea trials:

- activation test (see [2.2.3])
- test to demonstrate the performance required in [2.1.1]
- test required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures.

Note 1: During the test, the power and rotational speed of the alternative propulsion system and the ship speed are to be recorded.

3.2.2 Steering gear

The performance test of the steering gear is to be carried out assuming a single failure, in accordance with the provisions of [2.3.2].

Section 2 Duplicated Propulsion System (AVM-DPS)

1 General

1.1 Application

1.1.1 The additional class notation **AVM-DPS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.3] to self propelled ships arranged with duplicated propulsion and steering systems complying with the requirements of this Section.

1.2 Principle

1.2.1 General

Ships having the notation **AVM-DPS** are to be fitted with at least:

- two independent propulsion sets, so arranged that at least 50% of the overall power remains available whenever any of the propulsion plant is not in operation
- two steering sets, so arranged that the full steering capability of the ship is maintained in case of failure of one steering set.

Note 1: The propulsion sets may be installed in the same compartment.

Note 2: The steering gears may be installed in the same compartment.

1.2.2 Propulsion

Each propulsion set is to be so designed as to individually comply with the relevant provisions of Part C, Chapter 1 and Part C, Chapter 2. In particular, its operation is to be maintained or restored even in case of single failure of one component, as listed in [2.2.1]. Partial reduction of the propulsion set capability may however be accepted when it is demonstrated that the safe operation of the ship is not impaired.

1.2.3 Steering

Each steering set is to be so designed as to individually comply with the provisions of Pt C, Ch 1, Sec 12.

1.3 Definitions

1.3.1 Propulsion set

A propulsion set includes the following components:

- propeller (or impeller)
- shafting
- gear box (where provided)
- driven generators and pumps (where provided)
- flexible coupling (where provided)
- prime mover
- fuel supply, lubrication, cooling, starting and control systems.

1.3.2 Independent propulsion sets

Propulsion sets are said to be independent where no common auxiliary systems are provided. It means that each propulsion set has dedicated fuel supply, lubrication, cooling, starting and control systems.

1.3.3 Steering set

A steering set includes the rudder, the rudder stock and the steering gear.

1.4 Documentation to be submitted

1.4.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Machinery spaces general arrangement
2	A	Description of the propulsion installation
3	A	Description of the steering installation
4	A	A risk analysis demonstrating the availability of the operating conditions as per [2.1.1] in case of a single failure as per [2.2.1] **(2)**
5	I	An operating manual with the description of the operations necessary to recover: • the propulsion in case of failure of one propulsion set • the operation of a propulsion set when affected by a single failure (see [2.2.1]) • the steering in case of failure of one steering set.

(1) A : to be submitted for approval ; I : to be submitted for information.
(2) This analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 3, App 1 describes an acceptable procedure for carrying out the FMEA.

2 Design requirements

2.1 Performance of the propulsion plant with one propulsion set inoperative

2.1.1 Operating conditions to be achieved with one propulsion set inoperative

The performance required in [1.2.1] for the propulsion plant with one propulsion set inoperative is to satisfy the following criteria:

- full load speed not less than 7 knots
- no restriction of the operating range
- availability of safety systems, including fire fighting systems, bilge system, navigating lights, communication apparatus, life-saving appliances
- minimum habitability conditions, including minimum lighting, ventilation, air conditioning, galleys, refrigerated stores, drinking water or evaporator services (see Ch 3, Sec 1)
- operational efficiency (including combat system and stabilizers).

2.1.2 Services not required during the operation of the propulsion plant with one propulsion set inoperative

The non-essential services not listed in [2.1.1] need not be supplied during the operation of the propulsion plant with one propulsion set inoperative.

2.2 Single failures to be considered for the propulsion set design

2.2.1 The propulsion sets are to be so designed as to remain available when one of the following failures occurs:

- an electrically driven pump for fuel supply, cooling and lubrication
- an air compressor for starting or control purposes
- a tube heat exchanger
- a fan serving the concerned machinery compartment.

2.3 Design of machinery systems

2.3.1 Fuel oil system

At least two store tanks and two service tanks are to be fitted, with means to periodically equalize the content on each set of tanks during the consumption of the fuel.

An alarm is to be activated when the level in any fuel oil storage tank is below the calculated value necessary to achieve a 150 hours range.

2.3.2 Ventilation system

Where the propulsion sets are located in a common compartment, the ventilation system serving this compartment is to be so designed as to allow the operation of the propulsion sets with an aggregate capacity of at least 50% of the full capacity while satisfying the temperature criteria laid down in Pt C, Ch 1, Sec 1, [2.5.2].

2.3.3 Steering systems

Where ships do not have traditional rudder and steering gears, being their steering capability supplied by azimuth thrusters or equivalent features, means are to be provided to allow at least the same redundancy as that afforded by two independent steering systems.

2.3.4 Recovery of the propulsion and steering in case of failures

The time for recovering:

- the propulsion in case of failure of one propulsion set
- the operation of a propulsion set when affected by a single failure (see [2.2.1])
- the steering in case of failure on one steering set

is not to exceed half an hour.

2.4 Design of electrical installations

2.4.1 At least two main sources of electrical power and two main switchboards are to be provided.

2.5 Design of automation systems

2.5.1 The automation system is to be arranged in such a way as to prevent the possibility that a single failure of the control system may lead to the loss of more than one propulsion system.

3 Tests on board

3.1 Running tests

3.1.1 The duplicated propulsion system is to be subjected to the running tests required by the Rules for similar systems.

3.2 Sea trials

3.2.1 Operation of the ship with one propulsion set inoperative

The sea trials are to include the following tests with one propulsion set inoperative:

- propulsion recovery test (see [2.3.4])
- speed measurement test.

Note 1: During the test, the power and the rotational speed of the active propulsion set are also to be recorded.

3.2.2 Operation of a propulsion set in case of single failure

During the sea trials, each type of propulsion set is to be subjected to the following tests:

- propulsion recovery test (see [2.3.4])
- tests required by the risk analysis conclusions and, where deemed necessary, simulation of certain single failures.

3.2.3 Steering system

The sea trials are to include a a recovery test of the steering system with one steering set inoperative.

Section 3 Independent Propulsion System (AVM-IPSx-(V))

1 General

1.1 Application

1.1.1 The additional class notation **AVM-IPSx-(V)** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.4.4] to self propelled ships arranged with means for independent propulsion system complying with the requirements of this Section.

1.1.2 This notation is granted, provided that:

a) The ship is arranged with at least two propellers and the associated independent shafting, each one independently driven by separate machinery, in such a way that at least 50% of the power remains available whenever any of the propulsion machinery and the associated propeller and shafting are out of service.

   It is also applicable to ships arranged with at least two independent azimuth thrusters and any other equivalent arrangement.

b) The propulsive installations are arranged in different compartments, in such a way that at least 50% of the power installed on board is still available whenever the machinery arranged in any one compartment is not operating

c) The arrangement of the independent propulsion system is such as to allow the ship to reach the first suitable port or place of refuge, or to escape from severe environment, providing the minimum services for navigation, preservation of cargo and habitability in case of any single failure.

1.2 Coverage of AVM-IPSx-(V) notation

1.2.1 Applicability

The following operating conditions are to be achieved:

- In case one propulsion system becomes inoperative due to a system failure coming from any single failure of one of the items specified in Ch 3, Sec 1, [2.1.3], at least 50% of the propulsion systems of the ship remains available and allows the ship to proceed at a speed of not less than 7 knots assuming that:
  - the ship is fully laden
  - the wind speed is equal to 11 m/s
  - the significant wave height is 2,4 m with a mean period equal to 6,5 s.
- In case of a fire or a flooding casualty, sufficient propulsion power is to remain available to allow the ship to proceed at speed of not less than 7 knots assuming that:
  - the ship is fully laden
  - the wind speed is equal to 11 m/s
  - the significant wave height is 2,4 m with a mean period equal to 6,5 s.
- Full load speed not less than **V** knots, where V is a speed specified by the owner, but not less than 7 knots
- Range of 1000 nautical miles or range corresponding to 1/2 of the range achievable with the full supply of fuel, whichever is the less
- Duplicated steering rudder and steering gear, or equivalent arrangement to ensure full steering capability in case of a major failure of the rudder or steering gear
- Availability of safety systems, including fire fighting systems, bilge system, navigating lights, communication apparatus, life-saving appliances
- Habitability conditions, including minimum lighting, ventilation, galleys, refrigerated stores, drinking water or evaporator services
- Operational efficiency (including combat system and stabilizers).

1.2.2 Services not available during emergency operation of the independent propulsion system

The following services need not to be supplied during the emergency operation of one (or more) of the propulsion systems, when any of the propulsion system is not available due to a single failure of any component of the propulsion plant or of any of the auxiliaries and equipment necessary for the propulsion:

Non essential services.

1.2.3 Use of the independent propulsion system in case of single failure

In order to grant **AVM-IPSx-(V)**, the independent propulsion system is to be arranged in such a way that the ship can continue or can recover in such a short time, as not to impair the safety of the ship, its operation in the case of a single failure (as defined in Ch 3, Sec 1, [2.1.3]) of any component of the main propulsion, steering or power generation system.

1.2.4 Single failure concept

a) A single failure of static and non-static components of the propulsion, steering and power generation systems is to be considered. Consequence failures, i.e. any failure of any component directly caused by a single failure of another component, are also to be considered.

b) The loss of one or more compartment due to fire or flooding. The possible notations in this respect are:

- **AVM-IPS1-(V)** notation is granted to ships having the propulsion systems and power generating stations arranged in compartments which are contiguous each other, and therefore the damage in way of a bulkhead, and the consequent loss of two adjacent compartments due to flooding does not allow the ship to comply with the condition in [1.2.1]
- **AVM-IPS2-(V)** notation is granted to ships having the propulsion and auxiliary systems arranged in non contiguous compartments and arranged so that a damage in way of a bulkhead, and the consequent loss of two adjacent compartments due to flooding still allows the ship to comply with the condition in [1.2.1]; irrespective of what above, the steering gear arrangements need not to be installed in non-contiguous spaces, provided that the functionality of the steering gears is granted also under flooded condition by means of either the selection of adequate components (e.g. having a suitable degree of protection) or of their position with respect to the waterline in flooded conditions.

1.2.5 Redundancy

All the redundancies normally required by the Rules are to be foreseen also under a single failure case of independent propulsion, with the exception of its control system.

1.3 Documentation to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document
1	I	Machinery spaces general arrangement
2	A	Description of the independent propulsion system
3	A	An analysis demonstrating the availability of the operating conditions as per Ch 3, Sec 1, [2.1.1] in case of a single failure as per Ch 3, Sec 1, [2.1.3] **(2)**
4	I	An operating manual with the description of the operations necessary to recover the propulsion and essential services in case of a single failure as described in Ch 3, Sec 1, [2.1.3]

(1) A : to be submitted for approval ; I : to be submitted for information.
(2) This analysis may be in the form of a Failure Mode and Effect Analysis (FMEA). Ch 3, App 1 describes an acceptable procedure for carrying out the FMEA.

2 Special arrangements

2.1 Systems for cooling, lubrication, fuel supply, air starting, monitoring and control

2.1.1 General

The systems are to be constructed such as to satisfy the conditions stipulated in Ch 3, Sec 1, [2.1]. In addition to what stated in the relevant parts of the Rules, the following requirements apply.

2.1.2 Pumps

For the assignment of the **AVM-IPSx-(V)** notation, the systems concerned are to be provided with at least two pumps, one as a stand-by of the other. One of the two pumps may be driven by the propulsion machinery, while the other pump is to be independently driven.

2.1.3 Cooling system

Separate cooling systems are to be provided for each compartment of the main propulsion system. In general, separate cooling systems are to be provided for each main propulsion system, unless the FMEA demonstrates that one cooling system serving all propulsion systems within one compartment is arranged in such a way that any single failure of the system does not make inoperative all the propulsion systems of the compartment.

2.1.4 Lubricating oil system

Each main propulsion system is to be fitted with a separate lubrication oil system.

2.1.5 Fuel oil system

At least two store tanks and two service tanks are to be fitted. Means are to be provided to periodically equalize the content on each set of tanks during the consumption of the fuel, in order to achieve the minimum range indicated in [1.2.1] after a single failure.

2.1.6 By-pass

Means are to be provided to by-pass and shut-off each of the components which may be subject of a single failure, as defined in Ch 3, Sec 1, [2.1.3], without impairing the functioning of the system itself (including machinery and equipment) or of the other systems which are to be operated in connection with navigation in emergency.

2.1.7 Piping segregation

Piping systems connecting the independent propulsion systems located in different spaces or piping systems serving one propulsion systems and passing through the spaces where another independent propulsion system is arranged are to be fitted with closing devices on both sides of the separating bulkheads, which are to be kept permanently closed.

2.2 Rudders and steering gears

2.2.1

a) Duplicated rudders and steering gears are to be arranged in separate compartments.

b) Where ships do not have traditional rudder and steering gears, being their steering capability supplied by azimuth thrusters or equivalent features, means are to be provided to allow at least the same redundancy as required in a) above.

2.3 Electrical installations

2.3.1

a) Where the propulsion systems are supplied by the main source of electrical power, the capacity of the electric generators is to be that indicated in Pt C, Ch 2, Sec 3, [2.2], with the exception of those services indicated in [1.2.4], including the power requested for the duplicated propulsion, without recourse to the emergency source of electrical power and with any one of the generating sets spaces unavailable.

b) At least two main sources of electrical power and two main switchboards are to be provided.

c) The power supplies to a machinery space are not to pass through the spaces where other independent propulsion systems are arranged, unless a second power supply to the same apparatus is fitted and not passing through the same spaces.

2.4 Automation

2.4.1 The automation system is to be arranged in such a way as to prevent the possibility that a single failure of the control system may lead to the loss of more than one propulsion system.

3 Tests on board

3.1 Running tests

3.1.1 The independent propulsion system is to be subjected to the running tests required by the Rules for similar systems.

3.2 Sea trials

3.2.1 In the course of sea trials the single failures mentioned in Ch 3, Sec 1, [2.1.3] are to be simulated and the values of the power and speed developed in this condition are to be recorded.

Appendix 1 Procedures for Failure Modes and Effect Analysis

1 General

1.1 Introduction

1.1.1 FMEA requirement

As specified in Ch 3, Sec 1, Ch 3, Sec 2 and Ch 3, Sec 3 in order to grant the **AVM** notations, an FMEA is to be carried out, with the exception indicated in Note 2 of Ch 3, Sec 1, Tab 1 to demonstrate that, in case of single failure to the propulsion, steering or power generating system, the ship is still capable to achieve the performances indicated in the applicable Sections as a condition for granting the notation.

1.1.2 Scope of the Appendix

This Appendix describes a failure mode and effects analysis (FMEA) and gives guidance as to how it may be applied by:

a) explaining basic principles

b) providing the procedural steps necessary to perform an analysis

c) identifying appropriate terms, assumptions, measures and failure modes, and

d) providing examples of the necessary worksheets.

1.1.3 Definition of FMEA

A practical, realistic and documented assessment of the failure characteristics of the ship and its component systems aiming at defining and studying the important failure conditions that may exist.

1.1.4 FMEA principles

The FMEA is based on a single failure concept under which each considered system at various levels of a system's functional hierarchy is assumed to fail by one probable cause at a time. The effects of the postulated failure are analysed and classified according to their severity. Such effects may include secondary failures (or multiple failures) at other level(s). Any failure mode which may cause a catastrophic effect should be safeguarded by either system or equipment redundancy unless the probability of such failure is extremely improbable. For failure modes causing hazardous effects corrective measures may be accepted in lieu.

1.1.5 Alternatives

While FMEA is suggested as one of the most flexible analysis techniques, it is accepted that there are other methods which may be used and which in certain circumstances may offer an equally comprehensive insight into particular failure characteristics. These methods may be accepted by the Society on case by case base.

1.2 Objectives

1.2.1 Primary objective

The primary objective of FMEA is to provide a comprehensive, systematic and documented investigation which establishes the important failure conditions of the ship propulsion, steering and power generation systems and assesses their significance with regard to the safety of the ship and her occupants.

1.2.2 Aim of the analysis

The main aims of undertaking the analysis are to:

a) provide ship and system designers with data to audit their proposed designs

b) provide the Owner with the results of a study into ship's selected systems failure characteristics so as to assist in an assessment of the measures to be taken to limit the damages consequent of the failure within acceptable limits

c) provide the Master and crew of the ship with data to generate comprehensive training, operational and maintenance programmes and documentation.

1.3 Sister ships

1.3.1 For ships of the same design and having the same equipment, one FMEA on any one of such ships may be sufficient.

1.4 FMEA basics

1.4.1 Before proceeding with a detailed FMEA into the effects of the failure of the system elements on the system functional output it is necessary to perform a functional failure analysis of the considered systems. In this way only systems which fail the functional failure analysis need to be investigated by a more detailed FMEA.

1.4.2 Operational modes

When conducting a system FMEA the following typical operational modes within the normal design environmental conditions of the ships are to be considered:

a) normal seagoing conditions at full speed

b) maximum permitted operating speed in congested waters

c) manoeuvring alongside

d) seagoing conditions in emergency, as defined in Ch 3, Sec 1, Ch 3, Sec 2 and Ch 3, Sec 3.

1.4.3 Functional interdependence

This functional interdependence of these systems is also to be described in either block diagrams or fault tree diagrams or in a narrative format to enable the failure effects to be understood. As far as applicable, each of the systems to be analysed is assumed to fail in the following failure modes:

a) complete loss of function

b) rapid change to maximum or minimum output

c) uncontrolled or varying output

d) premature operation

e) failure to operate at a prescribed time

f) failure to cease operation at a prescribed time.

Depending on the system under consideration other failure modes may have to be taken into account.

1.4.4 Systems which can fail without catastrophic effects

If a system can fail without any hazardous or catastrophic effect, there is no need to conduct a detailed FMEA into the system architecture. For systems whose individual failure can cause hazardous or catastrophic effects and where a redundant system is not provided, a detailed FMEA as described in the following paragraphs should be followed.

1.4.5 Redundant systems

Where a system, the failure of which may cause a hazardous or catastrophic effect, is provided with a redundant system, a detailed FMEA may not be required provided that:

a) The redundant system can be put into operation or can take over the failed system within the time-limit dictated by the most onerous operational mode without hazarding the ship

b) The redundant system is completely independent from the system and does not share any common system element the failure of which would cause failure of both the system and the redundant system. Common system element may be acceptable if the probability of failure complies with [4]

c) If the redundant system uses the same power source as the system, an alternative power source is readily available with regard to the requirement of a) above.

The probability and effects of operator's error to bring in the redundant system are also to be considered.

1.5 FMEA analysis

1.5.1 The systems to be subject to a more detailed FMEA investigation at this stage are to include all those that have failed the system FMEA and may include those that have a very important influence on the safety of the ship and her occupants and which require an investigation at a deeper level than that undertaken in the system functional failure analysis. These systems are often those which have been specifically designed or adapted for the ship, such as the craft's electrical and hydraulic systems.

2 FMEA performance

2.1 Procedures

2.1.1 The following steps are necessary to perform an FMEA:

a) to define the system to be analysed

b) to illustrate the interrelationships of functional elements of the system, by means of block diagrams

c) to identify all potential failure modes and their causes

d) to evaluate the effects on the system of each failure mode

e) to identify failure detection methods

f) to identify corrective measures for failure modes

g) to assess the probability of failures causing hazardous or catastrophic effects, where applicable

h) to document the analysis

i) to prepare FMEA report.

2.2 System definition

2.2.1 The first step in an FMEA study is a detailed study of the system to be analysed, through the use of drawings and equipment manuals. A narrative description of the system and its functional requirements is to be drawn up including the following information:

a) general description of system operation and structure

b) functional relationship among the system elements

c) acceptable functional performance limits of the system and its constituent elements in each of the typical operational modes

d) system constraints.

2.3 Development of system block diagram

2.3.1 Block diagram

The next step is to develop block diagram(s) showing the functional flow sequence of the system, both for technical understanding of the functions and operation of the system, and for the subsequent analysis. As a minimum the block diagram is to contain:

a) breakdown of the system into major sub-systems or equipment

b) all appropriate labelled inputs and outputs and identification numbers by which each sub-system is consistently referenced

c) all redundancies, alternative signal paths and other engineering features which provide “fail-safe” measures.

2.3.2 Block diagrams and operational modes

It may be necessary to have a different set of block diagrams prepared for each different operational modes.

2.4 Identification of failure modes, causes and effects

2.4.1 Failure mode

Failure mode is the manner by which a failure is observed. It generally describes the way the failure occurs and its impact on the equipment or system. As an example, a list of failure modes is given in Tab 1. The failure modes listed in Tab 1 can describe the failure of any system element in sufficiently specific terms. When used in conjunction with performance specifications governing the inputs and outputs on the system block diagram, all potential failure modes can be thus identified and described. Thus, for example, a power supply may have a failure mode described as “loss of output” (29), and a failure cause “open (electrical)” (31).

2.4.2 System failure

A failure mode in a system element could also be the failure cause of a system failure. For example, the hydraulic line of a steering gear system might have a failure mode of “external leakage” (10). This failure mode of the hydraulic line could become a failure cause of the steering gear system’s failure mode “loss of output” (29).

2.4.3 Top-down approach

Each system should be considered in a top-down approach, starting from the system’s functional output, and failure is to be assumed by one possible cause at a time. Since a failure mode may have more than one cause, all potential independent causes for each failure mode are to be identified.

2.4.4 Delay effect when operating back-up systems

If major systems can fail without any adverse effect there is no need to consider them further unless the failure can go undetected by an operator. To decide that there is no adverse effect does not mean just the identification of system redundancy. The redundancy is to be shown to be immediately effective or brought on line with negligible time lag. In addition, if the sequence is: “failure - alarm - operator action - start of back up- back up in service”, the effects of delay should be considered.

Table 1 : Example of failure mode list

1	Structural failure (rupture)
2	Physical binding or jamming
3	Vibration
4	Fails to remain in position
5	Fails to open
6	Fails to close
7	Fails open
8	Fails closed
9	Internal leakage
10	External leakage
11	Fails out of tolerance (high)
12	Fails out of tolerance (low)
13	Inadvertent operation
14	Intermittent operation
15	Erratic operation
16	Erroneous indication
17	Restricted flow
18	False actuation
19	Fails to stop
20	Fails to start
21	Fails to switch
22	Premature operation
23	Delayed operation
24	Erroneous input (increased)
25	Erroneous input (decreased)
26	Erroneous output (increased)
27	Erroneous output (decrease)
28	Loss of input
29	Loss of output
30	Shorted (electrical)
31	Open (electrical)
32	Leakage (electrical)
33	Other unique failure conditions as applicable to the system characteristics, requirements and operational constraints

2.5 Failure effects

2.5.1 Concept

The consequence of a failure mode on the operation, function, or status of an equipment or a system is called a “failure effect”. Failure effects on a specific sub-system or equipment under consideration are called “local failure effects”. The evaluation of local failure effects will help to determine the effectiveness of any redundant equipment or corrective action at that system level. In certain instances, there may not be a local effect beyond the failure mode itself.

2.5.2 End effect

The impact of an equipment or sub-system failure on the system output (system function) is called an “end effect”. End effects should be evaluated and their severity classified in accordance with the following categories:

a) catastrophic

b) hazardous

c) major

d) minor.

The definition of these four categories of failure effects is in Article [4].

2.5.3 Catastrophic and hazardous effects

If the end effect of a failure is classified as hazardous or catastrophic, back-up equipment is usually required to prevent or minimize such effect. For hazardous failure effects corrective operational procedures may be generally accepted.

2.6 Failure detection

2.6.1 Detectable failures

The FMEA study in general only analyses failure effects based on a single failure in the system and therefore a failure detection means, such as visual or audible warning devices, automatic sensing devices, sensing instrumentation or other unique indications, is to be identified.

2.6.2 Non detectable failures

Where the system element failure is non-detectable (i.e. a hidden fault or any failure which does not give any visual or audible indication to the operator) and the system can continue with its specific operation, the analysis is to be extended to determine the effects of a second failure, which in combination with the first undetectable failure may result in a more severe failure effect e.g. hazardous or catastrophic effect.

2.7 Corrective measures

2.7.1 Back-up equipment response

The response of any back-up equipment, or any corrective action initiated at a given system level to prevent or reduce the effect of the failure mode of system element or equipment, is also to be identified and evaluated.

2.7.2 Corrective design provisions

Provisions which are features of the design at any system level to nullify the effects of a malfunction or failure, such as controlling or deactivating system elements to halt generation or propagation of failure effects, activating back-up or standby items or systems, are to be described. Corrective design provisions include:

a) redundancies that allow continued and safe operation

b) safety devices, monitoring or alarm provisions, which permit restricted operation or limit damage

c) alternative modes of operation.

2.7.3 Manual corrective actions

Provisions which require operator action to circumvent or mitigate the effects of the postulated failure are to be described. The possibility and effect of operator's errors is to be considered, if the corrective action or the initiation of the redundancy requires operator input, when evaluating the means to eliminate the local failure effects.

2.7.4 Acceptability of corrective action

It is to be noted that corrective responses acceptable in one operational mode may not be acceptable at another, e.g. a redundant system element with considerable time lag to be brought into line, while meeting the operational mode "normal seagoing conditions at full speed" may result in a catastrophic effect in another operational mode, e.g. "maximum permitted operating speed in congested water".

2.8 Use of probability concept

2.8.1 Acceptance criteria

If corrective measures or redundancy as described in previous paragraphs are not provided for any failure, as an alternative the probability of occurrence of such failure is to meet the following criteria of acceptance:

a) a failure mode which results in a catastrophic effect is to be assessed to be extremely improbable

b) a failure mode assessed as extremely remote is to not result in worse than hazardous effects

c) a failure mode assessed as either frequent or reasonably probable is not to result in worse than minor effects.

2.8.2 Data

Numerical values for various levels of probabilities are laid down in [4]. In areas where there is no data from ships to determine the level of probabilities of failure other sources can be used such as:

a) workshop test

b) history of reliability used in other areas under similar operating conditions

c) mathematical model if applicable.

2.9 Documentation

2.9.1 Worksheet

It is helpful to perform FMEA on worksheets. Tab 2 shows an example of worksheet.

2.9.2 Worksheet organization

The worksheets are be organized to first display the highest system level and then proceed down through decreasing system levels.

Table 2 : FMEA worksheet

<table>
<tr><td colspan="7">Name of system:
Mode of operation:
Sheet No:
Date:
Name of analyst:</td><td colspan="5">References:
System block diagram:

Drawings:</td></tr>
<tr><td rowspan="2">Equipment name or number</td><td rowspan="2">Function</td><td rowspan="2">Ident. No.</td><td rowspan="2">Failure mode</td><td rowspan="2">Failure cause</td><td colspan="2">Failure effect</td><td rowspan="2">Failure detection</td><td rowspan="2">Corrective action</td><td rowspan="2">Severity of failure effect</td><td rowspan="2">Probability of failure (if applicable)</td><td rowspan="2">Remarks</td></tr>
<tr><td>Local effect</td><td>End effect</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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</table>

3 Tests and reporting

3.1 Reporting

3.1.1 The FMEA report is to be a self-contained document with a full description of the craft, its systems and their functions and the proposed operation and environmental conditions for the failure modes, causes and effects to be understood without any need to refer to other plans and documents not in the report. The analysis assumptions and system block diagrams are to be included, where appropriate.

The report is to contain a summary of conclusions and recommendations for each of the systems analysed in the system failure analysis and the equipment failure analysis. It is also to list all probable failures and their probability of failure where applicable, the corrective actions or operational restrictions for each system in each of the operational modes under analysis.

4 Probabilistic concept

4.1 General

4.1.1 For the purposes of this Chapter, the following definitions apply.

4.2 Occurrences

4.2.1 Occurrence

Occurrence is a condition involving a potential lowering of the level of safety.

4.2.2 Failure

Failure is an occurrence in which a part, or parts, of the ship fail. A failure includes:

a) a single failure

b) independent failures in combinations within a system, and

c) independent failures in combinations involving more than one system, taking into account:

   1) any undetected failure that is already present

   2) such further failures as would be reasonably expected to follow the failure under consideration, and

d) common cause failure (failure of more than one component or system due to the same cause).

Note 1: In assessing the further failures which follow, account should be taken of any resulting more severe operating conditions for items that have not up to that time failed.

4.2.3 Event

Event is an occurrence which has its origin outside the craft (e.g., waves).

4.2.4 Error

Error is an occurrence arising as a result of incorrect action by the operating crew or maintenance personnel.

4.3 Probability of occurrences

4.3.1 Frequent

Frequent is an occurrence which is likely to happen often during the operational life of a particular ship.

4.3.2 Reasonably probable

Reasonably probable is an occurrence which is unlikely to happen often but which may happen several times during the total operational life of a particular ship.

4.3.3 Recurrent

Recurrent is a term embracing the total range of frequent and reasonably probable.

4.3.4 Remote

Remote is an occurrence which is unlikely to happen to every ship but may happen to a few ships of a type over the total operational life of a fleet of ship of the same type.

4.3.5 Extremely remote

Extremely remote is an occurrence which is unlikely to happen when considering the total operational life of a fleet of ships of the same type, but nevertheless is considered as being possible.

4.3.6 Extremely improbable

Extremely improbable is an occurrence which is so unlikely to happen extremely remote that it is considered as not being possible to happer.

4.4 Effects

4.4.1 Effect

Effect is a situation arising as a result of an occurrence.

4.4.2 Minor effect

Minor effect is an effect which may arise from a failure, an event, or an error which can be readily compensated for by the operating crew; it may involve:

a) a small increase in the operational duties of the crew or in their difficulty in performing their duties, or

b) a moderate degradation in handling characteristics, or

c) slight modification of the normal operating conditions.

4.4.3 Major effect

Major effect is an effect which produces:

a) a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself should not be outside the capability of a competent crew provided that another major effect does not occur at the same time, or

b) significant degradation in handling characteristics, or

c) significant modification of the normal operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

4.4.4 Hazardous effect

Hazardous effect is an effect which produces:

a) a dangerous increase in the operational duties of the crew or in their difficulty in performing their duties of such magnitude that they cannot reasonably be expected to cope with them and will probably require outside assistance, or

b) dangerous degradation of handling characteristics, or

c) dangerous degradation of the strength of the ship, or

d) marginal conditions for, or injury to, occupants, or

e) an essential need for outside rescue operations.

4.4.5 Catastrophic effect

Catastrophic effect is an effect which results in the loss of the craft and/or in fatalities.

4.5 Safety level

4.5.1 Safety level is a numerical value characterizing the ship performance. The safety levels and the corresponding severity of effects on crew and safety criteria for ship performance are defined in Tab 3.

Table 3 : Safety levels and severity of effects on crew

Effect	Criteria not to be exceeded Type of load	Value **(2)**	Comment
Level 1 Minor Effect Moderate degradation of safety	Maximum acceleration measured horizontally **(1)**		0,08g and 0,20g/s **(3)**: Elderly person will keep balance when holding 0,15g and 0, g/s: Mean person will keep balance when holding 0,15g and 0,80g/s: Sitting person will start holding
Level 2 Major Effect Significant degradation of safety	Maximum acceleration measured horizontally **(1)**		0,25g and 2g/s: Maximum load for mean person keeping balance when holding 0,45g and 10g/s: Mean person fails out of seat when nor wearing seat belts
Level 3 Hazardous Effect Major degradation of safety	Collision design condition calculated Maximum structural design load, based on vertical acceleration at centre of gravity		Risk of injury to persons, safe emergency operation after collision 1g: Degradation of person safety
Level 4 Catastrophic Effect			Loss of ship and/or fatalities

(1) The recording instruments used are to be such that the acceleration accuracy is better than 5% of the real value and frequency response is to be minimum 20 Hz. Antialiasing filters with maximum passband attenuation 100 + 5% are to be used
(2) g = gravity acceleration (9,81 m/s_2)
(3) g-rate of jerk may be evaluated from acceleration/time curves.

4.6 Numerical values

4.6.1 Where numerical probabilities are used in assessing compliance with requirements using the terms similar to those given above, the approximate values given in Tab 4 may be used as guidance (values are on an hourly basis). The probabilities quoted in the analysis should be on an hourly or per journey basis, depending on which is more appropriate to the assessment in question.

Note 1: Different occurrences may have different acceptable probabilities, according to the severity of their consequences (see Tab 5).

Table 4 :

Frequent	More than 10^{-3}
Reasonably probable	10^{-3} to 10^{-5}
Remote	10^{-5} to 10^{-7}
Extremely remote	10^{-7} to 10^{-9}
Extremely improbable	Whilst no approximate numerical probability is given for this, the figures used should be substantially less than 10^{-9}

Table 5 :

SAFETY LEVEL	**1**	**1**	**1**	**2**	**3**	**4**
EFFECT ON SHIP AND OCCUPANTS	Normal	Nuisance	Operating limitations	Emergency procedures; significant reduction in safety margins; difficult for crew to cope with adverse conditions; person injuries	Large reduction in safety margin; crew over-burden because of work-load or environmental conditions; serious injuries to small number of persons	Casualties and deaths, usually with loss of ship
F.A.R. PROBABILITY**(1)**	Probable			Improbable		Extremely improbable
JAR-25 PROBABILTY**(2)**	Probable			Improbable		Extremely improbable
	Frequent		Reasonably probable	Remote	Extremely remote	
	10^{-0}	10^{-2}	10^{-3}	10^{-5}	10^{-7}	10^{-9}
CATEGORY OF EFFECT	Minor			Major	Hazardous	Catastrophic

(1) The United States Federal Aviation Regulation
(2) European Joint Airworthiness Regulations

Part E
Additional Class Notations

CHAPTER 4
AUTOMATION SYSTEMS (AUT)

Section 1 Qualified Automation Systems (AUT-QAS)

Section 2 Automated Operation in Port (AUT-PORT)

Section 3 Integrated Automation Systems (AUT-IAS)

Section 1 Qualified Automation Systems (AUT-QAS)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-QAS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.5.2] to ships fitted with automated installations enabling periodically unattended operation of machinery spaces, and complying with the requirements of this Section.

Note 1: Machinery spaces are defined in Pt C, Ch 1, Sec 1.

1.1.2 The arrangements provided are to be such as to ensure that the safety of the ship in all sailing conditions, including manoeuvring, is equivalent to that of a ship having the machinery spaces manned.

1.2 Communication system

1.2.1 A reliable means of vocal communication is to be provided among all machinery spaces, their machinery control room, the continuously manned central operating position(s) and the navigation bridge.

1.2.2 Navigation bridge, continuously manned control position and propulsion and steering control positions are to be served by a reliable communication network able to permit simultaneous communication.

1.2.3 The location and the design of the means of communication referred to in [1.2.2] are to be such that the manual operation of the propulsion and steering machinery may be assured also in case of failure of the remote control system.

1.2.4 Means of communication are to be capable of being operated even in the event of failure of supply from the main source of electrical power.

1.2.5 The capacity of the battery assuring the continuity of the supply is to be of at least 30 min.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to those mentioned in Pt C, Ch 3, Sec 1, Tab 1, the documents in Tab 1 are required.

Table 1 : Documents to be submitted

No.	I/A**(1)**	Document
1	A	Means of communication diagram
2	A	Layout of remote control positions
3	A	System of protection against flooding
4	A	Fire detection system: diagram, location and cabling
5	I	Plan of fire detection test for the machinery spaces and vehicle spaces.
(1) A: to be submitted for approval I: to be submitted for information		

3 Fire and flooding precautions

3.1 Fire prevention

3.1.1 The requirements regarding piping and arrangements of fuel oil and lubricating oil systems given in Pt C, Ch 1, Sec 10 are applicable.

3.1.2 Where heating is necessary, it is to be arranged with automatic control. A high temperature alarm is to be fitted in all damage control stations and the possibility of adjusting its threshold according to the fuel quality is to be provided.

3.2 Fire detection

3.2.1 For fire detection, the requirements given in Part C, Chapter 4 are applicable.

3.2.2 An automatic fire detection system is to be fitted in machinery spaces as defined in Pt C, Ch 4, Sec 1, [2] intended to be unattended.

3.2.3 The fire detection system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm in the damage control station.

3.2.4 The fire detection indicating panel is to be located in the damage control station.

3.2.5 The fire detection indicating panel is to indicate the place of the detected fire in accordance with the arranged fire zones by means of a visual signal. Audible signals clearly distinguishable in character from any other signals are to be audible in the damage control station.

3.2.6 Fire detectors are to be of such type and so located that they will rapidly detect the onset of fire in conditions normally present in the machinery space. Consideration is to be given to avoiding false alarms. The type and location of detectors are to be approved by the Society and a combination of detector types is recommended in order to enable the system to react to more than one type of fire symptom.

3.2.7 Except in spaces of restricted height and where their use is specially appropriate, detection systems using thermal detectors only are not permitted. Flame detectors may be installed, although they are to be considered as complementary and are not to replace the main installation.

3.2.8 Fire detector zones are to be arranged in a manner that will enable the operating staff to locate the seat of the fire. The arrangement and the number of loops and the location of detector heads are to be approved in each case. Air currents created by the machinery are not to render the detection system ineffective.

3.2.9 When fire detectors are provided with the means to adjust their sensitivity, necessary arrangements are to be allowed to fix and identify the set point.

3.2.10 When it is intended that a particular loop or detector is to be temporarily switched off, this state is to be clearly indicated. Reactivation of the loop or detector is to be performed automatically after a preset time.

3.2.11 The fire detection indicating panel is to be provided with facilities for functional testing.

3.2.12 The fire detection system is to be continuously powered and is to have an automatic change over to a stand by power supply in case of loss of normal power supply.

3.2.13 The capacity of the battery assuring the continuity of the supply is to be of at least 30 min.

3.2.14 Facilities are to be provided in the fire detecting system to manually release the fire detection alarm from the following places:

- passageways having entrances to engine and boiler rooms
- damage control station.

3.2.15 Spaces where main and auxiliary engines are located, are to be supervised by TV camera monitored from the continuously manned damage control station.

3.2.16 The detection equipment is to be designed so as to signal in less than 3 minutes a conventional seat of fire resulting from a cold smoke generator system in all conditions normally present in machinery spaces. Alternative means of testing may be accepted at the discretion of the Society in order to test the heat and flame detectors.

3.3 Fire fighting

3.3.1 Pressurization of the fire main at suitable pressure by starting main fire pumps and carrying out the other necessary operations is to be possible from the damage control station.

3.3.2 In addition to the fire-extinguishing arrangements mentioned in Part C, Chapter 4, periodically unattended spaces containing steam turbines (whose power is at least 375 kW) are to be provided with one of the fixed fire-extinguishing systems required in the same Chapter for machinery spaces of category A containing oil fired boilers or fuel oil units.

3.4 Protection against flooding

3.4.1 Bilge wells or machinery spaces bilge levels are to be monitored in such a way that the accumulation of liquid is detected in normal angles of trim and heel.

All compartments considered as foldable for the damage stability verification (see Pt B, Ch 3, Sec 3) have to be provided with water level detectors.

3.4.2 Where the bilge pumps are capable of being started automatically, means shall be provided to indicate when the influx of liquid is greater than the pump capacity or when the pump is operating more frequently than would normally be expected.

3.4.3 Where the bilge pumps are automatically controlled, they are not be started when the oil pollution level is higher than accepted in Pt C, Ch 2, Sec 1.

3.4.4 The location of controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system shall be so sited as to allow adequate time for operation in case of influx of water to the space, having regard to the time likely to be required in order to reach and operate such controls. If the level to which the space could become flooded with the ship in the fully loaded condition so requires, arrangements shall be made to operate the controls from a position above such level.

3.4.5 Bilge level alarms are to be given in the damage control station.

4 Control of machinery

4.1 General

4.1.1 Under all sailing conditions, including manoeuvring, the speed, direction of thrust and, if applicable, the pitch of the propeller are to be fully controllable from the navigation bridge.

4.1.2 All manual operations or services expected to be carried out with a periodicity of less than 24 h are to be eliminated or automated, particularly for: lubrication, topping up of make up tanks and filling tanks, filter cleaning, cleaning of centrifugal purifiers, drainage, load sharing on main engines and various adjustments. Nevertheless, the transfer of operation mode may be effected manually.

4.1.3 A centralized control position shall be arranged with the necessary alarm panels and instrumentation indicating any alarm.

4.1.4 Parameters for essential services which need to be adjusted to a preset value are to be automatically controlled.

4.1.5 The control system is to be such that the services needed for the operation of the main propulsion machinery and its auxiliaries are ensured through the necessary automatic arrangements.

4.1.6 It is to be possible for all machinery essential for the safe operation of the ship to be controlled from a local position, even in the case of failure in any part of the automatic or remote control systems.

4.1.7 The design of the remote automatic control system shall be such that in the case of its failure an alarm will be given. Unless impracticable, the preset speed and direction of thrust of the propeller it is to be maintained until local control is in operation.

4.1.8 Critical speed ranges, if any, are to be rapidly passed over by means of an appropriate automatic device.

4.1.9 Propulsion machinery is to stop automatically only in exceptional circumstances which could cause quick critical damage, due to internal faults in the machinery. The design of automation systems whose failure could result in an unexpected propulsion stop is to be specially examined. An overriding device for cancelling the automatic shutdown is to be considered.

4.1.10 Where the propulsive plant includes several main engines, a device is to be provided to prevent any abnormal overload on each of them.

4.1.11 Where standby machines are required for other auxiliary machinery essential to propulsion, automatic changeover devices shall be provided.

4.1.12 In the continuously manned control position, it is to be possible to restore the normal electrical power supply in the case of power failure (e.g. with remote control of the generating sets).

4.1.13 In addition to the automatic restart of essential auxiliaries remote control from the continuously manned control position is to be provided.

4.2 Diesel propulsion plants

4.2.1 When a diesel engine is used for the propulsion plant, monitoring and control of equipment is to be performed according to Tab 2 for slow speed engines or Tab 3 for medium or high speed engines.

4.3 Gas turbine propulsion plants

4.3.1 For gas turbines, monitoring and control elements are required according to Tab 4.

Table 2 : Main propulsion slow speed diesel engine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil system							
• Fuel oil pressure after filter (engine inlet)	L	R					
						X	
• Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)	H + L						
					X		
• Leakage from high pressure pipes where required	H						
Lubricating oil system							
• Lubricating oil to main bearing and thrust bearing pressure	L	R	X				
	LL			X			
						X	
• Lubricating oil to crosshead bearing pressure when separate	L	R	X				
	LL			X			
						X	
• Lubricating oil to camshaft pressure when separate	L						
	LL			X			
						X	
• Lubricating oil to camshaft temperature when separate	H						
					X		
• Lubricating oil inlet temperature	H						
					X		
• Thrust bearing pads or bearing outlet temperature	H	local	X				
• Main, crank, crosshead bearing oil outlet temp. or oil mist concentration in crankcase **(5)**	H		X				
• Flow rate cylinder lubricator (each apparatus)	L		X				
• Level in lubricating oil tanks or oil sump, as appropriate**(4)**	L						
• Lubricating oil to turbocharger inlet pressure	L						
• Turbocharger lubricating oil outlet temperature on each bearing	H						
Piston cooling system							
• Piston coolant inlet pressure	L		X **(1)**				
						X	
• Piston coolant outlet temperature on each cylinder	H	local	X				
• Piston coolant outlet flow on each cylinder **(2)**	L	local	X				
• Level of piston coolant in expansion tank	L						
Sea water cooling system							
• Sea water cooling pressure	L						
						X	

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand by Start	Stop
Cylinder fresh cooling water system							
• Cylinder fresh cooling water system inlet pressure	L	local**(3)**	X				
						X	
• Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local	X				
• Oily contamination of engine cooling water system (when main engine cooling water is used in fuel and lubricating oil heat exchangers)	H						
• Level of cylinder cooling water in expansion tank	L						
Fuel valve coolant system							
• Pressure of fuel valve coolant	L						
						X	
• Temperature of fuel valve coolant	H						
• Level of fuel valve coolant in expansion tank	L						
Scavenge air system							
• Scavenging air receiver pressure		R					
• Scavenging air box temperature (detection of fire in receiver, see [3.2.2])	H	local	X				
• Scavenging air receiver water level	H						
Exhaust gas system							
• Exhaust gas temperature after each cylinder	H	R	X				
• Exhaust gas temperature after each cylinder, deviation from average	H						
• Exhaust gas temperature before each turbocharger	H	R					
• Exhaust gas temperature after each turbocharger	H	R					
Miscellaneous							
• Speed of turbocharger		R					
• Engine speed (and direction of speed when reversible)		R					
					X		
• Engine overspeed **(3)**	H			X			
• Wrong way	X						
• Control, safety, alarm system power supply failure	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine.
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.
(3) For engines of 220 KW and above.
(4) If separate lubricating oil tanks are installed, then an individual level alarm for each tank is required.
(5) For engines having a power of more than 2250 kw or a cylinder bore of more than 300 mm.

Table 3 : Main propulsion medium or high speed diesel engine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil system							
• Fuel oil pressure after filter (engine inlet)	L	R					
						X	
• Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)	H + L						
					X		
• Leakage from high pressure pipes where required	H						
Lubricating oil system							
• Lubricating oil to main bearing and thrust bearing pressure	L	R	X				
	LL			X			
	X					X	
• Lubricating oil filter differential pressure	H	R					
• Lubricating oil inlet temperature	H	R					
					X		
• Oil mist concentration in crankcase **(1)**	H			X			
• Flow rate cylinder lubricator (each apparatus)	L		X				
• Lubricating oil to turbocharger inlet pressure **(2)**	L	R					
Sea water cooling system							
• Sea water cooling pressure	L	R					
						X	
Cylinder fresh cooling water system							
• Cylinder water inlet pressure or flow	L	R	X				
						X	
• Cylinder water outlet temperature	H	R					
			X				
• Level of cylinder cooling water in expansion tank	L						
Scavenge air system							
• Scavenging air receiver temperature	H						
Exhaust gas system							
• Exhaust gas temperature after each cylinder **(3)**	H	R	X				
• Exhaust gas temperature after each cylinder **(3)**, deviation from average	H						
Miscellaneous							
• Engine speed		R					
					X		
• Engine overspeed	H			X			
• Control, safety, alarm system power supply failure	X						

(1) Only for medium speed engines having a power of more than 2250 kw or a cylinder bore of more than 300 mm. One oil mist detector for each engine having two independent outputs for initiating the alarm and shutdown would satisfy the requirement for independence between alarm and shutdown system.
(2) If without integrated self-contained oil lubrication system.
(3) For engine power > 500 kW/cyl.

Table 4 : Propulsion gas turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Lubricating oil system							
• Turbine supply pressure	L		X			X	
	LL			X			
• Differential pressure across lubricating oil filter	H						
• Bearing or lubricating oil (discharge) temperature	H						
Mechanical monitoring of gas turbine							
• Speed		R			X		
	H			X			
• Vibration	H						
	HH			X			
• Rotor axial displacement (not applicable to roller bearing)	H						
	HH			X			
• Number of cycles performed by rotating parts	H						
Gas generator monitoring system							
• Flame and ignition failure				X			
• Fuel oil supply pressure	L						
• Fuel oil supply temperature	H + L						
					X		
• Cooling medium temperature	H						
• Exhaust gas temperature or gas temperature in specific locations of flow gas path (alarm before shutdown)	H						
	HH			X			
• Pressure at compressor inlet (alarm before shutdown)	L						
Miscellaneous							
• Control system failure	X						
• Automatic starting failure	X						

4.4 Electrical propulsion plant

4.4.1 Documents to be submitted

The following additional documents are to be submitted to the Society:

- A list of the alarms and shutdowns of the electrical propulsion system
- When the control and monitoring system of the propulsion plant is computer based, a functional diagram of the interface between the programmable logic controller and computer network.

4.4.2 Alarm system

The following requirements are applicable to the alarm system of electrical propulsion:

- Alarms circuits of electrical propulsion are to be connected to the main alarm system on board. As an alternative, the relevant circuit may be connected to a local alarm unit. In any case, a connection between the local alarm unit and the main alarm system is to be provided.
- The alarms can be arranged in groups, and shown in the control station. This is acceptable when a discrimination is possible locally.
- When the control system uses a computer based system, the requirements of Pt C, Ch 3, Sec 4 are applicable, in particular, for the data transmission link between the alarm system and the control system.
- Individual alarms are considered as critical and are to be individually activated at the control stations, and acknowledged individually.
- Shutdown activation is to be considered as an individual alarm.

4.4.3 Safety functions

The following requirements are applicable to the safety system of electrical propulsion:

- As a general rule, safety stop using external sensors such as temperature, pressure overspeed, main cooling failure, stop of converter running by blocking impulse is to be confirmed by the automatic opening of the main circuit using a separate circuit.
- In order to avoid accidental stop of the propulsion line and limit the risk of blackout due to wire break, the tripping of the main circuit-breaker is to be activated by an emission coil with a monitoring of the line wire break.
- In the case of a single line propulsion system, the power limitation order is to be duplicated.
- As a general rule, when the safety stop is activated, it is to be maintained until local acknowledgement.

4.4.4 Transformers

For transformers, parameters according to Tab 5 are to be controlled or monitored.

4.4.5 Converters

For converters, parameters according to Tab 6, Tab 7 and Tab 8 are to be monitored or controlled.

4.4.6 Smoothing coil

For the converter reactor, parameters according to Tab 9 are to be monitored or controlled.

4.4.7 Propulsion electric motor

For propulsion electric motors, parameters according to Tab 10 are to be monitored or controlled.

Table 5 : Transformers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Earth failure on main propulsion circuits	I						
Circuit-breaker, short-circuit	I **(2)**			X			
Circuit-breaker, overload	I **(2)**			X			
Circuit-breaker, undervoltage	I **(2)**			X			
Temperature of winding on phase 1, 2, 3 **(1)**	G						
	I, H		X **(3)**				
	I, HH			X			
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
Cooling pump pressure or flow	G, L						
			X				
						X	
Cooling medium temperature	G, H			X			
Leak of cooling medium	G						
			X				

(1) A minimum of 6 temperature sensors are to be provided:
- 3 temperature sensors to be connected to the alarm system (can also be used for the redundant tripping of the main circuit-breaker)
- 3 temperature sensors connected to the control unit.

(2) To be kept in the memory until local acknowledgement.
(3) Possible override of slowdown by the operator.

Table 6 : Network converter

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Short-circuit current I max	I			X			
Overvoltage	G			X			
Undervoltage	G						
Phase unbalanced	I			(X) **(1)**			
Power limitation failure	I						
Protection of filter circuit trip	I						
Circuit-breaker opening operation failure	I						
Communication circuit, control circuits, power supplies, watchdog of control system according to supplier's design	G			X			
(1) This parameter, when indicated in brackets, is only advisable according to the supplier's requirements.							

Table 7 : Motor converter

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Short-circuit current I max	I			X			
Overvoltage	G			X			
Undervoltage	G			X			
Phase unbalanced	I						
Protection of filter circuit trip	I						
Communication circuit, control circuits, power supplies, watchdog of control system according to supplier's design	G			X			
Speed sensor system failure	G					X **(1)**	
Overspeed	I			X			
(1) Automatic switch-over to the redundant speed sensor system.							

Table 8 : Converter cooling circuit

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Air cooling temperature high	I	R					
Ventilation, fan failure	G						
			X				
Cooling pump pressure or flow low	G	R					
						X	
Cooling fluid temperature high	G						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						

Table 9 : Smoothing coil

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Temperature of coil	I, H	R					
	I, HH						
Air cooling temperature	I, H						
Ventilation fan failure	G						
			X				
Cooling pump pressure or flow low	G	R					
						X	
Cooling fluid temperature high	G						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						

Table 10 : Propulsion electric motor

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Motor			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Automatic tripping of overload and short-circuit protection on excitation circuit	G, H			H			
Loss of excitation	G			X			
Winding current unbalanced	G						
Harmonic filter supply failure	I						
Interface failure with power management system	I		X				
Earthing failure on stator winding and stator supply	I	R					
Temperature of winding on phase 1, 2, 3	G	R					
	I, H		X				
	I, HH			X			
Motor cooling air temperature	I, H	R					
Cooling pump pressure or flow	G,L	R					
			X				
						X	
Cooling fluid temperature	G, H						
Leak of cooling medium	G						
			X				
Temperature sensor failure (short-circuit, open circuit, supply failure)	G						
Motor bearing temperature	G, H	R					
Bearing lubrication oil pressure (for self-lubricated motor, when the speed is under the minimum RPM specified by the manufacturer, shutdown is to be activated)	I, L	R					
			X				
						X	
Bearing lubrication oil pressure	G, L						
Turning gear engaged	I						
Brake and key engaged	I						
Shaft reduction gear bearing temperature	I, H						
Shaft reduction gear lubricating oil temperature	I, H						
Shaft reduction gear bearing pressure	I, L						
				X			

4.4.8 All parameters listed in the tables of this item are considered as a minimum requirement for unattended machinery spaces.

Some group alarms may be locally detailed on the corresponding unit (for instance loss of electronic supply, failure of electronic control unit, etc.).

4.5 Shafting, clutches, CPP, gears

4.5.1 For shafting and clutches, parameters according to Tab 11 are to be monitored or controlled.

4.5.2 For controllable pitch propellers, parameters according t Tab 12 are to be monitored or controlled.

4.5.3 For reduction gears and reversing gears, parameters according to Tab 13 are to be monitored or controlled.

Table 11 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Temperature of each shaft thrust bearing (not applicable for ball or roller bearings)	H		X				
Sterntube bush oil gravity tank level	L						
Clutch lubricating oil temperature	H		X				
Clutch oil tank level	L						

Table 12 : Controllable pitch propeller

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Control oil temperature	H	R					
Oil tank level	L	R					

Table 13 : Reduction gears/reversing gears

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Lubricating oil temperature at the oil cooler outlet	H	R **(1)**	X				
Lubricating oil pressure	L **(1)**	R		X			
						X	
Oil tank level	L	R	X				
	LL			X			
(1) May be omitted in the case of restricted navigation notation.							

4.6 Auxiliary system

4.6.1 Where standby machines are required for other auxiliary machinery essential to propulsion, automatic change- over devices shall be provided.

Change-over restart is to be provided for the following systems:

- cylinder, piston and fuel valve cooling
- cylinder cooling of diesel generating sets (where the circuit is common to several sets)
- main engine fuel supply
- diesel generating sets fuel supply (where the circuit is common to several sets)
- sea water cooling for propulsion plant
- sea water to main condenser (main turbines)
- hydraulic control of clutch, CPP or main thrust unit
- thermal fluid systems (thermal fluid heaters).

4.6.2 When a standby machine is automatically started, an alarm is to be activated.

4.6.3 When the propulsion plant is divided into two or more separate units, the automatic standby auxiliary may be omitted, when the sub-units concerned are fully separated with regard to power supply, cooling system, lubricating system etc.

4.6.4 Means shall be provided to keep the starting air pressure at the required level where internal combustion engines are used.

4.6.5 Where daily service fuel oil tanks are filled automatically, or by remote control, means shall be provided to prevent overflow spillages.

4.6.6 Arrangements are to be provided to prevent overflow spillages coming from equipment treating flammable liquids.

4.6.7 Where daily service fuel oil tanks or settling tanks are fitted with heating arrangements, a high temperature alarm shall be provided.

4.6.8 For auxiliary systems, the following parameters, according to Tab 14 to Tab 24 are to be monitored or controlled.

Table 14 : Control and monitoring of auxiliary electrical systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Electric circuit, blackout	X						
Power supply failure of control, alarm and safety system	X						

Table 15 : Incinerators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand-by Start	Stop
Combustion air pressure	L			X			
Flame failure	X			X			
Furnace temperature	H			X			
Exhaust gas temperature	H						
Fuel oil pressure	L						
Fuel oil temperature or viscosity , where heavy fuel is used	H + L						

Table 16 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Water level	L + H			X	X		
Fuel oil temperature	L + H			X	X		
Flame failure	X			X			
Combustion air supply fan low pressure				X			
Temperature in boiler casing (fire)	H						
Steam pressure	H **(1)**			X	X		
Steam temperature				X **(2)**			

(1) When the automatic control does not cover the entire load range from zero load.
(2) For superheated steam over 330°C.

Table 17 : Fuel oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Fuel oil tank level, overflow	H **(1)**						
Air pipe water trap level on fuel oil tanks	H **(2)**						
Outlet fuel oil temperature	H **(4)**			X **(5)**	X		
Sludge tank level	H						
Fuel oil settling tank level	H **(1)**						
Fuel oil settling tank temperature	H **(3)**						
Fuel oil centrifugal purifier overflow	H			X			
Fuel oil in daily service tank level	L						
Fuel oil daily service tank temperature	H **(3)**				X		
Fuel oil in daily service tank level (to be provided if no suitable overflow arrangement)	H **(1)**						

(1) Or sight-glasses on the overflow pipe.
(2) Or alternative arrangement as per Pt C, Ch 1, Sec 10.
(3) Applicable where heating arrangements are provided.
(4) Or low flow alarm in addition to temperature control when heated by steam or other media.
(5) Cut off of electrical power supply when electrically heated.

Table 18 : Lubricating oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Air pipe water trap level of lubricating oil tank See Pt C, Ch 1, Sec 10	H						
Sludge tank level	H						
Lubricating oil centrifugal purifier overflow	H						
(stop of oil supply)							X

Table 19 : Thermal oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Forced draft fan stopped				X			
Thermal fluid temperature	H						
				X			
Thermal fluid pressure							X
Flow through each element	L			X			
Heavy fuel oil temperature or viscosity	H + L				X		
Burner flame failure	X			X			
Flue gas temperature (when exhaust gas heater)	H			X			
Expansion tank level	L						X **(1)**
(1) Stop of burner and fluid flow.							

Table 20 : Hydraulic oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Pump pressure	L + H						
Service tank level	L **(1)**						
(1) The low level alarm is to be activated before the quantity of lost oil reaches 100 litres or 50% of the circuit volume, whichever is the lesser.							

Table 21 : Boiler feed and condensate system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Sea water flow or equivalent	L					X	
Vacuum	L						
	LL			X			
Water level in main condenser (unless justified)	H + L						
					X		
	HH			X			
Salinity of condensate	H						
Feed water pump delivery pressure	L					X	
Feed water tank level	L						
Deaerator inside temperature or pressure	L + H**(1)**						
Water level in deaerator	L + H						
Extraction pump pressure	L						
Drain tank level	L + H						
(1) In the case of forced circulation boiler.							

Table 22 : Compressed air system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand-by Start	Stop
Air temperature at compressor outlet	H						
Compressor lubricating oil pressure (except where splash lubrication)	LL			X			
Control air pressure after reducing valves	L + H	R					
					X		
Starting air pressure before main shut-off valve	L **(2)**	local + R **(1)**					
					X		
	X					X	
Safety air pressure	L + H						
					X		

(1) Remote indication is required if starting of air compressor is remote controlled, from wheelhouse for example.
(2) For starting air, the alarm minimum pressure set point is to be so adjusted as to enable at least four starts for reversible propulsion engines and two starts for non-reversible propulsion engines.

Table 23 : Cooling system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Sea water pump pressure or flow	X					X	
	L						
Fresh water pump pressure or flow	X					X	
	L						
Level in cooling water expansion tank	L						

Table 24 : Thrusters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Control oil temperature (preferably before cooler)	H						
Oil tank level	L						

4.7 Control of electrical installation

4.7.1 Where the electrical power can normally be supplied by one generator, suitable load shedding arrangement shall be provided to ensure the integrity of supplies to services required for propulsion and steering as well as the safety of the ship.

4.7.2 In the case of loss of the generator in operation, adequate provision shall be made for automatic starting and connecting to the main switchboard of a standby generator of sufficient capacity to permit propulsion and steering and to ensure the safety of the ship with automatic restarting of the essential auxiliaries including, where necessary, sequential operations.

4.7.3 The standby electric power is to be available in not more than 45 seconds.

4.7.4 If the electrical power is normally supplied by more than one generator simultaneously in parallel operation, provision shall be made, for instance by load shedding, to ensure that, in the case of loss of one of these generating sets, the remaining ones are kept in operation without overload to permit propulsion and steering, and to ensure the safety of the ship.

4.7.5 Following a blackout, automatic connection of the standby generating set is to be followed by an automatic restart of the essential electrical services. If necessary, time delay sequential steps are to be provided to allow satisfactory operation.

4.7.6 Monitored parameters for which alarms are required to identify machinery faults and associated safeguards are listed in Tab 25 and Tab 26. These alarms are to be indicated at the control location for machinery as individual alarms; where the alarm panel with all individual alarms is installed on the engine or in the vicinity, a common alarm in the control location for machinery is required. For communication of alarms detailed requirements are contained in Article [5].

Table 25 : Auxiliary reciprocating I.C. engines driving generators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Stand-by Start	Stop
Fuel oil viscosity or temperature before injection	L + H	local					
					X **(4)**		
Fuel oil pressure		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil temperature	H						
Lubricating oil pressure	L	local				X	
	LL			X **(1)**			
Oil mist concentration in crankcase **(2)**	H			X			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air	H	local					
Level in cooling water expansion tank, if not connected to main system	L						
Engine speed		local					
					X		
	H			X			
Fault in the electronic governor system	X						
Level in fuel oil daily service tank	L						
Starting air pressure	L						
Exhaust gas temperature after each cylinder **(3)**	H						

(1) Not applicable to emergency generator set.
(2) For engines having a power of more than 2250 kW.
(3) For engine power above 100 kW/cyl.
(4) Only when HFO is used

Table 26 : Auxiliary steam turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indic	Slow-down	Shut-down	Control	Standby Start	Stop
Turbine speed		local					
					X		
	HH			X			
Lubricating oil supply pressure	L					X	
	LL			X			

5 Alarm system

5.1 General

5.1.1 A system of alarm displays and controls is to be provided which readily allows identification of faults in the machinery and satisfactory supervision of related equipment. This is to be arranged at the continuously manned damage control station and at subsidiary control stations and as far as practicable at the machinery local control position if any. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

5.1.2 The alarm system is to be designed to function independently of control and safety systems, so that a failure or malfunction of these systems will not to prevent the alarm system from operating. Common sensors for alarms and automatic slowdown functions are acceptable as specified in each specific table.

5.1.3 The alarm system shall be continuously powered and shall have an automatic change-over to a standby power supply in the case of loss of normal power supply.

5.2 Alarm system design

5.2.1 The alarm system and associated sensors are to be capable of being tested during normal machinery operation.

5.2.2 Insulation faults on any circuit of the alarm system are to generate an alarm, when an insulated earth distribution system is used.

5.2.3 The alarm system is to have a connection to the engineers' public rooms and to each of the engineers' cabins through a selector switch, to ensure connection to at least one of those cabins.

5.2.4 An engineers' alarm is to be activated when the machinery alarm has not been accepted in the machinery spaces or control room within 5 minutes.

5.2.5 Requirements [5.2.3] and [5.2.4] may be omitted for ships where machinery installations are under continuous supervision from the centralized control position. Means to check the operator alertness is to be provided, when alone.

5.3 Machinery alarm system

5.3.1 The local silencing of the alarms in the continuously manned damage control station or subsidiary control stations is not to stop the audible machinery space alarm.

5.3.2 As far as practicable, machinery faults are to be indicated at the control locations for machinery.

5.4 Alarm system

5.4.1 The alarm system is to activate an audible and visual alarm on the navigation bridge for any situation which requires action by or the attention of the officer on watch.

5.4.2 Alarms associated with faults requiring speed reduction or automatic shutdown are to be separately identified on the bridge.

5.4.3 Individual alarms are to be provided at the navigation bridge indicating any power supply failures of the remote control of propulsion machinery.

6 Safety systems

6.1 General

6.1.1 Safety systems of different units of the machinery plant are to be independent. Failure in the safety system of one part of the plant is not to interfere with the operation of the safety system in another part of the plant.

6.1.2 In order to avoid undesirable interruption in the operation of machinery, the system is to intervene sequentially after the operation of the alarm system by:

- starting of standby units
- load reduction or shutdown, such that the least drastic action is taken first.

6.1.3 The arrangement for overriding the shutdown of the main propelling machinery is to be such as to preclude inadvertent operation.

6.1.4 Safeguard disactivation, if provided at the centralised control position, is to be so arranged so that it cannot be operated accidentally; the indication «safety devices off» is to be clearly visible. This device is not to disactivate the overspeed protection.

6.1.5 After stoppage of the propulsion engine by a safety shutdown device, the restart is only to be carried out, unless otherwise justified, after setting the propulsion bridge control level on «stop».

7 Testing

7.1 General

7.1.1 Tests of automated installations are to be carried out according to Pt C, Ch 3, Sec 6 to determine their operating conditions. The details of these tests are defined, in each case, after having studied the concept of the automated installations and their construction. A complete test program is to be submitted for approval and may be as follows:

7.1.2 The tests of equipment carried out alongside under normal conditions of use include, for instance:

- the electrical power generating set
- the auxiliary steam generator
- the automatic bilge draining system
- automatic centrifugal separators or similar purifying apparatus
- automatic change-over of service auxiliaries
- detection of high pressure fuel leaks from diesel generating sets or from flexible boiler burner pipes.

7.1.3 Sea trials are used to demonstrate the proper operation of the automated machinery and systems. For this purpose, for instance, the following tests are to be carried out:

- Test of the remote control of propulsion:
  - checking of the operation of the automatic control system: programmed or unprogrammed starting speed increase, reversal, adjusting of the propeller pitch, failure of supply sources, etc.
  - checking of the crash astern sequence, to ensure that the reversal sequence is properly performed from full away, the ship sailing at its normal operation speed. The purpose of this check is not to control the nautical performances of the ship (such as stopping distance, etc.)
  - finally, checking of the operation of the whole installation in normal working conditions, i.e. as a general rule without watch-keeping personnel for the monitoring and/or running of the machinery during 6 h at least
  - The following procedure may, for instance, be chosen: «underway» during 3 h, then decreasing to «full ahead». Staying in that position during 5 min. Then stopping for 15 min. Then, putting the control lever in the following positions, staying 2 minutes in each one: astern slow, astern half, astern full, full ahead, half ahead, stop, full astern, stop, ahead dead slow, half ahead, then increasing the power until «underway» position.
- Test of the operating conditions of the electrical production:
  - automatic starting of the generating set in the event of a blackout
  - automatic restarting of auxiliaries in the event of a blackout
  - load-shedding in the event of generating set overload
  - automatic starting of a generating set in the event of generating set overload.
- Test of fire and flooding system:
  - Test of normal operation of the fire detection system (detection, system faults)
  - Test of detection in the scavenging air belt and boiler air duct
  - Test of the fire alarm system
  - Test of protection against flooding.
- Test of operating conditions, including manoeuvring, of the whole machinery in an unattended situation for 6 h.

Section 2 Automated Operation in Port (AUT-PORT)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-PORT** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.5.3] to ships fitted with automated installations enabling the ship's operation in port without personnel specially assigned for the watch-keeping of the machinery in service, and complying with the requirements of this Section.

1.1.2 The arrangements provided are to be such as to ensure that the safety of the ship in port is equivalent to that of a ship having the machinery spaces manned.

1.2 Communication system

1.2.1 The requirements of Ch 4, Sec 1, [1.2] are applicable.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the those mentioned in Pt C, Ch 3, Sec 1, Tab 1, documents according to Tab 1 are required.

Table 1 : Documentation to be submitted

No.	I/A**(1)**	Document
1	A	Technical description of automatic engineers' alarm and connection of alarms to remote positions
2	A	System of protection against flooding
3	I	List of machinery to be in operation in port
(1) A: to be submitted for approval I: to be submitted for information.		

3 Fire and flooding precautions

3.1 General

3.1.1 The requirements given in Ch 4, Sec 1, [3] are applicable unless otherwise indicated below.

3.1.2 The remote control of the main fire pumps for the pressurisation of the fire main is to be located at the continuously manned control station in port.

4 Control of machinery

4.1 Plant operation

4.1.1 The machinery and systems which are to be in operation in port are to be designed according to Ch 4, Sec 1, [4], unless otherwise stated.

4.1.2 The requirements of Ch 4, Sec 1 regarding electrical production for propulsion are not applicable.

4.1.3 The operation of auxiliaries, other than those associated with propulsion, is to be designed according to Ch 4, Sec 1.

5 Alarm system

5.1 General

5.1.1 The alarm system is to be designed according to Ch 4, Sec 1, [5], unless otherwise stated in this Section.

5.1.2 The alarm system is to be designed so as to inform of any situation which requires attention of the personnel on watch. For this purpose, an audible and visual alarm is to be activated in the continuously manned control station in port.

6 Location of the continuously manned control station

6.1 General

6.1.1 A CMCS enabling the ship operation in port is to be provided.

6.1.2 However this station may be left unmanned where all monitoring, alarm, safety and control function are transferred to another CMCS located either on another ship or a shore.

7 Testing

7.1 Tests after completion

7.1.1 Tests are to be carried out of all systems which are required to be in operation in port, such as: the fuel oil purifier system, electrical power generation, auxiliary steam generator, etc.

Section 3 Integrated Automation Systems (AUT-IAS)

1 General

1.1 Application

1.1.1 The additional class notation **AUT-IAS** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.5.4] to ships fitted with automated installations enabling periodically unattended operation of machinery spaces and additionally with integrated systems for the control and monitoring of platform systems.

This notation is assigned when the requirements of this Section are complied with in addition to those of Ch 4, Sec 1 for the assignment of the notation **AUT-QAS**.

1.1.2 The design of automation systems, including computer based systems when applicable, is to be such that even when a single failure occurs in the system leading to the loss of the functionality of the service, then a secondary independent means is to be made available to restore the functionality of the service.

1.1.3 The need of redundancy of subsystems, I/O sensors and final actuators is to be evaluated on a case by case basis.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the those mentioned in Pt C, Ch 3, Sec 1, Tab 1 and Ch 4, Sec 1, Tab 1, documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A(**1**)	Document
1	I	Block diagram of the integrated computer based systems
2	A	FMEA study
2	I	Description of the data transmission protocol
3	I	Description of the auto-diagnosis function
(1) A: to be submitted for approval I: to be submitted for information.		

3 Design requirements

3.1 General

3.1.1 The computer network is to be capable of supporting all the integrated subsystems ensuring the minimum performance required in Pt C, Ch 3, Sec 3.

3.1.2 Consequences of a possible fault are to be taken into account. Normally, no consideration is given to defects occurring simultaneously; however in the case of defects which would remain undetected, it might be necessary to take into consideration the adding of several independent defects.

3.1.3 Necessary arrangements are to be made to avoid interaction between the various automatic control circuits in the event of a fault in one of them (e.g. galvanic separation of automatic control electric circuits or earth leak monitoring device with possibility of disconnecting the faulty circuit, keeping the others in service).

3.1.4 Arrangements are to be made to avoid self-oscillation of these automatic control devices; their natural frequencies are to be sufficiently far from those of the controlled installation to avoid resonance.

3.1.5 Sequential controls are to ensure checking of the condition necessary for automatic starting of main and auxiliary machinery. If one of these conditions is not fulfilled, the starting process is to be locked. A new starting attempt may be allowed only after returning to a steady and safe position.

3.1.6 To determine the operating conditions of the sequences, transducers are to check the parameter resulting from each step. The use of simple time delays for controlling the sequences is to be limited to cases where they can previously be clearly defined.

3.2 Integrated computer based systems

3.2.1 The following requirements apply in addition to those in Pt C, Ch 3, Sec 3 and Ch 4, Sec 1.

3.2.2 In addition to the requirements of Pt C, Ch 3, Sec 3 the computer network is to be single fault tolerant.

3.2.3 The integrated automation system is to be designed such that the subsystem is still operating in the case of loss of transmission of the network.

3.2.4 A document is to be issued when a modification of the configuration of the integrated system is carried out.

3.2.5 In case of failure of one computer server on which software is resident, at least another computer server is to be available.

3.2.6 In the case of failure of one workstation, the corresponding functions are to be possible from at least another work station in the same location, without a stop of the system in operation.

4 Testing

4.1 Additional testing

4.1.1 In addition to those required in Ch 4, Sec 1, the following additional tests are to be carried out along side or at sea where necessary:

- checking of the fire detection system
- checking of the proper operating condition of the integrated computer based systems used for monitoring and control and, in particular:
  - visual inspection
  - functional operation of workstation
  - transfer of control of workstation
  - inhibition function of alarms
  - alarm acknowledgement procedure
  - simulation of internal and external failure of the integrated system, including loss or variation of power supply
  - wrong data insertion test.

Part E
Additional Class Notations

CHAPTER 5
MONITORING EQUIPMENT (MON)

Section	1	Hull Stress and Motion Monitoring (MON-HULL)
Section	2	Shaft Monitoring (MON-SHAFT)

Section 1 Hull Stress and Motion Monitoring (MON-HULL)

1 General

1.1 Application

1.1.1 The additional class notation **MON-HULL** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.7.2] to ships equipped with a Hull Stress and Motion Monitoring System (hereafter referred to as Hull Monitoring System for easy reference), complying with the requirements of this Section.

1.1.2 A Hull Monitoring System is a system which:

- provides real-time data to the Captain and the Officers of the ship on hull girder longitudinal bending moments and motions the ship experiences while navigating and during loading and unloading operations in harbour (notation: **MON-HULL**)
- optionally, allows the storage of real-time data and/or of a set of statistical results.

The stored information should be organized in view of a later exploitation by the Owner, for instance as an additional element in the exploitation and maintenance of the ship or as an addition to her logbook. This option is distinguished by the additional class notation **+S**, the notation becoming **MON-HULL+S**.

Note 1: The information provided by the Hull Monitoring System is to be considered as an aid to the Captain. It does not replace his own judgement or responsibility.

1.2 Documentation

1.2.1 The following documents are to be submitted to the Society for approval:

- specification of the main components: sensors, processing units, display unit, storage unit, power supply and cabling
- functional scheme of the system
- principles and algorithm used for the data processing, either in **MON-HULL** or in **MON-HULL+S**
- determination of measurement ranges
- determination of data limits
- initial calibration procedure including calibration values and tolerances
- procedure for the periodical checks.

1.3 Data limits, warning levels

1.3.1 The information provided by the transducers is to be compared against relevant limits corresponding to maximum values obtained from the requirements on the basis of which the hull structure is approved. When a limit is reached, an alarm is to be issued.

1.3.2 The above information can also be compared against warning levels determined by the Owner.

A warning level is always to be less than the corresponding alarm level mentioned in [1.3.1].

When a warning level is reached, a signal is to be emitted, different from the alarm mentioned in [1.3.1].

2 Hull monitoring system

2.1 Main functions

2.1.1 The Hull Monitoring System is to be able to ensure the following main functions:

- collection of data
- data processing: scaling, consistency checks, statistical processing when needed by the plain **MON-HULL** implementation
- management of the displays, handling of the alarms and warnings
- in **MON-HULL+S**: selection, compression, if any, and storage of the information.

Note 1: The resources needed for the later onshore exploitation of the recorded results need not be considered as part of the Hull Monitoring System, provided that they cannot have access to the storage medium in order to modify the content.

2.2 Sensors

2.2.1 The sensors are to consist of a set of devices able to provide at least:

- indirect information on the longitudinal bending moment of the hull, at least at one location where the maximum hull girder normal stress can be expected during navigation, loading and unloading
- information on the vertical acceleration at the bow

  If a consistent monitoring of the vertical acceleration in any point of the hull girder is required, vertical acceleration is also to be collected at the stern
- information on the transverse acceleration due to the roll and the heel.

2.2.2 Attention is drawn to the possible existence of local strains induced by temperature gradients in the hull structure.

The strain sensors are to be located in areas free from these temperature gradients.

If a temperature compensation device is implemented, the Manufacturer is to demonstrate its effectiveness on site.

2.2.3 The sensors are to comply with the applicable requirements concerning protection against conducted and radiated electric and radioelectric emissions.

2.2.4 The sensors are to be selected and installed in such a way that a periodical on-site check can be carried out without extra equipment.

When this operation is impossible, the Manufacturer is to declare what are the period and procedure for a shop recalibration and demonstrate that the calibration remains valid within the period.

2.3 Specifications

2.3.1 For each type of measurement, the Manufacturer is to state the limits of the domain, according to the ship.

The limits are to include:

- the strain ranges
- the acceleration ranges
- the corresponding frequency range
- the temperature ranges: sea water, open air, hull structure, sheltered, accommodation.

2.3.2 The global resolution of the instrument is to be such that the uncertainty as to the displayed information is less than 7% of its full scale display. The global resolution applies on the entire domain, display included; the specification of the components is to be set accordingly.

2.3.3 The system is to be able to detect and signal the malfunctions which can impair the validity of the data, e.g.:

- data are out of range
- data remain strictly constant
- data are corrupted by high intensity noise
- the system stops or hangs.

2.4 Real time data processing

2.4.1 Wave-induced data are to be processed through any convenient procedure (maximum peak value, root mean square, mean value, frequency spectrum, etc.) selected in order that the displayed information is significant, not confusing, immediately understood and as close as possible to the nautical experience of the crew.

The procedure is to produce smoothed results that are not to deviate by more than 10% from one cycle to the next when in steady navigation conditions.

The procedure is to be such that a significant aggravation in the navigation conditions appears on the display after no more than three cycles.

The system is to switch automatically from port to sea conditions, and vice versa.

2.4.2 Provision is to be made for a transfer of information to a Voyage Data Recorder where this is fitted on board, according to the standards of the Voyage Data Recorder.

2.5 Visual display

2.5.1 A graphical display is to be fitted, with the following features:

- it is to be simple, clear and non-confusing
- the user is to be able to obtain the information through one reading
- it is to be readable at a distance of at least 0,5 m
- two major pieces of information (e.g. stress and/or vertical acceleration at bow) are declared as "default conditions" and displayed at power up and before the user takes any action
- when an alarm is emitted, the corresponding information is to be displayed instead of the above "default conditions".

2.5.2 When the system detects a malfunction, the corresponding status is to be superimposed on the display.

2.6 Alarms

2.6.1 For each limit stated in [1.3.1], visual and audible alarms are to be fitted on the bridge to indicate when the limit is approached and exceeded.

The alarms associated with each limit are to be clearly distinguishable from those relevant to other limits.

2.6.2 When a warning level is reached (see [1.3.2]), a visible signal is to be issued, distinct from those of the alarms for limits stated in [2.6.1].

2.6.3 When the system detects a malfunction, the alarms and warnings associated with the data are to be inhibited and a malfunction alarm is to be issued (see also [2.5.2]).

2.7 Data storage (MON-HULL+S)

2.7.1 The real time data are to be stored either by a recording device which is part of the Hull Monitoring System, according to [2.7.2] to [2.7.4], or by the integrated bridge system, if any.

2.7.2 An electronic data storage recording device suitable for accumulating statistical information for feedback purposes is to be fitted.

2.7.3 The data storage recording device is to be:

- entirely automatic, excluding replacement operations of the storage support
- such that its operation does not interrupt or delay the process of collecting and processing data.

2.7.4 Data are to be recorded with information on the date and time.

2.8 Exploitation and checking of stored data (MON-HULL+S)

2.8.1 The data stored according to [2.7] are to be processed by the Owner through a statistical process.

2.8.2 Periodicity of exploitation of data is to be defined by the Owner depending on the ship's operation.

2.8.3 Means are to be incorporated which ensure that the integrity of the collected data can be checked at the exploitation stage.

2.9 Power supply unit

2.9.1 The Hull Monitoring System is to be powered by the main power source of the ship and in addition with an internal uninterruptible 30 minute power source.

2.10 Calibration

2.10.1 The initial calibration of indirect information of the bending moment is to be based on an approved loading case in still water.

The differences between results obtained from the Hull Monitoring System and approved values are to be less than 5%.

2.10.2 The initial calibration of the Hull Monitoring System is to be carried out with a Surveyor in attendance.

2.11 Periodical inspections

2.11.1 Checks of the main functions of the Hull Monitoring System are to be carried out at intervals as agreed by the Society and not exceeding one year.

The instrument is to include an auto-checking facility so that the verification of the Hull Monitoring System can be carried out without the need of external devices.

Section 2 Shaft Monitoring (MON-SHAFT)

1 General

1.1 Applicability of MON-SHAFT notation

1.1.1 The additional class notation **MON-SHAFT** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.7.3], to ships fitted with oil or water lubricated systems for tailshaft bearing complying with the requirements of this Section.

1.1.2 The assignment of this notation allows a reduced scope for complete tailshaft surveys (see Pt A, Ch 2, Sec 2, [6.6.4]).

1.1.3 The requirements of this section apply in addition to those listed in Pt C, Ch 1, Sec 7, [2.4].

2 Requirements for oil lubricated tailshaft bearings

2.1 Arrangement

2.1.1 Oil sealing glands design is to be approved by the Society. Seals replacement is to be possible without shaft withdrawal.

2.1.2 A temperature sensor for each bearing or other approved arrangements are to be provided. In particular, the aftmost bearing is to be fitted with a temperature monitoring system.

2.1.3 The aftmost bearing is to be arranged with facilities for measurement of bearing weardown.

2.2 Lubricating oil analysis

2.2.1 Analysis frequency

Stern bearing lubricating oil is to be analysed regularly; in any event, the interval between two subsequent analyses is not to exceed six months.

2.2.2 Records

The lubricating oil analysis documentation is to be available on board showing in particular the trend of the parameters measured according to [2.2.3].

2.2.3 Content of analysis

Each analysis is to include the following parameters:

- water content
- chloride content
- bearing material and metal particle content
- oil ageing (resistance to oxidation).

The oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube stern tube.

2.2.4 Additional data to be recorded

In addition to the results of the oil sample analysis, the following data are to be regularly recorded:

- oil consumption
- bearing temperatures (a temperature sensor for each bearing or other approved arrangements are to be provided).

3 Requirements for water lubricated tailshaft bearings

3.1 General requirements

3.1.1 Bearing material is to be approved by the Society.

3.1.2 The tailshaft is to be made of a corrosion-resistant material or protected against corrosion by a continuous liner or cladding

3.1.3 The bearings are to be arranged with facilities for measuring the bearing weardown while the ship is afloat. The relevant procedure including the maximum permissible weardown will have to be submitted.

3.1.4 Sensors are to be provided for the aft bearing and any other bearings not accessible when the ship is afloat, giving alarm in case of bearing wear down exceeding a predetermined threshold. An alarm is to be activated in the event of failure of the position sensor circuit.

3.1.5 Alternatively, arrangements are to be made for endoscopic examination of the tailshaft surface in particular in way of the bearings with the shaft in place. The relevant procedure will have to be submitted to the Society.

3.1.6 Where required by Pt C, Ch 1, Sec 7, [3.3], the shaft alignment calculations are to be performed for both initial conditions (new bearings) and conditions of maximum permissible weardown according to the bearing manufacturer's recommendations and deemed satisfactory by the Society.

3.1.7 Sealing glands design is to be approved by the Society. Replacement of seals is to be possible without withdrawal of tailshaft.

3.2 Additional requirements for forced water lubrication systems

3.2.1 Water lubrication piping diagram is to be submitted for review.

The water pumping system is to include:

- two pumps
- a filtering system designed in accordance with bearing and pump manufacturer requirements
- two independent flow sensors allowing permanent flow monitoring and activating an alarm in case of low flow.

Note 1: Where two shaft lines are installed, it is acceptable to have a single pump per shaft line, provided the safety of the ship is not impaired with one pump disabled. Special attention is to be paid to the applicable requirements when the ship is to be assigned an AVM additional class notation.

3.2.2 The operating restrictions of the propulsion installation in case of low flow alarm are to be stated.

3.2.3 Filters are to be cleaned or replaced in accordance with manufacturer recommendations. Records of cleaning and replacement of filters are to be available onboard.

3.2.4 Unless otherwise justified, an interlock arrangement is to be provided to prevent the propulsion starting if sufficient water flow is not established.

3.3 Data to be recorded

3.3.1 The following data are to be regularly recorded and available on board:

- water flow
- bearings weardown
- failure alarms.

Part E
Additional Class Notations

CHAPTER 6
COMFORT ON BOARD (COMF)

Section	1	General Requirements
Section	2	Additional Requirements for Notation COMF-NOISE
Section	3	Additional Requirements for Notation COMF-VIB

Section 1 General Requirements

1 General

1.1 Application

1.1.1 The following additional class notations are assigned, in accordance with Pt A, Ch 1, Sec 2, [6.8], to naval ships complying with the applicable requirements of the present Chapter:

- **COMF-NOISE** with regard to noise criteria
- **COMF-VIB** with regard to vibration criteria.

Both class notations may be assigned separately.

The requirements corresponding to those additional class notations are given in Ch 6, Sec 2 and Ch 6, Sec 3.

1.1.2 Special requirements

Special requirements related to the specific activities and/or missions of the ship are not covered by these Rules. The following additional class notation only considers noise/vibration sources connected with the ship platform.

1.2 Basic principles

1.2.1 The comfort class grade is granted on the basis of measurements performed by an acoustic and vibration specialist from the Society during building stage, sea trials or in service.

However, measurements may be performed by another acoustic and vibration specialist from external company provided that this specialist has duly obtained the relevant delegation from the Society.

1.2.2 These Rules take into account several International standards and are deemed to preserve their general principles.

1.3 Regulations - Standards

1.3.1 The present chapter refer to the following standards applicable to noise:

- IMO Resolution MSC.337(91) "Adoption of the Code on noise levels on board ships"
- ISO 2923 "Acoustic: Measurements of noise on board vessels"
- ISO 31/VII "Quantities and units of acoustics"
- IEC Publication 61672 "Electroacoustics - Sound level meters"
- IEC Publication 61260 "Octave, half-octave and third octave band filters"
- IEC Publication 60942 "Electroacoustics - Sound calibrators"
- ISO 140 "Acoustics - Measurements of sound insulation in buildings and of building elements", namely:
  Part 14 - 2004, "Guidelines for special situation in field"
- ISO 16283-1 "Acoustics - Field measurement of sound insulation of buildings and of building elements - Part 1: Airborne sound insulation"
- ISO 717 "Acoustics - Rating of sound insulation in buildings and of building elements", namely:
  Part 1 - 1997, "Airborne sound insulation in buildings and interior elements".
- ISO 1996 "Acoustics - Description, measurements and assessment of environmental noise", namely:
  - Part 1 "Basic quantities and assessment procedure"
  - Part 2 "Determination of environmental noise levels"

1.3.2 The present Chapter refer to the following standards applicable to vibrations:

- ISO 2041 "Vibration and shock - Vocabulary"
- ISO 6954 "Mechanical vibration and shock - Guidelines for the overall evaluation of vibration in merchant ships"
- ISO 2631 "Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration"
- ISO 8041 "Human response to vibration – Measuring instrumentation".

1.4 Documentation to be submitted

1.4.1 Prior to the trials, some documents are to be submitted, as listed in Tab 1.

Table 1 : Documents to be submitted

No.	A/I **(1)**	Documents
1	I	General arrangements
2	A	Measurement program: • loading conditions • propulsion operating conditions • other equipment to be run • weather conditions • measuring instruments
(1) A: to be submitted for approval ; I: to be submitted for information		

2 Conditions of attribution

2.1 Measurements

2.1.1 Measurements aiming at giving the comfort class notation are to be performed under the conditions specified in Article [3].

2.1.2 Measurement and calibration equipment are to meet the requirements of ISO 2923, IEC 61672-1, IEC 61260 and IEC 60942 for noise, and ISO 2631 and ISO 8041 for vibration.

Sound insulation measurements are to be carried out according to ISO 16283-1 and ISO 140-14.

Noise and vibration calibrators are to be verified at least every year. Measuring equipment are to be verified at least every two years. This verification shall be done by a national standard laboratory or a competent laboratory accredited according to ISO 17025 (2005) as corrected by (Cor 1:2006).

2.1.3 When it is not possible for the Society to follow or to do all the required measurements, spot-check is to be performed by the Society. This spot-check consists of a cross-comparison between:

- a sample of at least 10% of the measurements provided by the shipyard/external specialist

Note 1: The maximum deviations allowed during the cross-comparison are 2 dB(A) for noise measurements and 0,3mm/s for vibration measurements for overall frequency weighted RMS readings.

- and the corresponding readings obtained during the spot-check measurements.

This procedure enables the validation of the entire set of measurements provided by the shipyard/external specialist.

2.2 Acceptance criteria

2.2.1 The **COMF-NOISE** notation is assigned on condition that none of the measured values exceeds the limits given in Ch 6, Sec 2, Tab 1 and Ch 6, Sec 2, Tab 2. A tolerance on noise levels may be accepted but shall not exceed the following maximum values:

- 3 dB(A) for 25% and 5 dB(A) for 5% of the measuring points
- 1 dB for 20% and 2 dB for 10% of apparent weighted sound reduction indexes R'w (with a minimum of one partition).

The **COMF-VIB** notation is assigned on condition that none of the measured values exceeds the limits given in Ch 6, Sec 3, Tab 1. A tolerance on vibration levels may be accepted but shall not exceed 0,3 mm/s for 20% of measuring points for overall frequency weighted r.m.s. velocity criteria.

2.3 Measuring locations

2.3.1 Measurements are to be carried out in each type of space, if existing, specified in Ch 6, Sec 2, Tab 1 according to the following principles:

- at least 30% of the cabins and all cabins adjacent to engine casing or machinery spaces
- all mess rooms and recreational spaces
- all spaces permanently manned in normal operational conditions

For spaces larger than $50m^2$, two measurements are to be taken conveniently spaced.

The measurement locations are to be chosen to assure a good representation of the overall noise and vibration environment on board.

The list of measuring points is to be prepared prior to the tests by the Society or the external company (see [1.2.1]). This list may be adjusted during the tests.

3 Testing conditions

3.1 General

3.1.1 This Article gives the conditions to be fulfilled during measurements. Additional details of these conditions may be taken from International Standards, namely:

- IMO Resolution MSC.337(91), ISO 2923 for noise
- ISO 6954 for vibrations.

3.1.2 Prior to the tests, possible divergence on the required conditions may be accepted by the Society. If any, it is to be clearly mentioned in the report.

3.1.3 The measurement program has to be approved before the trials (see [1.4.1]). During the tests, some additional measurements may be decided upon request of the Society.

3.1.4 During measurements, especially for noise, rooms have to be preferably fully completed (outfitting, furniture, covering...). Measurements may be performed even in an unfinished state, which generally suppose better final results.

3.2 Harbour test conditions

3.2.1 The sound insulation measurements are to be conducted at quay or at anchorage. For these specific tests, measurements should preferably be performed without machinery, ventilation or air conditioning running.

3.3 Sea trial conditions

3.3.1 Propulsion plant power

During the measurements, propeller output is to correspond to the operating conditions specification of the ship and not less the 80% of the maximum continuous rating (MCR) unless other conditions are specified by the Naval Authority.

Ships which are frequently operated by means of a Dynamic Positioning system (DP system) shall require additional measurements to be performed in DP mode. The Owner, Shipyard and Society shall agree on a process to simulate the operation of the DP thruster system under conditions which would approximate station-holding at, or above, 40 per cent of maximum thruster power for design environmental conditions that the ships operates in.

3.3.2 Auxiliaries

During measurements, forced ventilation and air conditioning system (HVAC systems) are to be operating, as well as auxiliary systems used in normal service condition. Any other frequently used equipment (more than 1/3 of the time at sea) is to be run at its normal operating conditions (if practicable.

3.3.3 Human activity

- During measurements, noise arising from every kind of unnecessary human activity is to be avoided as far as possible.
- To this end only the personnel needed for the normal operation of the ship and those carrying out the measurements are to be present.

3.3.4 Ship course

Ship course has to be kept constant, with rudder angle less than 2 degrees portside or starboard, for the duration of the measurement. If ship manoeuvring is needed, measurements must be stopped until recovery of heading

3.3.5 Water depth

Water depth is greater than 5 times the mean ship draught.

3.3.6 Meteorological conditions

Tests have to be conducted in sea and weather condition 3 or less. Measurements carried out with worst weather conditions may be accepted at the sight of the results.

Section 2 Additional Requirements for Notation COMF-NOISE

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable when the additional class notation **COMF-NOISE** is assigned. They are additional to the applicable requirements of Ch 6, Sec 1.

2 Measurement procedure

2.1 Instrumentation

2.1.1 The instrumentation is to be calibrated in situ, before and after the tests, and is to include one third octave band filter (see Ch 6, Sec 1, [2.1.2]). The instrument is to be able to give LAeq measurements.

2.2 Data processing - Analysis

2.2.1 The nominal noise level is evaluated with LAeq,T value. LAeq,T (dB(A) re. 20 μPa) is the equivalent continuous A weighted sound pressure level, T greater than 20 seconds. Results are to be given on table in global values (dB(A)). Upon request of the Society or his representative, they may have to be presented in a table giving the third octave band analysis.

2.2.2 To evaluate the required privacy inside accommodations, the apparent weighted sound reduction index R'w is to be calculated. R'w (dB) is a field measure of airborne sound insulation between rooms. This index is to be determined in accordance with ISO 717-1 and ISO 16283-1.

2.3 Measuring condition

2.3.1 Tests are to be conducted in the conditions described in Ch 6, Sec 1, [3]. Air conditioning is to be in normal operation. Doors and windows are to be closed, unless they are kept open in normal use.

Measurements are to be conducted with all equipment in normal operating conditions.

2.4 Measuring positions

2.4.1 Measurements are to be taken at a height between 1,2 m and 1,6 m from the deck and at a distance above 1,0 m from any boundary surface of the room. In cabins and offices, one measurement will be performed in the middle of the space. The measurement is to be taken at 2,0 m at least from the existing noise sources (e.g. inlet/outlet of air conditioning openings). The selection of noise level measuring locations is indicated in Ch 6, Sec 1, [2.3]. Three measuring points are to be carried out in the wheelhouse (centre line and both sides).

2.4.2 The insulation measurements location have to fulfil the recommendations of ISO 140-14.

The selection of sound insulation measuring locations is to be representative of the different types of insulation provided in Tab 2 (a minimum of two measurements of each insulation type is required).

3 Noise levels and sound insulation measurement

3.1 Noise level requirements

3.1.1 For each space typology, maximum noise levels are given in Tab 1 unless otherwise specified by the Naval Authority.

3.2 Sound insulation measurement

3.2.1 Between two adjacent accommodation spaces, apparent weighted sound reduction index R'w is to be higher than the requirements given in Tab 2. Measurements are to be performed in situ.

Table 1 : Noise level requirements

Location	LAeq,T (dB(A))
Wheelhouse	65
Operational rooms	60
Cabins	60
Offices	65
Recreational spaces	65
Mess Rooms	65
Hospital	60
Galleys (without food processing equipment operating)	75
Workshop, laundries (without equipment operating)	85
Engine control room	75

Table 2 : Apparent weighted sound reduction indexes R'w

Walls between cabins and	R'w (dB)
Cabin	30
Corridor	30
Recreational room, mess room, public spaces	45

Section 3 Additional Requirements for Notation COMF-VIB

1 General

1.1 Application

1.1.1 The requirements of this Section are applicable when the additional class notation **COMF-VIB** is assigned. They are additional to the applicable requirements of Ch 6, Sec 1.

2 Measurement procedure

2.1 Instrumentation

2.1.1 The instrumentation is to be calibrated in situ, before and after the tests (see Ch 6, Sec 1, [2.1.2]).

The instrumentation is to include at least a transducer (accelerometer or velocity transducer) with an appropriate amplifier, and a FFT analyser.

Should the vibration measurements be performed on a soft floor, the use of a rigid plate with the person standing on the plate and the accelerometer rigidly fixed on is recommended.

2.2 Data processing, presentation of results and analysis

2.2.1 The criterion of vibration is to be expressed in terms of overall frequency-weighted r.m.s. velocity (mm/s) from 1 to 80 Hz as defined by ISO 6954:2000.

2.3 Measuring conditions

2.3.1 Tests are to be conducted in the conditions described in Ch 6, Sec 1, [3]

Measurements are to be conducted with all equipment in normal operating conditions.

2.4 Measuring positions

2.4.1 Measurements are to be taken in vertical direction. In cabins, offices or other small size rooms, measurements are to be taken on the floor in the centre of the room. For larger rooms, several measuring points may be required and are to be chosen according to the local structure (measurements of the different existing types of stiffened panels).

Three measuring points are to be carried out in the wheelhouse (centre line and both sides).

In addition to vertical direction, measurements in transverse and longitudinal directions are to be performed on one point on each deck.

3 Vibration level requirements

3.1 General

3.1.1 Vibration level requirements are provided in Tab 1 in accordance with ISO 6954-2000. The limits listed in Tab 1 are applicable for any directions.

Table 1 : Overall velocity level requirements

Space	Vibration velocity values (mm/s) / values from 1 Hz to 80 Hz
Wheelhouse	3,2
Operational rooms	3,2
Cabins	3,2
Offices	4,0
Recreational spaces	4,0
Mess Rooms	4,0
Hospital	3,2
Galleys (without food processing equipment operating)	6,0
Workshop, laundries (without equipment operating)	6,0
Engine control room	6,0

Part E
Additional Class Notations

CHAPTER 7
ENVIRONMENTAL PROTECTION (CLEANSHIP)

Section 1 General Requirements

Section 2 Design Requirements for the Notations CLEANSHIP and CLEANSHIP SUPER

Section 3 Design Requirements for the Pollution Prevention Notations other than CLEANSHIP and CLEANSHIP SUPER

Section 4 Onboard Surveys

Section 1 General Requirements

1 Scope and application

1.1 General

1.1.1 This Chapter contains the requirements for the prevention of sea and air pollution.

1.1.2 Additional class notations for the prevention of sea and air pollution include:

- **CLEANSHIP** and **CLEANSHIP SUPER** notations
- other notations having a specific scope.

For the assignment of the **CLEANSHIP SUPER** notation, at least three notations among those referred to as “eligible” in Tab 1, column 4, are also to be assigned.

The relevant symbol, scope, reference to the Rules and assignment conditions are given in Tab 1.

Examples of notations are given below:

- **CLEANSHIP**
- **CLEANSHIP**, **BWE**
- **CLEANSHIP SUPER (AWT, NOX-80%, SOX-60%)**
- **OWS-5 ppm**
- **AWT**, **NDO-2 days**

1.2 Applicable rules and regulations

1.2.1 It is a prerequisite for the assignment of any additional class notation listed in Tab 1 that the ship complies with the following regulations:

a) adopted Annexes of the MARPOL 73/78 Convention

b) International Convention on the control of harmful anti-fouling systems, 2001.

1.2.2 Additional requirements may be imposed by the ship flag Authorities and/or by the State or Port Administration in the jurisdiction of which the ship is intended to operate, in particular with respect to:

- exhaust gas smoke (particulate emissions, smoke opacity)
- fuel oil sulphur content
- bilge water oil content
- on board waste incineration.

Table 1 : Additional class notations for the prevention of pollution

Symbol	Scope	Reference to the Rules	Eligible for the assignment of **CLEANSHIP SUPER** notation	Assignment conditions
CLEANSHIP	Prevention of sea and air pollution	Ch 7, Sec 2, [2]	N/A	
CLEANSHIP SUPER	Prevention of sea and air pollution	Ch 7, Sec 2, [2] Ch 7, Sec 2, [2]	N/A	At least 3 eligible notations are to be assigned
AWT	Fitting of an Advanced Wastewater Treatment plant	Ch 7, Sec 2, [3]	Yes	
BWE	The ship is designed for ballast water exchange in accordance with the technical provisions of BWM Convention (2004), Regulation D-1	Ch 7, Sec 2, [3]	No	
BWT	Fitting of a ballast water treatment plan	Ch 7, Sec 3	Yes	
GREEN PASSPORT	Hazardous material inventory	NR528	No	
GWT	Fitting of a treatment installation for Grey Waters	Ch 7, Sec 3	Yes	
Note 1: N/A = not applicable.				

Symbol	Scope	Reference to the Rules	Eligible for the assignment of **CLEANSHIP SUPER** notation	Assignment conditions
HVSC	Fitting of a High Voltage Shore Connection	NR557	Yes	Alternatively, use of natural gas as fuel when the ship is at berth may be accepted, provided that the provisions of NR529 are complied with
NDO-x days	The ship is designed for No Discharge Operation during x days	Ch 7, Sec 3	Yes	
NOX-x%	Average NOx emissions of engines not exceeding x% of IMO Tier II limit	Ch 7, Sec 3	Yes	
OWS-x ppm	Fitting of an Oily Water Separator producing effluents having a hydrocarbon content not exceeding x ppm (parts per million)	Ch 7, Sec 3	Yes	
SOX-x%	Oil fuels used within and outside SECAs have a sulphur content not exceeding x% of the relevant IMO limit	Ch 7, Sec 3	Yes	As an alternative, equivalent arrangements (e.g. exhaust gas cleaning systems) may be accepted
Note 1: N/A = not applicable.				

2 Definitions and abbreviations

2.1 Definitions related to sea pollution

2.1.1 Hazardous wastes

Hazardous wastes are those wastes composed of substances which are identified as marine pollutants in the International Maritime Dangerous Goods Code (IMDG Code).

Hazardous wastes include in particular:

- photo processing chemicals
- dry cleaning waste
- used paints
- solvents
- heavy metals
- expired chemicals and pharmaceuticals
- waste from printers
- hydrocarbons and chlorinated hydrocarbons
- used fluorescent and mercury vapour light bulbs
- batteries.

Note 1: Empty packagings previously used for the carriage of hazardous substances are to be considered as hazardous substances.

2.1.2 Wastewater

Wastewater includes both sewage and grey water defined hereunder.

2.1.3 Sewage

Sewage means:

- drainage and other wastes from any form of toilets, urinals, and WC scuppers, here designated as black waters
- drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises
- drainage from spaces containing live animals, or
- other waste waters when mixed with the drainages defined above.

2.1.4 Sewage sludge

Sewage sludge means any solid, semi-solid, or liquid residue removed during the treatment of on-board sewage.

2.1.5 Grey water

Grey water includes drainage from dishwashers, showers, sinks, baths and washbasins, laundry and galleys.

2.1.6 Garbage

Garbage means all kinds of victual, domestic and operational waste excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically, except those substances which are defined or listed in Annexes I, II, III and IV to MARPOL 73/78.

Garbage includes all kinds of solid wastes like plastics, paper, oily rags, glass, metal, bottles, and incinerator ash. Food wastes are considered as garbage.

2.1.7 Oil residue (sludge)

Oil residue (sludge) means the residual waste oil products generated during the normal operation of a ship such as those resulting from the purification of fuel or lubricating oil for main or auxiliary machinery, separated waste oil from oil filtering equipment, waste oil collected in drip trays, and waste hydraulic and lubricating oils.

2.1.8 Oil residue (sludge) tank

Oil residue (sludge) tank means a tank which holds oil residue (sludge) from which sludge may be disposed directly through the standard discharge connection or any other approved means of disposal.

2.1.9 Oily bilge water

Oily bilge water means water which may be contaminated by oil resulting from things such as leakage or maintenance work in machinery spaces. Any liquid entering the bilge system including bilge wells, bilge piping, tank top or bilge holding tanks is considered oily bilge water.

2.1.10 Oily bilge water holding tank

Oily bilge water holding tank means a tank collecting oily bilge water prior to its discharge, transfer or disposal.

2.1.11 Oily wastes

Oily wastes means oil residues (sludge) and oily bilge water.

2.1.12 Advanced Wastewater Treatment (AWT)

Any treatment of wastewater that goes beyond the secondary or biological water treatment stage and includes the removal of nutrients such as phosphorus and nitrogen and a high percentage of suspended solids. AWT water effluent standard corresponds to the technology currently available for municipal wastewater treatment plants.

2.1.13 Accidental discharge

All discharge to sea caused by unforeseen or accidental events, such as damage to the ship or its equipment, and including discharge necessary for the purpose of protection of the ship or saving life at sea.

2.1.14 No discharge condition

Condition without discharge of hazardous wastes, treated and untreated wastewater, oily wastes or garbage into the sea.

Note 1: Where the **AWT** notation is assigned to the ship, the discharge of treated sewage and treated grey water is allowed.

Note 2: In the “No discharge condition”, no effluents from exhaust gas cleaning systems may be discharged into the sea.

2.2 Definitions related to air pollution

2.2.1 Emission

Emission means any release of substances, subject to control by Annex VI of MARPOL 73/78, from ships into the atmosphere or sea.

2.2.2 Global warming potential (GWP)

GWP means the climatic warming potential of a greenhouse gas relative to that of carbon dioxide (CO_2), calculated in terms of the 100-year warming potential of one kilogram of a greenhouse gas relative to one kilogram of CO_2.

2.2.3 Ozone depleting substances

Ozone-depleting substances means controlled substances defined in paragraph (4) of article 1 of the Montreal Protocol on Substances that Deplete the Ozone Layer, 1987, listed in Annexes A, B, C or E to the said protocol in force at the time of application of Annex VI of MARPOL 73/78.

Ozone-depleting substances that may be found on board ship include, but are not limited to:

- Halon 1211 Bromochlorodifluoromethane
- Halon 1301 Bromotrifluoromethane
- Halon 2402 1,2-Dibromo-1,1,2,2-tetrafluoroethane (also known as Halon 114B2)
- CFC-11 Trichlorofluoromethane
- CFC-12 Dichlorodifluoromethane
- CFC-113 Trichloro-1,2,2-trifluoroethane
- CFC-114 1,2-Dichloro-1,1,2,2-tetrafluoroethane
- CFC-115 Chloropentafluoroethane.

2.2.4 NOx technical code

NOx Technical Code means the Revised Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines adopted at MEPC 58 on 10 October 2008 with IMO Resolution MEPC.177(58) as amended by IMO Resolution MEPC.317(74).

2.2.5 Emission control area

Emission control area means an area where the adoption of special mandatory measures for emissions from ships is required to prevent, reduce and control air pollution from NOx or SOx and particulate matter or all three types of emissions and their attendant adverse impacts on human health and the environment. Emission control areas include those listed in, or designated under, regulations 13 and 14 of Annex VI of MARPOL 73/78.

2.2.6 Shipboard incineration

Shipboard incineration means the incineration of wastes or other matter on board a ship, if such wastes or other matter were generated during normal operation of that ship.

2.2.7 Shipboard incinerator

Shipboard incinerator means a shipboard facility designed for the primary purpose of incineration.

2.2.8 Exhaust gas smoke

Exhaust gas smoke is a visible suspension of solid and/or liquid particles in gases resulting from combustion or pyrolysis.

Note 1:

- Black smoke (soot) is mainly comprised of carbon particles
- blue smoke is usually due to droplets resulting from the incomplete combustion of fuel or lubricating oil
- white smoke is usually due to condensed water and/or liquid fuel
- yellow smoke is caused by NO_2.

2.3 Abbreviations

2.3.1 AWT

AWT means advanced wastewater treatment.

2.3.2 ECA

ECA means emission control area.

2.3.3 EGC

EGC means exhaust gas cleaning.

2.3.4 OWS

OWS means oily water separator.

3 Documents to be submitted and applicable standards

3.1 Documents to be submitted

3.1.1 Certificates

The certificates to be submitted prior to the delivery of the additional class notations **CLEANSHIP**, **CLEANSHIP SUPER** and other notations are listed in Tab 2.

3.1.2 Operational procedures

The operational procedures to be submitted are listed in Tab 3.

3.1.3 Plans and documents

The plans and documents to be submitted are listed in Tab 4.

3.2 Modifications and additions

3.2.1 In case of modifications or additions to the approved installations, arrangements or procedures, the relevant details are to be submitted for review.

Table 2 : Required certificates

Notations	Certificate	Applicable Rules and Regulations
CLEANSHIP **CLEANSHIP SUPER**	IOPP certificate **(1)**	Annex I of MARPOL 73/78, Appendix II
	Type approval certificate of: • 15 ppm bilge separator • 15 ppm bilge alarm	IMO Resolution MEPC.107(49) as amended by MEPC.285(70): • Part 1 of the Annex • Part 2 of the Annex
	ISPP certificate **(1)**	Annex IV of MARPOL 73/78, Appendix
	Type approval certificate of the sewage system	IMO Resolution MEPC.227(64) as amended by MEPC.284(70)
	Type approval certificate of the incinerator **(2)**	• IMO Resolution MEPC.244(66) • Annex VI of MARPOL 73/78, Appendix IV
	IAPP certificate **(1)**	• Annex VI of MARPOL 73/78, Appendix I • IMO Resolution MEPC.194(61)
	EIAPP certificates of diesel engines **(3)(4)**	NOx Technical Code 2008, Appendix I
	SOx emission compliance certificate Certificate of unit approval for exhaust gas cleaning system **(5)**	IMO Resolution MEPC.340(77), Appendix I
	IAFS certificate or Declaration on Anti-fouling system	International Convention on the control of Harmful and Anti-fouling systems, 2001, Annex 4, Appendices 1and 2
AWT	Type approval of the AWT plant	Ch 7, Sec 3, [2]
BWE	N/R	
BWT	Type approval certificate of the ballast water management system (BWMS)	IMO BWMS Code, IMO Resolution MEPC.169(57)
GREEN PASSPORT	See NR528	
GWT	Type approval certificate of the grey water treatment plant	Ch 7, Sec 3, [5]
HVSC	See NR557	
NDO-x days	N/R	
NOX-x%	EIAPP certificates of diesel engines **(4)**	Ch 7, Sec 3, [7]
OWS-x ppm	Type approval certificate of the oily water separator with indication of "x ppm" performance	Ch 7, Sec 3, [8]
SOX-x%	Type approval certificate of the exhaust gas cleaning system **(5)**	Ch 7, Sec 3, [9]

(1) Only where required by MARPOL 73/78 Convention, according to the ship's gross tonnage.
(2) Shipboard incinerator is not required. However, when fitted on board, it is to be type-approved.
(3) Only where required by Annex VI of MARPOL 73/78 Convention, according to the engine power and intended use.
(4) The EIAPP certificate may include a NOx-reducing device as a component of the engine. See NOx Technical Code 2008, regulation 2.2.5.
(5) Where such an equivalent arrangement is provided in pursuance of Annex VI of MARPOL 73/78 Convention, regulation 4.
Note 1: N/R = not required

Table 3 : Required operational procedures

Notations	Operational procedure	Applicable Rules and Regulations
CLEANSHIP **CLEANSHIP SUPER**	Shipboard oil pollution emergency plan **(1)**	IMO Resolution MEPC.54(32) as amended by MEPC.86(44)
	Procedure to prepare and maintain an oil record book **(1)**	Annex I of MARPOL 73/78, Appendix III
	Procedure to maintain, operate and troubleshoot bilge water treatment systems	IMO Circular MEPC.1/Circ.677
	Bunkering procedure	–
	Measures to prevent oil pollution	–
	Sewage and grey water management plan and discharge control plan **(1)**	IMO Resolution MEPC.157(55)
	Garbage management plan including procedures to prepare and maintain a garbage record book and hazardous waste procedures**(1)**	• IMO Resolution MEPC.220(63) • IMO Circular MEPC/Circ.317 • Annex V of MARPOL 73/78, Appendix • IMO Resolution MEPC.92(45)
	Operating procedure to be followed to minimise the risk and the consequences of ozone-depleting refrigerant leakage, under normal and emergency conditions, including: • checking of the piping tightness • recharge • detection of leakage • maintenance and repair **(2)**	–
	Procedure to prepare and maintain the ozone-depleting substances record book	–
	NOx emission control plan	–
	Fuel oil quality management plan	• Annex VI of MARPOL 73/78, Regulation 18 and Appendix VI • IMO Resolution MEPC.182(59)
	Where an exhaust gas cleaning (EGC) system is used: • SOx emission compliance plan • Onboard monitoring manual • Procedure to prepare and maintain the EGC record book	IMO Resolution MEPC.340(77)
AWT	Wastewater management plan and discharge control plan	–
BWE	Ballast water management plan, with procedures to prepare and maintain a Ballast Water Record Book	IMO Resolution MEPC.127(53) as amended by MEPC.306(73)
BWT	As above for **BWE** notation	• IMO Resolution MEPC.127(53) as amended by MEPC.306(73) • IMO Circular BWM.2/Circ.20
	Detailed procedures and information for safe application of active substances	
GREEN PASSPORT	See NR528	
GWT	Grey water management plan and discharge control plan	–
HVSC	See NR557	
NDO-x days	Management and storage plan for liquid effluents and solid waste in case of no-discharge operation	–
NOX-x%	NOx emissions control plan	–
OWS-x ppm	Performance monitoring plan for the oily water separator	–
SOX-x%	SOx emissions control plan	–

(1) Only where required by MARPOL 73/78 Convention, according to the ship's gross tonnage.
(2) Only where ozone-depleting substances are used on board.

Table 4 : Required plans and documents

Notation	Documents	Approval status
CLEANSHIP CLEANSHIP SUPER	General:	
	• general arrangement plan with indication of the waste collection and conveying circuits, storage means and treatment installations intended for the prevention of pollution by oil, sewage, grey waters, garbage and hazardous packaged substances	I
	• capacity plan	I
	• program for a waste source reduction, minimization and recycling	A
	Prevention of pollution by oil:	
	• diagram of the oil residue (sludge) system,	I
	• diagram of the independent clean drain system, where provided	I
	• diagram of the oily bilge system (pumping, treatment, discharge)	I
	• details of the bilge water holding tank	A
	• calculation of the bilge water holding tank capacity	A
	Prevention of pollution by sewage and wastewater:	
	• diagram of the grey water system (collection, treatment, discharge)	I
	• diagram of the sewage system (collection, treatment, discharge)	I
	• details of the sewage holding tank and grey water holding tank	A
	• calculation of the sewage holding tank and grey water holding tank capacity	A
	• description of the sewage treatment plant or comminuting/disinfecting system	I
	Prevention of pollution by garbage:	
	• general information on the equipment intended for collecting, storing, processing and disposing of garbage (except where type-approved)	I
	• calculation of the necessary storing, processing and disposing capacities	A
	• diagram of control and monitoring systems for garbage handling equipment	A
	Prevention of pollution by oil spillage and leakage:	
	• diagram of the fuel oil and lubricating oil overflow systems	A
	• diagram of the fuel oil and lubricating oil filling, transfer and venting systems	I
	• arrangement of the fuel oil and lubricating oil spillage containment systems	A
	• diagram of the control and monitoring system for fuel oil filling, transfer and overflow systems	I
	• diagram of the stern tube lubricating oil system	A
	Prevention of oil pollution in case of collision or stranding:	
	• arrangement of the fuel oil tanks, lubricating oil tanks and sludge tanks with indication of the volume and of the distance between the tank and the ship base line/ship shell side	I
	Prevention of pollution by anti-fouling systems:	
	• specification of antifouling paint	A
	Prevention of pollution by refrigerants and fire-fighting media:	
	• arrangement of retention facilities including material specifications, structural drawings, welding details and procedures, as applicable	A
	• means to isolate portions of the plant so as to avoid release of medium	A
AWT	• diagram of the grey water system (collection, treatment, discharge)	I
	• diagram of the sewage system (collection, treatment, discharge)	I
	• details of the sewage holding tank and grey water holding tank	A
	• calculation of the sewage holding tank and grey water holding tank capacity	A
	• description of the Advanced Wastewater Treatment (AWT) plant and relevant operating principles	I

Note 1:
I = to be submitted for information
A = to be submitted for approval
A/I = to be submitted for approval or information, in accordance with the relevant Rules or Rule Note.
Note 2: Diagrams are to include information about monitoring and recording of parameters.

Notation	Documents	Approval status
BWE	See IMO Resolution MEPC.149(55) and Pt C, Ch 1, Sec 10	A / I
BWT	See Regulation 5.7 of IMO Resolution MEPC.279(70) or Regulation 5.1 of IMO Resolution MEPC.174(58), as appropriate, and NR467, Pt C, Ch 1, Sec 13	A / I
GREEN PASSPORT	See Rule Note NR528	A / I
GWT	• diagram of the grey water system (collection, treatment, discharge) • details of the grey water holding tank • calculation of the grey water holding tank capacity • description of the grey water treatment plant and relevant operating principles	I A A I
HVSC	See Rule Note NR557	A / I
NDO-x days	Calculation of the storage capacity for solid wastes and liquid effluents	A
NOX-x%	• calculation of the weighted average NOx emission level of the ship • calculation of the weighted average IMO Tier II NOx emission limit of the ship	A A
OWS-x ppm	Description of the OWS plant and relevant operating principles	I
SOX-x%	Where low sulphur fuel oils are used: • diagram of the fuel oil supply systems • change-over procedure Where an exhaust gas cleaning system is fitted: • washwater diagram • description of the system and relevant operating principles	 I I A I
Note 1: I = to be submitted for information A = to be submitted for approval A/I = to be submitted for approval or information, in accordance with the relevant Rules or Rule Note. **Note 2:** Diagrams are to include information about monitoring and recording of parameters.		

Section 2 Design Requirements for the Notations CLEANSHIP and CLEANSHIP SUPER

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER**.

Requirements for onboard surveys are given in Ch 7, Sec 4 and Pt A, Ch 5, Sec 9.

1.1.2 Ships having the additional class notation **CLEANSHIP** are to comply with the provisions of Article [2].

Ships having the additional class notation **CLEANSHIP SUPER** are to comply with the provisions of Articles [2] and [3].

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** are listed in Ch 7, Sec 1, Tab 2.

1.2.2 Operational procedures

The operational procedures to be submitted for the additional class notation **CLEANSHIP** are listed in Ch 7, Sec 1, Tab 3.

1.2.3 Plans and documents

The plans and documents to be submitted for the additional class notations **CLEANSHIP** and **CLEANSHIP SUPER** are listed in Ch 7, Sec 1, Tab 4.

2 Design requirements for the additional class notation CLEANSHIP

2.1 Waste management

2.1.1 Waste generation

The waste quantities to be considered for the calculation of:

- the volume of the holding tanks
- the capacity of the waste treatment and storage equipment

are to be derived from the experience gained on similar types of ships operated in similar conditions. Where no data are available, the figures listed in Tab 1 are to be used.

2.1.2 Separation of waste streams

Design arrangements and procedures for collecting, sorting, treating, storing and discharging solid and liquid waste and harmful substances are to be such that the discharge or discharge prohibition criteria laid down in annexes I, IV and V of MARPOL 73/78 Convention can be fulfilled.

Generally, this implies that the following categories of wastes are separated before any treatment or storage:

- products containing hazardous substance, as defined in Ch 7, Sec 1, [2.1.1]
- plastics, which have to be separated from wastes ultimately discharged to sea (sewage or food wastes for instance)
- sewage, including drainage from medical premises, which has to be collected separately from grey water, except if a common treatment installation is installed on board.

Note 1: This does not preclude the mixing of effluents after treatment (e.g. treated sewage mixed with grey water).

Note 2: When sea water is mixed with wastewater (e.g. for the purpose of washing the holding tanks), the discharge requirements for the wastewater apply to the resulting mixture.

Note 3: When categories of wastewater having different discharge requirements are mixed together, the most stringent requirements apply to the resulting mixture.

Table 1 : Waste generation quantities

No	Type of Waste	Unit	Quantities for			
			Cruise ships	Ro-ro passenger ships designed for night voyages	Ro-ro passenger ships designed for day voyages	Cargo ships
1	Plastics	kg/person/day	0,1	0,1	0,1	0,1
2	Paper and cardboard	kg/person/day	1,0	1,0	1,0	1,0
3	Glass and tins	kg/person/day	1,0	1,0	1,0	1,0
4	Food wastes	kg/person/day	0,7	0,7	0,7	0,7
5	Total garbage (1 + 2 + 3 + 4)	kg/person/day	2,8	2,8	2,8	2,8
6	Black water	litres/person/day	12 for a vacuum system 100 for a conventional flushing system			
7	Grey water (excluding laundry and galley)	litres/person/day	160	150	50	100
8	Laundry	litres/person/day	80	20	20	40
9	Galley	litres/person/day	90	30	30	60
10	Total grey water (7 + 8 + 9)	litres/person/day	330	200	100	200

2.1.3 Incineration and disposal

Although disposal into the sea and onboard incineration are possible in the conditions specified in MARPOL 73/78 Convention, storage and subsequent discharge to port reception facilities is to be given first priority.

Except otherwise stated in this Article, storage arrangements are to be provided for all kinds of liquid and solid wastes, with a capacity corresponding to one day operation of the ship.

Note 1: The attention is drawn to the specific requirements imposed by certain flag Authorities and / or State or Port Administration, which may restrict or prohibit waste discharge and/or incineration in the waters under their jurisdiction.

2.2 Oily wastes

2.2.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the following requirements of MARPOL 73/78 Convention, Annex I, and with the relevant unified interpretations:

- Reg. 12 for arrangement and capacity of oil residues (sludge) tanks
- Reg. 13 for standard discharge connection
- Reg. 14 for oil filtering equipment
- Reg. 15 for oil discharge criteria
- Reg. 17 for oil record book (machinery space operations).

2.2.2 Bilge water holding tank

All machinery space bilges and spaces containing hydraulic equipment have to be drained into a bilge water holding tank before separation and oil filtration or discharge ashore. This bilge holding tank is to be separate and independent from the sludge tanks.

Sea or freshwater drains not contaminated by oil may be discharged overboard.

For ships operating with heavy fuel oil having a relative density greater than 0,94 at 15°C, the bilge water holding tank is to be fitted with heating facilities.

The bilge water holding tank is to be arranged so as to facilitate the separation of any oil (or oil emulsions resulting from the use of bilge cleaning agents) from the bilge water and the removal of accumulated sediments.

The shore discharge piping system from the bilge water holding tank is to be terminated by the standard discharge connection specified in MARPOL 73/78 Convention, Annex I, Reg. 13.

2.2.3 Oil water separating equipment

The following approved equipment is to be provided in accordance with IMO Resolution MEPC.107(49) as amended by IMO Resolution MEPC.285(70):

- 15 ppm bilge separator
- 15 ppm bilge alarm
- automatic stopping device.

The capacity of the bilge separator is to take into account the route of the vessel, the volume of the bilge water holding tanks and the separating technology.

The 15 ppm bilge separator and the 15 ppm bilge alarm are to be installed in accordance with the provisions of IMO Resolution MEPC.107(49) as amended by IMO Resolution MEPC.285(70), paragraph 6.

2.2.4 Oil residue (sludge) tanks

Oil residue (sludge) may be disposed of directly from the oil residue (sludge) tanks through the standard discharge connection referred to in MARPOL 73/78, Annex I, Reg. 13, or any other approved means of disposal.

2.2.5 Overboard discharges from the bilge pumping system

The overboard discharge valve of any bilge overboard discharge line, unless passing through the 15 ppm bilge separator, is to be kept shut and provided with lead-sealing arrangements.

2.2.6 Segregation of oil and water ballast

No ballast water is to be carried in any fuel oil or lubricating oil tank.

2.2.7 Discharge records

Provisions are to be made to record the following parameters related to the oily water discharge:

- date and time of the discharge
- ship location
- quantity and oil content of oily water discharged.

2.3 Wastewaters

2.3.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the relevant requirements of MARPOL 73/78 Convention, Annex IV, revised according to IMO Resolution MEPC.115(51):

- Reg. 10 for standard discharge connection
- Reg. 11 for discharge criteria.

Note 1: Discharge of grey water is not regulated by MARPOL 73/78 Convention.

Note 2: Attention is drawn to the fact that some national regulations prohibit the discharge of sewage (treated or untreated) and grey water while in port or within other designated areas.

2.3.2 Design and arrangement of the sewage system

The ship is to be equipped with one of the following sewage systems:

- a sewage treatment plant, or
- a sewage comminuting and disinfecting system fitted with facilities for temporary storage of sewage when the ship is less than 3 nautical miles from the nearest land, or
- a holding tank of the capacity to the satisfaction of the Society for the retention of all sewage, having regard to the operation of the ship, the number of persons on board and other relevant factors.

2.3.3 Holding tanks

The holding tanks are to be efficiently protected against corrosion and fitted with a level indicator and a high level alarm.

2.3.4 Sewage treatment plants and piping

Sewage treatment plants are to be of a type approved in accordance with the provisions of IMO Resolution MEPC.227(64) as amended by MEPC.284(70).

Provisions are to be made in the design for easy access points for the purpose of obtaining representative influent and effluent samples.

2.3.5 Discharge records

Provisions are to be made to record the following parameters related to the sewage discharge:

- date and time of discharge
- position of the ship (latitude and longitude)
- quantity of sewage discharged.

2.4 Garbage and hazardous wastes

2.4.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the requirements of MARPOL 73/78, Annex V:

- Reg. 3, 4, 5 and 6 for disposal into the sea criteria
- Reg. 9 for placards, garbage management plans and garbage record-keeping.

2.4.2 Garbage management plan

Procedures for collection, sorting, processing and disposal of garbage are to be available in the garbage management plan required by MARPOL 73/78, Annex V, Reg. 9.

The garbage management plan is to include procedures in order to make sure that the following hazardous wastes are not discharged at sea nor mixed with other waste streams:

- photo processing waste (including X-ray development fluid waste)
- dry cleaning waste, containing in particular tetrachloroethylene or perchloroethylene (PERC)
- printing materials, like inks, except soy based, non chlorinated hydrocarbon based ink products
- laser printer toner cartridges
- unused and outdated pharmaceuticals
- fluorescent / mercury vapour bulbs
- batteries
- used cleaners, solvents, paints and thinners
- products containing metals such as lead, chromium, copper, cadmium and mercury.

2.4.3 Handling of hazardous waste

Hazardous wastes are to be collected and stored in separate leakproof containers prior to disposal ashore. The storage capacity is to be sufficient for the average production of 30 days. The contents of all containers are to be clearly marked.

Note 1: Waste fluids associated with photo processing, including X-ray development, may be treated to remove silver for recycling. The effluent from the recovery unit may be led to the grey water provided it contains less than 5 parts per million (ppm). The residues from the recovery unit are to be landed ashore for disposal or recycling.

2.4.4 Collection of garbage

Garbage bins are to be placed at suitable places and within a suitable distance in accommodation spaces and open decks.

Hazardous wastes, plastics and food contaminated wastes are to be collected separately from other wastes.

2.4.5 Storage of garbage

The ship is to have sufficient capacity to store all kinds of garbage produced during one day, taking into account the daily waste generation figures given in [2.1.1] and the values of density given in Tab 2.

If incineration is permitted in the areas where the ship is intended to operate, the needed capacity for wastes other than glass and tins may be reduced by 40%, without being less than the needed volume corresponding to one day.

Table 2 : Waste density

Type of waste	Density (kg/m^3)	
	compacted waste	uncompacted waste
Glass, tin	1600	160
Paper, cardboard, plastic	410	40
Food wastes	–	300

2.4.6 Food wastes

Arrangements are to be made to store food wastes prior to discharge to port reception facilities or, where permitted, disposal into the sea.

The onboard storage capacity is to be sufficient for one day food waste production, taking into account the figures given in [2.1.1] and the values of density given in Tab 2.

Where food waste disposal into the sea is permitted, precautions are to be taken to ensure that plastics contaminated by food wastes, like plastic food wrappers, are not discharged to sea with other food wastes.

2.4.7 Incinerators

Where fitted, incinerators are to be type-approved by the Society, designed and constructed according to the requirements of:

- IMO Resolution MEPC.244(66)
- MARPOL Annex VI, Appendix IV.

Proper hazardous waste management procedures including segregating hazardous wastes are to be instituted onboard each ship to assure hazardous wastes are not introduced into the incinerator. In particular, batteries are to be removed from any waste that will be incinerated onboard.

Ashes containing toxic or heavy metal residues are to be kept on board in a suitable container and landed ashore for disposal. Other ashes may be discharged at sea where permitted.

Note 1: Ashes are considered as free from toxic or heavy metal residues when metal analysis show that the limit concentrations given in Tab 3 are not exceeded.

Table 3 : Limit concentrations of toxic and heavy metals substances in ashes

Substance	Limit concentration (ppm)
Arsenic	0,3
Barium	4,0
Cadmium	0,3
Chromium	5,0
Lead	1,5
Mercury	0,01
Selenium	0,3
Silver	0,2

2.4.8 Discharge records

Provisions are to be made to record the following parameters related to the garbage discharge:

- date and time of discharge
- ship location (latitude and longitude) or location of ashore discharge facilities
- estimated amounts discharged for each category, including incinerator ash (in cubic meters).

2.5 Hull anti-fouling systems

2.5.1 Compliance with IMO AFS Convention

Ships granted with the additional class notation **CLEANSHIP** are to comply with the relevant requirements of IMO Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001, requiring the complete prohibition of organotin compounds which act as biocides and of cybutryne in anti-fouling systems.

2.5.2 Type-approval of anti-fouling systems

Anti-fouling paints are to be of a type approved by the Society, on the basis of the following criteria:

- the product is to be free of organotin tributyltin (TBT)
- small quantities of organotin compounds acting as a chemical catalyst are allowed provided their concentration does not exceed 2500 mg total tin per kg of dry paint
- average values of cybutryne are not to exceed 200 mg of cybutryne per kg of dry paint.

2.6 Prevention of pollution by oil spillage and leakage

2.6.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with MARPOL 73/78 Convention, Annex I, regulation 12A (Oil fuel tank protection).

2.6.2 Overflow systems

All fuel and lubricating oil tanks the capacity of which exceeds 10 m^3 are to be fitted with an overflow system and a high level alarm or a flow alarm in the overflow system. The alarm signal is to be given where the person in charge of the bunkering or transfer operation will normally be located.

Note 1: The overflow system is to comply with the provisions of Pt C, Ch 1, Sec 10, [9.3].

2.6.3 Containment systems

On the weather and superstructure decks, each fuel or lubricating oil tank vent, overflow and fill pipe connection and each other area where oil spillage may occur is to be fitted with a fixed deck container or enclosed deck area with a capacity of:

- 80 litres if the gross tonnage of the ship is between 300 and 1600
- 160 litres if the gross tonnage of the ship is greater than 1600.

The deck container or area is to be sitted with a closed drainage system.

2.6.4 Stern tube leakage

Sealing glands are to be provided with an oil leak prevention air seal or the stern tube oil is to be of a non-toxic and biodegradable quality approved in accordance with recognized standards.

The oil tanks are to be fitted with a level sensor giving an alarm in case of low level. Arrangements are to be made to record the level of those tanks.

All oil filling or topping up operations are to be recorded.

2.6.5 Oily condensates from venting pipes

Venting pipes from machinery spaces and containing hydrocarbon vapours are to be led to a venting box provided with a draining pipe connected to a suitable oily drain tank.

2.7 Refrigeration systems

2.7.1 Application

The following requirements apply to the ship centralized refrigerating plants, centralized air conditioning plants and gas reliquefaction plants.

They do not apply to the refrigeration facilities intended for the storage of the galley supplies and to the air conditioning plants for limited parts of the ship, such as the control rooms and the wheelhouse.

2.7.2 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with MARPOL 73/78 Convention, Annex VI, regulation 12 (Ozone Depleting Substances).

2.7.3 Acceptable refrigerants

The use of halogenated substances, including hydrochlorofluorocarbons (HCFCs), as refrigerant is prohibited.

2.7.4 Retention facilities

Refrigeration systems are to be fitted with retention facilities having the capability to retain all the refrigerants, should the necessity to evacuate the whole plant arise in an emergency. The retention facilities may be tanks for liquid media and/or bottles for gaseous media. If only tanks for liquid are used as retention facilities, one or more compressors having the combined capacity to discharge completely the medium from the system into the tanks are to be installed.

2.7.5 Prevention of leakage

Refrigeration systems are to be designed in such a way as to minimise the risk of medium release in the case of maintenance, repair or servicing. Arrangements are to be made to isolate those sections which are to be serviced by a system of valves and by-passes, in such a way as not to stop the operation of the plant, while in service, preventing the risk of release of the medium outside of the plant.

Means are to be provided to avoid the possibility of leak to the atmosphere of the refrigerants or its vapours in any case of failure of the plant.

A warning instruction plate stating that deliberate emissions of halogenated substances is prohibited is to be displayed in the vicinity of the vessels and of the releasing devices.

Note 1: This requirement does not apply to spaces containing only pipes

2.7.6 Leak detection

The spaces where the medium might be likely to leak are to be continuously monitored by appropriate leak detectors, which are to be of a type approved by the Society.

2.7.7 Alarm

Any detection of medium leak is to activate an audible and visible alarm in a normally manned location. The alarm is to be activated when the concentration of refrigerant reaches a value agreed with the Society on a case by case basis.

2.8 Fire-fighting systems

2.8.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with MARPOL 73/78 Convention, Annex VI, regulation 12 (Ozone Depleting Substances).

2.8.2 Acceptable fire-fighting media

The use of halon and halocarbons media in the fixed and portable fire fighting equipment is prohibited.

2.8.3 Design requirements for fire-fighting systems

Provisions are to be made for the safe containment and disposal of fire-fighting media in case of spillage during maintenance or repair.

2.9 Emission of nitrogen oxides (NOx)

2.9.1 Compliance with MARPOL 73/78

Diesel engines fitted to ships granted with the additional class notation **CLEANSHIP** have to comply with the requirements of:

- MARPOL 73/78, Annex VI, Reg. 13
- NOx Technical Code (2008)

2.9.2 Application

The following requirements apply to all diesel engines, independently of the service, with a rated power of more than 130 kW, installed on the ship, with the exceptions of:

- emergency diesel engines, diesel engines installed in lifeboats and any other diesel engines intended to be used solely in an emergency situation, independently of their rated power
- engines which are subject to alternative measures for limiting NOx emission, under special consideration of the Society.

Note 1: NOx emissions from gas only engines, gas turbines, boilers and incinerators are not subject to these requirements.

2.9.3 NOx certification of engines

Prior to installation onboard the ship, engines have to be NOx-certified in accordance with the relevant provisions of the NOx Technical Code for the intended application. A valid EIAPP certificate (or statement of compliance) is normally to be issued by the Society.

2.9.4 NOx reduction methods

Where NOx reduction methods (such as water injection, fuel oil emulsification, charge air humidification, exhaust gas after-treatment) are used, they are to be approved by the Society and taken into account in the EIAPP certificate of the engine.

The measurement of NOx emission levels, where required for the control of the reduction process (e.g. to adjust the injection rate of the reduction agent for SCR systems), is to be carried out by means of type-approved analysers.

2.9.5 Urea solutions used for SCR systems

The SCR storage tank containing the chemical treatment fluids is to be protected from excessively high or low temperatures applicable to the particular concentration of the solution. Depending on the operational area of the ship, this may necessitate the fitting of heating and/or cooling systems. The physical conditions recommended by applicable recognized standards (such as ISO 18611-3) are to be taken into account to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage.

2.10 Emission of sulphur oxides (SOx)

2.10.1 Compliance with MARPOL 73/78

Ships granted with the additional class notation **CLEANSHIP** have to comply with the relevant requirements of MARPOL 73/78 Convention, Annex VI and related Guidelines:

- Reg. 13 for Sulphur Oxides (SOx) and Particulate Matter
- Reg. 18 and Appendices V and VI for fuel oil quality
- IMO Resolution MEPC.182(59) for the sampling of fuel oil.

2.10.2 Use of low sulphur fuel oils

Where several types of fuel are used in pursuance of [2.10.1], arrangements are to be made to allow the complete flushing of the high sulphur fuel supply system before entering the emission control area (ECA).

Arrangements are to be made to record the following parameters:

- volume of fuel oil in each tank
- date, time and position of the ship when the fuel change-over operation is completed or started (respectively when entering the ECA or leaving the ECA).

2.10.3 Use of exhaust gas cleaning systems

Exhaust gas cleaning (EGC) systems, which may be accepted as an arrangement equivalent to the use of low sulphur fuel oils in pursuance of MARPOL 73/78 Convention, Annex VI, Regulation 4.1, are to be approved in accordance with IMO Resolution MEPC.340(77): 2021 Guidelines for exhaust gas cleaning systems.

EGC systems are to be fitted with data measuring, recording and processing devices in accordance with the aforesaid Resolution.

The discharge washwater is to satisfy the criteria given in the aforesaid Resolution.

Washwater treatment residues generated by the EGC unit are to be stored in a holding tank having a capacity sufficient for 30 days operation of the ship, then delivered ashore to adequate reception facilities. Such residues are not be discharged to the sea or incinerated on board.

3 Additional design requirements for the additional class notation CLEANSHIP SUPER

3.1 Waste minimization and recycling program

3.1.1 Direct waste minimization and recycling programs involving significant reduction of the waste amounts mentioned in Tab 1 are to be implemented. Such programs are to cover the influence of measures such as:

- use of technical water (e.g. air conditioning condensate) where possible
- use of water recovery systems (e.g. filtering and reuse of laundry water - last rinse use for first wash)

- reclamation and reuse of properly treated and filtered wastewaters as technical water (e.g. in toilet flushing, laundry, open deck washing)

Note 1: Effluents from water treatment plants may be reused or recycled only if they comply with a recognised quality standard for potable water.

- active water conservation (e.g. use of reduced flow shower heads, vacuum systems for toilets, laundry equipment that utilizes less water)
- use of reusable packaging and bulk packaging
- replacement of plastic packaging by containers built in other material
- minimization of the amount of oily bilge water and processing of the oily bilge water and oil residue (sludge) in accordance with the Integrated Bilge Water Treatment System (IBTS) concept (see IMO Circular MEPC.1/Circ.642 as amended).

3.1.2 In addition to the procedures required in [2.4.2], the procedures for garbage source reduction, minimization and recycling are to be available in the garbage management plan.

3.2 Oily wastes

3.2.1 The bilge water holding tank is to have a capacity that provides to the ship the flexibility of operation in ports, costal waters and special areas, without the need to discharge de-oiled water overboard. The minimum capacity of the bilge water holding tank is not to be less than the greater of the two following values (in m^3):

- 0,075 S, where S is the surface of the vertical projection, in m^2, of the largest machinery space drained into the bilge holding tank
- the value calculated from Tab 4.

Table 4 : Minimum capacity of the bilge water holding tank according to main engine rating

Main engine rating (kW)**(1)**	Capacity (m^3)
up to 1000	1,5
above 1000 up to 20000	1,5 + (P – 1000) / 1500
above 20000	14,2 + 0,2 (P – 20000) / 1500
(1) For diesel-electric propulsions, the main engine rating is to be substituted with the aggregate power of the electric power motors.	

3.3 Wastewaters

3.3.1 Design and arrangement of the sewage and grey water systems

The ship is to be fitted with a sewage system and a grey water system designed and arranged as follows:

- an approved sewage treatment plant or sewage comminuting and disinfecting system is to be provided
- a tank is to be provided for the storage of untreated or treated sewage with a capacity complying with [3.3.2]
- a tank is to be provided for the storage of grey waters with a capacity complying with [3.3.2]
- grey waters from galleys are to be collected separately from other grey waters and led through a grease trap prior to additional treatment, storage or discharge.

Note 1: Treated sewage and grey water holding tanks may be combined together.

Note 2: Plastic garbage is to be separated from sewage and/or grey waters before entering the treatment unit.

3.3.2 Holding tanks

Holding tanks for sewage and grey water are to have a capacity sufficient for 24 hours operation of the ship, having regard to the maximum number of persons on board, the daily production of wastewater given in Tab 1 and other relevant factors.

3.3.3 Sewage sludges

Sludges from sewage treatment are to be collected and stored then discharged ashore or, where permitted, incinerated onboard.

Where provided, incineration devices are to completely burn the sludges to a dry and inert ash and not to discharge fly ash, malodors or toxic substances.

The capacity of the sewage sludge tanks is to be calculated taking into consideration:

- the maximum period of voyage between ports where sludge can be discharged ashore, or
- the incinerator capacity and whether incineration is permitted in the areas where the ship is intended to operate.

In the absence of precise data, a figure of 30 days is to be used.

Ashes from sludge incineration are be disposed ashore except where permitted under [2.4.7].

3.3.4 Discharge records

Provisions are to be made to record the following parameters related to the sewage and grey water discharges:

- date and time of discharge
- position of the ship (latitude and longitude)
- quantity of sewage and/or grey water discharged
- quantity of sludges incinerated or discharged ashore.

3.4 Food wastes

3.4.1 Food wastes and wastes contaminated with food are to be stored in high integrity sealed packaging and refrigerated to 5°C.

3.5 Prevention of pollution by oil spillage and leakage

3.5.1 Containment systems

A seven-barrel spill kit containing the following is to be available on board, ready to be used during bunkering operation:

- sorbents sufficient to absorb seven barrels of oil
- non-sparking hand scoops, shovels and buckets
- portable containers suitable for holding seven barrels of recovered solid waste and seven barrels of recovered liquid waste
- a minimum of 60 litres of a deck cleaning agent
- appropriate protective clothing to protect personnel from inhalation hazards, eye exposure and skin contact
- non-sparking portable pumps with appropriate hoses.

3.5.2 Oil detection in cooling water circuits

Hydrocarbon detectors are to be provided in sea water and fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water.

3.6 Protection against oil pollution in the event of collision or grounding

3.6.1 All fuel oil and lubricating oil tanks are to be located in protected locations in accordance with the provisions of NR467, Pt C, Ch 1, Sec 10, [11.5.3].

Note 1: This requirement does not apply to engine lubricating oil drain tanks.

3.7 Prevention of air pollution

3.7.1 All refrigerants used onboard are to have:

- a Global Warming Potential (GWP) not exceeding 2000
- an Ozone Depleting Potential (ODP) equal to zero.

3.8 Monitoring and recording systems

3.8.1 On-board emission measurement and monitoring equipment

Ships having the additional class notation **CLEANSHIP SUPER** are to provided with a type-approved measurement, monitoring and recording equipment, for:

- NOx emissions, in compliance with MO Resolution MEPC.103(49)
- SO2 and CO2 emissions, in compliance with IMO Resolution MEPC.340(77).

Note 1: The correspondence between the SO2/CO2 ratio and the sulphur content of the fuel oil is detailed in IMO Resolution MEPC.340(77) Table 1 and Appendix II.

3.8.2 Remote transmission of the parameters related to waste discharge and air emissions

All the waste discharge and air emission parameters required to be monitored and recorded as per the requirements of Articles [2] and [3] are to be transmitted on a regular basis (e.g. every day) via a satellite communication system to a shipowner facility ashore. Such information is to be made available to the Surveyor of the Society upon request.

Section 3 Design Requirements for the Pollution Prevention Notations other than CLEANSHIP and CLEANSHIP SUPER

1 General

1.1 Application

1.1.1 The requirements of this Section apply to ships having one of the additional class notations for pollution prevention listed in Ch 7, Sec 1 other than **CLEANSHIP** and **CLEANSHIP SUPER**.

Requirements for onboard surveys are given in Ch 7, Sec 4 and in Pt A, Ch 5, Sec 9.

1.2 Documents to be submitted

1.2.1 Certificates

The certificates to be submitted for the aforementioned additional class notations are listed in Ch 7, Sec 1, Tab 2.

1.2.2 Operational procedures

The operational procedures to be submitted for the aforementioned additional class notations are listed in Ch 7, Sec 1, Tab 3.

1.2.3 Plans and documents

The plans and documents to be submitted for the aforementioned additional class notations are listed in Ch 7, Sec 1, Tab 4.

2 Additional class notation AWT

2.1 Scope

2.1.1 The additional class notation **AWT** applies to ships fitted with an advanced wastewater treatment (AWT) plant, capable of treating both sewage and grey waters with an effluent quality complying with [2.3].

Note 1: Effluents from the AWT plant may be reused or recycled only if they comply with a recognised quality standard for potable water.

2.2 Definitions and abbreviations

2.2.1 7-day average

The 7-day average is the arithmetic mean of pollutant parameter values for samples collected in a period of 7 consecutive days.

2.2.2 30-day average

The 30-day average is the arithmetic mean of pollutant parameter values for samples collected in a period of 30 consecutive days.

2.2.3 BOD5

BOD5 is the 5-day measure of the pollutant parameter biochemical oxygen demand.

2.2.4 Percent removal

The percent removal is a percentage expression of the removal efficiency across a treatment plant for a given pollutant parameter, as determined from the 30-day average values of the raw wastewater influent pollutant concentrations to the AWT plant and the 30-day average values of the effluent pollutant concentrations for a given time period.

2.2.5 TSS

TSS is the pollutant parameter total suspended solids.

2.3 Design of the AWT plant

2.3.1 Required capacity

The capacity of the AWT plant is to be sufficient for the maximum number of persons onboard, taking into account the sewage and grey water quantities given in Ch 7, Sec 2, [2.1.1].

2.3.2 Effluent quality

The AWT plant is to be so designed that the minimum level of effluent quality complies with the following limits:

a) BOD5
   1) the 30-day average is not to exceed 30 mg/l
   2) the 7-day average is not to exceed 45 mg/l
   3) the 30-day average percent removal is not to be less than 85 percent.

b) TSS
   1) the 30-day average is not to exceed 30 mg/l
   2) the 7-day average is not to exceed 45 mg/l
   3) the 30-day average percent removal is not to be less than 85 percent.

c) pH

   The effluent values for pH are to be maintained within the limits of 6,0 to 9,0.

d) Fecal coliform

   The geometric mean of the samples from the discharge during any 30-day period is not to exceed 20 fecal coliform/100 millilitres (ml) and no more than 10% of the samples may exceed 40 fecal coliform/100 ml.

e) Total residual chlorine

   Concentrations of total residual chlorine is not to exceed 10,0 micrograms per litre (µg/l).

2.3.3 Type tests

Advanced Wastewater Treatment plants are to be of a type approved in accordance with IMO Resolution MEPC.227(64) as amended by MEPC.284(70), taking into account the following effluent standards:

a) Fecal coliform standard:

   The geometrical mean of the fecal coliform count of the samples of the effluent taken during the test period should not exceed 14 coliforms/100 ml M.P.N. (most probable number) as determined by a 5 tube fermentation analysis or an equivalent analytical procedure. In addition, no more than 10% of the number of samples exceed an M.P.N. of 43 coliforms /100 ml.

b) Total suspended solids standard:

   The geometrical mean of total suspended solids is not to exceed 10 mg/l.

c) 5-day biochemical oxygen demand (BOD_5) standard:

   The geometrical mean of BOD_5 is not to exceed 20 mg/l.

d) Total nitrogen (TN) standard:

   The geometrical mean of TN is not to exceed 10 mg/l.

e) Total phosphorus (TP) standard:

   The geometrical mean of TP is not to exceed 1 mg/l.

3 Additional class notation BWE

3.1 Scope

3.1.1 The additional class notation **BWE** applies to ships intended for ballast water exchange at sea and whose design is in compliance with the technical provisions of BWM convention (2004), Regulation D-1, and with the requirements of this Article.

3.2 Design requirements

3.2.1 Design of the pumping and piping systems

The pumping and piping systems involved in the ballast water exchange are to comply with the provisions of Pt C, Ch 1, Sec 10, [7].

3.2.2 Sediment handling

Arrangements are to be made for:

- monitoring the sediment build up
- cleaning the tanks and removing the sediments
- disposing the sediments to reception facilities.

3.2.3 Discharge records

Provisions are to be made to get and record the following parameters related to the ballast water discharge:

- date and time of discharge
- ship location (latitude and longitude)
- amounts of water exchanged
- amount of sediments disposed to reception facilities.

4 Additional class notation BWT

4.1 Scope

4.1.1 The additional class notation **BWT** applies to ships complying with the International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 and to the relevant Guidelines, and fitted with an approved ballast water treatment system.

4.2 Design and installation requirements

4.2.1 General

The ballast water treatment system is to be designed and installed in accordance with the provisions of NR467, Pt C, Ch 1, Sec 13.

4.2.2 Ballast water treatment records

Provisions are to be made to get and record the following parameters related to the ballast water discharge/treatment:

- date and time of ballast water discharge and intake (when the treatment is performed at the intake stage)
- ship location (latitude and longitude)
- date, time, duration and conditions of treatment (at intake or discharge stage, or during voyage)
- amounts of water treated.

5 Additional class notation GWT

5.1 Scope

5.1.1 The additional class notation **GWT** applies to ships fitted with a grey water treatment system, the effluents from which have a quality complying with [5.2].

Note 1: Effluents from the grey water treatment plant may be reused or recycled only if they comply with a recognised quality standard for potable water.

5.2 Design of the grey water treatment plant

5.2.1 Required capacity

The capacity of the grey water treatment plant is to be sufficient for the maximum number of persons onboard, taking into account the daily production of grey water given in Ch 7, Sec 2, [2.1.1].

5.2.2 Effluent quality

The grey water treatment plant is to be so designed that the minimum level of effluent quality complies with the limits given in IMO Resolution MEPC.227(64) as amended by MEPC.284(70).

5.2.3 Type tests

Grey water treatment plants are to be type-approved in accordance with IMO Resolution MEPC.227(64) as amended by MEPC.284(70).

6 Additional class notation NDO-x days

6.1 Scope

6.1.1 The additional class notation **NDO-x days** applies to ships having sufficient onboard storage capacity for solid waste and liquid effluents, allowing the fully loaded ship to operate without discharging any substances into the sea during x consecutive days (no discharge period).

6.2 Design requirements

6.2.1 The no discharge operation presupposes that, during the no discharge period:

- no incineration is carried out
- no waste nor effluents are discharged into the sea.

Note 1: Where the **AWT** notation is assigned to the ship, the discharge of treated sewage and treated grey water is allowed.

Note 2: Discharge of washwaters from exhaust gas clean cleaning (EGC) systems are not allowed during the no discharge operation. The installation of closed loop EGC systems may be considered in this respect.

6.2.2 The storage capacity for each of the following solid and liquid wastes is to be sufficient to allow the no discharge operation of the ship during x days:

- plastics
- paper and cardboard
- glass and tins
- food waste
- sewage (see Note 1)
- grey water (see Note 1)
- sewage sludges (where applicable)
- bilge water
- oil residues (sludge)
- hazardous wastes
- washwater treatment residues from EGC units (where applicable).

Note 1: Storage capacity is not required for treated sewage and treated grey water when the notation **AWT** is assigned to the ship.

6.2.3 Except otherwise stated, the storage capacities are to be based on:

- the maximum number of persons onboard
- the daily production of solid waste and liquid effluents given in Ch 7, Sec 2, [2.1.1].

6.2.4 Unless otherwise justified, the minimum capacity required for the bilge water holding tank is not to be less than x times the capacity given in Ch 7, Sec 2, Tab 4.

7 Additional class notation NOX-x%

7.1 Scope

7.1.1 The additional class notation **NOX-x%** applies to ships fitted with diesel engines having a weighted average NOx emission level not exceeding x% of the weighted average IMO Tier II limit.

The NOx performance index x is to be ≤ 90.

7.2 Design requirements

7.2.1 General

The diesel engines to be considered are those referred to in Ch 7, Sec 2, [2.9.2].

NOx reducing devices may be considered if they are covered by the EIAPP certificate of the engine.

7.2.2 Calculation of the weighted average NOx emission level of the ship

The weighted average NOx emission level of the ship [NOx]ship ,in g/kWh, is to be calculated as follows:

$$[NOx]_{ship} = \frac{\sum_{i=1}^{n}[NOx]_i \cdot P_i}{\sum_{i=1}^{n} P_i}$$

where:

n : Total number of engines installed on the ship

[NOx]i : NOx emission level of each individual engine as per EIAPP certificate (in g/kWh)

P_i : Rated power of each engine (in kW).

7.2.3 Calculation of the weighted average IMO Tier II NOx emission limit of the ship

The weighted average IMO Tier II NOx emission limit of the ship [IMO]ship, in g/kWh, is to be calculated as follows:

$$[IMO]_{ship} = \frac{\sum_{i=1}^{n}[IMO]_i \cdot P_i}{\sum_{i=1}^{n} P_i}$$

where:

n, P_i : As defined in [7.2.2]

[IMO]i : Applicable IMO Tier II NOx emission limit of each individual engine as per MARPOL 73/78, Annex VI, Reg. 13.4 (in g/kWh).

7.2.4 Calculation of the NOx performance index x

The NOx performance index x is to be calculated as follows:

$$x = \frac{[NOx]_{ship}}{[IMO]_{ship}}$$

where:

[NOx]ship :Weighted average NOx emissions for the ship (in g/kWh), as calculated in [7.2.2]

[IMO]ship: Weighted average IMO Tier II NOx emission limit for the ship (in g/kWh), as calculated in [7.2.3].

8 Additional class notation OWS-x ppm

8.1 Scope

8.1.1 The additional class notation **OWS-x ppm** applies to ships fitted with an oily water separator (OWS) capable of producing effluents having a hydrocarbon content not exceeding x ppm.

The OWS performance index x is to be ≤ 10.

Note 1: ppm means parts of oil per million parts of water by volume.

8.2 Design requirements

8.2.1 The OWS is to be type-approved in accordance with the provisions of IMO Resolution MEPC.107(49) as amended by MEPC.285(70), for an effluent quality of x ppm.

The bilge alarm and the automatic stopping device are to be efficient for the x ppm limit.

9 Additional class notation SOX-x%

9.1 Scope

9.1.1 The additional class notation **SOX-x%** applies to ships using fuel oils complying with the following criteria:

- the sulphur content of fuel oils used in emission control areas (ECAs) is not is not to exceed x% of the IMO limit given in MARPOL 73/78, Annex VI, regulation 14.4
- the sulphur content of fuel oils used in other areas is not to exceed x% of the IMO limit given in MARPOL 73/78, Annex VI, regulation 14.1

The SOx performance index x is to be ≤ 90.

Alternative arrangements may be accepted if the resulting SOx emission reduction is deemed equivalent to that corresponding to the use of fuel oils with reduced sulphur content.

9.2 Design requirements

9.2.1 Use of fuel oils with reduced sulphur content

Where fuel oils with reduced sulphur content are used, the requirements in Ch 7, Sec 2, [2.10] are to be complied with.

9.2.2 Use of exhaust gas cleaning systems as alternative arrangement

Where exhaust gas cleaning systems are used, they are to be approved in accordance with IMO Resolution MEPC.340(77), for a SOx emission performance corresponding to the use of a fuel oil having a sulphur content of x% of the IMO sulphur limit applicable to ECAs.

Provisions of Ch 7, Sec 2, [2.10.3] and Ch 7, Sec 2, [3.8.1] for data measuring and recording are to be complied with.

Section 4 Onboard Surveys

1 Application

1.1

1.1.1 Survey requirements for the additional class notations **CLEANSHIP**, **CLEANSHIP SUPER** and other additional class notations listed in Ch 7, Sec 1, Tab 1 are given in Pt A, Ch 5, Sec 9.

This Section contains additional requirements applying to the additional class notations **CLEANSHIP**, **CLEANSHIP SUPER** and **AWT**.

2 Periodical tests and measurements done by the shipowner

2.1 General

2.1.1 Purpose

The following tests and measurements, done under the responsibility of the shipowner, are intended to demonstrate the effective implementation of the waste management procedures and the constant level over time kept by the quality of the effluents discharged at sea.

2.2 Initial period

2.2.1 Initial tests

During the first year of commercial operation, the Shipowner is to proceed with the following measurements and analyses:

- collection of actual shipboard data's concerning the volume of wastes generation, using the waste streams as defined in Ch 7, Sec 2, Tab 4
- analyses of the effluent and waste streams for pollutant concentration, according to the periodicity defined in Tab 1.

Table 1 : Frequency of analyses of waste streams during the first year of service

Waste stream	Frequency of analyses
Metals analyses in incinerator ash**(1)**	quarterly
Metals analyses in grey water	quarterly
Effluent analyses sewage treatment plan	yearly
Effluent analyses for Advanced Wastewater Treatment	quarterly
(1) If the ship is equipped to dump incinerator ash overboard.	

2.3 Periodical tests after first year of service

2.3.1 General

The effluents and wastes usually discharged to sea are to be periodically sampled and analyzed by a qualified laboratory. The frequency of these tests in a five-year term period is specified in Tab 2.

Tab 3 lists the number of occurrences where the pollutant maximum concentration may exceed the limit concentration specified in Tab 4 and Tab 5, without exceeding the reject value.

Test results of the measurements are to be recorded in the wastewater and garbage logbooks and made available to the surveyor during the periodical surveys.

Table 2 : Frequency of analyses of waste streams after the first year of service

Waste stream	Number of analyses in a 5-year period
Metals analyses in incinerator ash**(1)**	2
Metals analyses in grey water	2
Effluent analyses sewage treatment plan	2
Effluent analyses for Advanced Wastewater Treatment	20
Oil content analyses of machinery bilge water	2
(1) If the ship is equipped to dump incinerator ash overboard.	

Table 3 : Permissible number of analyses exceeding limit values

Number of analyses in a 5-year period	Maximum number of analyses above limit
2-5	0
20	3

2.3.2 Water effluent standard

The effluent standard for biological analyses of waters are given in Tab 4.

Table 4 : Biological analyses standard for waters

Water to be tested	Pollutant	Limit concentration	Reject value
Effluent of oil filtering equipment	Oil	15 ppm	–
Effluent of sewage treatment plant	Fecal coliform	100 coli/100 ml	–
	Total suspended solids (TSS)	35 mg/l	–
	5-day Biochemical Oxygen Demand (BOD_5)	25 mg/l	–
Effluent of AWT unit (applies only to ships having the additional class notation **AWT**)	Fecal coliform	14 coli/100 ml	43 coli/100 ml
	TSS	10 mg/l	25 mg/l
	BOD_5	20 mg/l	30 mg/l
	Total Nitrogen (TN)	10 mg/l	25 mg/l
	Total phosphorus (TP)	1 mg/l	5 mg/l

2.3.3 Metals analyses

The analyses given in Tab 5 are to qualify the incinerator ash and grey water as free from hazardous wastes. The metals listed in Tab 5 are considered as indicators of toxicity.

Table 5 : Detection of heavy metals in ashes and water

Metal	Limit concentration (ppm)
Arsenic	0,3
Barium	4,0
Cadmium	0,3
Chromium	5,0
Lead	1,5
Mercury	0,01
Selenium	0,3
Silver	0,2

3 Periodical surveys

3.1 Initial survey

3.1.1 Tests

After installation on board, the equipment and systems relevant to the requirements of the present Chapter are to be tested in the presence of the Surveyor under operating conditions. The control, monitoring and alarm systems are also to be tested in the presence of the Surveyor or their functioning is to be simulated according to a procedure agreed with the Society.

3.2 Periodical survey

3.2.1 The annual and class renewal surveys are to be carried out in accordance with the provisions of Pt A, Ch 5, Sec 9, [2].

Part E
Additional Class Notations

CHAPTER 8
CBRN

Section 1	General
Section 2	Ship Arrangement
Section 3	CBRN Protection
Section 4	Piping and Electrical Equipment

Section 1 General

1 General

1.1 Scope

1.1.1 The present chapter details requirements for the protection of personnel onboard naval ships intended for operation in atmospheres contaminated by chemical, biological, radiological or nuclear hazardous material (CBRN) for rescue or damage control purposes.

It is to be noted however that these requirements do not cover:

- Operation in outside explosive atmosphere.
- Resistance to the mechanical effects of explosions leading to CBRN contamination, except the resistance of the collective protection system to air blast for ships to be assigned the additional class notation **CBRN-AIR BLAST RESISTANCE**. In particular, this chapter does not cover the resistance of structure to air blast and thermal effects of nuclear or non-nuclear explosions.
- CBRN contamination coming from inside the ship.

In addition, it is to be noted that protection against, and especially detection of, biological contamination is covered only insofar as it is specified by the Naval Authority in the CBRN operation specification, considering the effective limits of the technical solutions available for this purpose.

1.2 Application

1.2.1 The additional class notation **CBRN** is assigned in accordance with Pt A, Ch 1, Sec 2, [6.11.1] to ships equipped in order to permit safe operation in CBRN conditions and complying with the requirements of the present chapter. The requirements of the additional class notation **CRBN** are applicable when considering a contamination coming only from outside of the ship. Other cases will be considered on a case-by-case basis.

1.2.2 The additional class notation CBRN may be completed by **-AIR BLAST RESISTANCE** for ships having a collective protection system designed to withstand air blast according to the requirements of Ch 8, Sec 3, [3].

1.3 Documentation to be submitted

1.3.1 The documentation to be submitted is listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	I	CBRN operation manual
2	I	Citadel and shelter general arrangement
3	A	Citadel, airlock and cleansing station ventilation drawing, system details and sizing calculation
4	A	Arrangement of the CBRN protection plant, including, for ships to be assigned the additional class notation **CBRN-AIR BLAST RESISTANCE**, details of the air blast protective device
5	A	Details of ventilation opening controls and monitoring
6	I	Engine room general arrangement
7	A	Details of engine air supply and engine casing
8	A	Details of door arrangement, control and monitoring
9	A	CBRN detection system drawing and details
10	A	Electrical equipment certificates for environmental protection, in line with Ch 8, Sec 4, [2.1.1]
11	A	Diagram of the scupper and sanitary discharge system
12	A	Pre-wetting and washdown system drawing, system details and sizing calculation
13	I	Calculation of required airflows, pressure and CO_2 levels during the collective protection ventilation test, unless this test is carried out with the specified maximum number of people on board, see [2.3.3]
(1) A: To be submitted for approval ; I : To be submitted for information		

No.	I/A **(1)**	Documentation
14	A	Fire control plan showing: • citadel, sub-citadels and/or shelter • storage location of personal protective equipment • CBRN detection system • pre-wetting and washdown system and associated control valves
15	I	Procedures in case of fire during CBRN operation
(1) A: To be submitted for approval ; I : To be submitted for information		

1.3.2 CBRN operation specification

It is the responsibility of the Naval Authority to detail the range of CBRN threats to be covered in order to enable efficient protection. The following information is to be clearly stated as a basis for design and in-service follow-up:

- CBRN agents to be considered (especially the list of chemical or bacteriological agents to be considered).
- Particulars of the required detection system(s), especially whether biological detection is required and whether a portable detection system is acceptable.
- Nature of operations to be carried out in the polluted area (mere crossing of the polluted area or e.g. personnel rescue, pollution control / cleanup, coordination etc.). Specific spaces and systems related to these operations that need to be operable in CBRN mode are to be listed.
- Maximum duration for such operations.
- Number of persons on board during operation (intervention personnel and rescued people).
- Number of persons that may be engaged simultaneously in a CBRN operation requiring wearing PPE, referred to in Ch 8, Sec 3, [5.2.2].
- List of spaces required to be included in the citadel, as well as functionalities that may be available to a limited extent under CBRN mode (e.g. cooking and food supply) as referred to in Section 2 [1.1.2]
- List of spaces allowed to be non-sheltered, if any, as referred to in Section 2 [3.1.1]
- Specific overpressure values and associated tolerances, especially if different from the reference values mentioned in this Chapter
- Particulate filters collection efficiency
- Required arrangement of cleansing stations
- Philosophy for decontamination operations, required capacity of the pre-wetting and washdown system if different from that given in Ch 8, Sec 3, [4.1.2] and whether specific systems or weapons need to be cleaned manually rather than covered by the pre-wetting and washdown system.

1.3.3 The CBRN operation manual is to include:

- The CBRN operation specification.
- A plan showing the citadel, space for rescued people, shelter, airlock and cleansing station arrangement.
- A plan showing all liquid and gastight closing appliances that need to be closed prior to CBRN operation, together with a detailed description of this system.
- A detailed description of the detection system required in Ch 8, Sec 3, [1] with relevant drawings, operating instructions and alarm codes for the CBRN detection system.
- A detailed description and drawings of the citadel ventilation system. Parts of the system to be used solely for CBRN operation are to be outlined.
- Detailed procedure for switching to CBRN mode including:
  - closure of all openings
  - modifications of the ventilation system if relevant
  - CBRN filter activation.
- Measures to be taken in case of alarm related to the CBRN system (e.g. loss of overpressure).
- Measures to be taken in case of fire during CBRN operation.
- Measures to be taken for the replacement of the filters and for their disposal after contamination.

1.4 Definitions and abbreviations

1.4.1 CBRN

Chemical, Biological, Radiological and Nuclear.

1.4.2 CBRN mode

Activation of the CBRN mode provides a contamination-free area in the whole citadel.

CBRN mode needs to be defined for the following systems:

- monitoring, control and alarm systems, including management of the airlocks and cleansing station
- CBRN detection system
- collective protection system
- pre-wetting and washdown system.

1.4.3 CBRN operation

Ship operation in an environment where CBRN hazard is expected. During CBRN operation, the citadel and the collective protection system are switched to CBRN mode.

1.4.4 Citadel

Space or group of spaces surrounded by liquid and gastight boundaries and protected by overpressure and filtrated air ventilation system, in view of allowing personnel inside the citadel to keep their operational capability without wearing PPE in case of external CBRN contamination.

1.4.5 Collective protection system

The collective protection system is the ventilation system that provides a contamination-free environment in the citadel by:

- keeping the citadel at an overpressure with respect to the outside atmosphere and,
- providing clean air inside the citadel.

1.4.6 Shelter

Space or group of spaces that can be made liquid and gastight.

1.4.7 Sub-citadel

Subdivision of the citadel that can be made gastight with respect to another sub-citadel.

2 Construction testing and inspection

2.1 General

2.1.1 This Article details acceptance tests to be carried out during ship commissioning. They may be carried out at yard or during sea trials.

2.2 Closure test

2.2.1 Remote closing of all openings in the citadel and shelter boundaries is to be tested, including doors, valves and ventilation openings.

2.3 Collective protection ventilation test

2.3.1 The collective protection ventilation system is to be tested upon building completion in order to demonstrate that the required overpressure can be maintained, and that the CO_2 level remains acceptable.

2.3.2 Once the pressure has been stabilized in the citadel, the overpressure is to be maintained for a duration corresponding to the minimum between:

- 1h and
- the maximum duration for CBRN operation according to the CBRN operation specification.

2.3.3 The required airflows, pressure and CO_2 levels may be assessed by the Shipyard based on calculation according to a standard acceptable to the Society. Alternatively, the test may be carried out with a number of people inside the citadel equal to the maximum number of people on board during CBRN operation according to the CBRN operation specification and it is to be checked that CO_2 levels in all spaces, including machinery spaces, remain acceptable during the whole test. In this case, the test duration may need to be adapted to ensure stabilization of the CO_2 level.

2.3.4 The citadel overpressure is to remain within the required range during the whole test. This includes:

- differential pressure between the citadel and the outside atmosphere
- differential pressure between the citadel, cleansing station, airlocks and outside atmosphere
- differential pressure between machinery spaces included in the citadel and the rest of the citadel, if applicable
- differential pressure between engine enclosure and machinery spaces, if applicable.

2.3.5 A functioning test of the airlocks and cleansing stations is to be carried out with the collective protection ventilation system working.

2.4 CBRN detection test

2.4.1 A functioning test of the CBRN detection system is to be carried out. However, no actual contamination is to be used for the purpose of this test.

2.4.2 Each line is to be tested from the level of the detector, with means defined by the system supplier, in order to verify that detector activation will trigger the required alarms.

2.5 Pre-wetting and washdown test

2.5.1 A functioning test of each section of the pre-wetting and washdown system is to be carried out.

2.5.2 It is to be checked that all external surfaces are actually covered by a film of water while the system is activated.

2.5.3 Proper drainage of the water is to be checked, i.e. that there is no water accumulation on deck.

2.5.4 Remote operation of each section valve is to be tested.

Section 2 Ship Arrangement

1 Citadel

1.1 Space to be included in the citadel

1.1.1 The ship is to be provided with a citadel covering all enclosed spaces that may need to be accessed during CBRN operation, as defined in the CBRN operation specification. The ventilation of the citadel is to comply with the requirements of Ch 8, Sec 3, [2].

1.1.2 The citadel is to include at least all accommodation spaces and normally manned control stations, galleys and pantries, any space dedicated to the storage of food, and normally manned machinery spaces.

However, where specified in the CBRN operation specification, some of these spaces may be excluded from the citadel provided that the required functionalities are available in the citadel.

Note 1: See Article [6] for machinery space arrangement, especially engine room.

1.2 Sub-citadels

1.2.1 On ships having two or more safety zones, the citadel is to be divided into at least two sub-citadels, the boundaries of which are to coincide as much as possible with those of safety zones.

Ships assigned the service notation **corvette** may however be provided with a single citadel not subdivided into sub-citadels if agreed with the Naval Authority.

1.2.2 The boundaries of the sub-citadels are to comply with [1.4].

1.2.3 Access between two separate sub-citadels is to be possible only through gastight, self-closing doors, or watertight doors. An indication of the position of such doors is to be provided at the damage control station.

1.3 Spaces where explosive atmosphere may occur

1.3.1 If spaces where an explosive atmosphere may occur, such as ro-ro or vehicle spaces, paint store, battery room, ammunition space or other spaces as relevant, need to be covered by the collective protection system, they are to be provided with a dedicated, gastight exhaust duct and their ventilation system is to comply with the requirements of Ch 8, Sec 3, [2.2].

1.3.2 If an aircraft hangar is included in the citadel, interlocks and visual and audible alarms are to be provided to prevent any opening of the hangar door while the personnel working inside the hangar are unprotected.

1.4 Boundaries of the citadel

1.4.1 All boundaries of the citadel are to be liquid and gastight.

1.4.2 All openings in the citadel boundaries, except air supply ducts directly led to engines enclosed in a gastight enclosure, are to be able to be made liquid and gastight:

- either automatically, or
- by manual operation, both locally and from the damage control station.

Doors and hatches that are required to be closed during CBRN operation need not be remotely controlled from the damage control station.

1.4.3 Doors in citadel boundaries are generally to open towards the inside of the citadel or the compartment with the highest overpressure level. Where this is not feasible due to e.g. means of escape design constraints, means of latching are to be provided so as to ensure that the door in closed position will withstand the pressure differential expected when the citadel is pressurized.

1.4.4 Hold-back hooks not subject to release from the damage control station are prohibited on doors in citadel boundaries.

1.4.5 Indication is to be provided in the damage control station as to whether each opening in the citadel boundary is open or closed.

1.4.6 Windows in the citadel boundary are to be liquid and gastight and of the non-opening type.

1.4.7 Cable and duct penetrations in citadel boundaries are to be reduced to a minimum and, where needed, are to be designed so as to reconstitute the tightness of the penetrated deck or bulkhead.

1.5 Means of access to the citadel

1.5.1 As a minimum, access to and egress from the citadel is to be possible through:

- One cleansing station complying with the requirements of Article [5] for access and/or egress during CBRN operation.
- One airlock - which may be combined with the airlock included in the cleansing station - complying with the requirements of Article [4] for egress during CBRN operations.

1.5.2 Ships assigned the service notation **aircraft carrier** are to be provided with at least two cleansing stations, preferably distributed over two separate sub-citadels. Ships assigned the service notation **corvette**, **military offshore patrol vessel**, **frigate**, **auxiliary naval vessel** or **amphibious vessel** may be provided with only one cleansing station.

1.5.3 As far as practicable, the airlocks and cleansing stations provided for access to and egress from the citadel are also to be the main and secondary escape routes from the citadel.

2 Space for rescued people

2.1 Accommodation for rescued people

2.1.1 When rescuing of people is part of the ship's CBRN operation specification, a dedicated space is to be available as accommodation for rescued people. This space is to be included in the citadel and provided with suitable ventilation, lighting and sanitary facilities.

2.1.2 Spaces for rescued people may be used for other purposes when the ship is not in CBRN rescuing operation. However, rescued people are not to be accommodated in the radio room, the wheelhouse or the damage control station and main access passageways, which are to be kept clear.

2.2 Means of escape

2.2.1 Spaces for rescued people are to be provided with means of escape in line with the applicable requirements of Pt C, Ch 4, Sec 8.

3 Shelter

3.1 Sheltered spaces

3.1.1 In general, any enclosed space that is not part of the citadel - i.e. not protected by overpressure ventilation - is to be capable of being made liquid and gastight for the whole duration of the CBRN operation. On a case-by-case basis and if agreed by the Naval Authority, unprotected and non-tight enclosed spaces may however be accepted.

3.1.2 Sheltered spaces are to be provided with means of cooling in order to maintain a temperature allowing proper functioning of the equipment installed therein during CBRN operation.

3.2 Openings in shelter boundary

3.2.1 Any opening in the boundaries of such shelters is to comply with the requirements of [1.4] for openings in the boundaries of the citadel.

4 Airlock

4.1 Arrangement

4.1.1 Airlocks are to have a simple shape in order to avoid air pockets and are to be provided with two doors not less than 1 m apart.

Airlocks intended for both access to, and egress from, the citadel are to be provided with 3 doors leading to:

- the citadel
- the other enclosures of the cleansing station, and
- the outside.

All three doors are to be not less than 1 m apart.

4.1.2 The ventilation of the airlocks is to comply with the requirements of Ch 8, Sec 3, [2.4].

4.1.3 Airlocks are to be enclosed by gastight boundaries and doors.

4.2 Doors

4.2.1 Airlock doors are to be self-closing doors or watertight doors. Doors leading to the open deck need not be self-closing doors.

4.2.2 Airlock doors are to be wide enough to allow the passage of personnel wearing Personal Protective Equipment (PPE).

4.2.3 Means are to be provided to ensure that only one door may be opened at a time during CBRN operation. An alarm is to be provided at the damage control station in case more than one of the doors is not fully closed.

4.3 Purging

4.3.1 The doors of airlocks are to be provided with interlocks ensuring that the door leading to the interior of the citadel will remain closed for a duration sufficient to ensure airlock purging after the door leading to the open deck or to the cleansing station has been opened.

4.3.2 Airlock purging is to consist of at least 5 air changes. Attention is to be paid to possible air pockets and toxic gases accumulation, considering actual airflow.

5 Cleansing station

5.1 Arrangement

5.1.1 A shower is to be arranged immediately outside the cleansing station for initial decontamination before entering the cleansing station.

5.1.2 Cleansing stations are to be so arranged as to allow total undressing of potentially contaminated personnel and undressing of Personal Protective Equipment (PPE), decontamination of personnel and containment and cleaning of contaminated PPE or clothing.

5.1.3 The cleansing station is to include four successive gastight enclosures complying with one of the following approaches:

a) 2-stage cleansing stations are to include:
   - One first stage enclosure
   - One central airlock complying with the provisions of Article [4]
   - One second stage enclosure, and
   - One final airlock complying with the provisions of Article [4] and giving access to the citadel.

b) 3-stage cleansing stations are to include:
   - 3 successive gastight enclosures, and
   - One final airlock complying with the provisions of Article [4] and giving access to the citadel.

Each enclosure and airlock listed in items a) and b) is to be gastight with respect to each other and they are to be maintained at an overpressure with respect to atmospheric pressure. The overpressure is to decrease gradually when going from the citadel towards the open deck. The ventilation of the airlocks and cleansing stations is to comply with the requirements of Ch 8, Sec 3, [2.4].

5.1.4 When rescuing people is part of the ship's CBRN operation specification or if specified by the Naval Authority:

- the enclosures of the cleansing station are to be sized to allow the entry and decontamination of personnel carrying a stretcher with a casualty and relevant medical equipment.
- access from the cleansing station to the ship hospital or medical area, if provided, is to be as direct as possible.

5.2 Doors and boundaries

5.2.1 Cleansing stations are to be enclosed by gastight boundaries and doors.

5.2.2 Cleansing station doors are to be self-closing doors without any fixing device.

5.2.3 Cleansing station doors, except the door leading to the open deck, are to be provided with viewing ports.

5.2.4 Means are to be provided to ensure that only one door can be opened at a time during CBRN operation. An alarm is to be provided at the damage control station in case more than one of the doors is not closed.

6 Machinery space arrangement

6.1 Allowable arrangements for engine room and internal combustion machinery spaces

6.1.1 The requirements of [6.1.2] to [6.1.4] are applicable to engine rooms and to all machinery spaces containing internal combustion machinery that is required to remain operational during CBRN operation. For ease of reading, such machinery spaces are called "engine room" in the following requirements.

6.1.2 Depending on the ship operating range and CBRN operation philosophy, the engine room may be:

- included in the citadel, i.e. ventilated with decontaminated air and maintained in overpressure with respect to the outside atmosphere, or
- sheltered, i.e. able to be closed liquid and gastight.

6.1.3 If the engine room is included in the citadel, the requirements of [6.2] are to be applied, together with all requirements applicable to spaces in the citadel.

6.1.4 If the engine room is sheltered:

- the ship is to be assigned the additional class notation **AUT-QAS** as defined in Pt A, Ch 1, Sec 2, [6.5.2] and Ch 4, Sec 1, and
- the requirements of [6.3] are to be applied.

6.2 Machinery space included in the citadel

6.2.1 Access from a machinery space included in the citadel to other spaces in the citadel and vice-versa is to be through a gastight door complying with the requirements of [1.4.3].

6.2.2 Internal combustion machinery required to remain operational during CBRN operation is to be enclosed in a gastight enclosure and provided with a dedicated air supply duct. Engines with gastight design may be accepted as an alternative to a gastight enclosure around the engine. Engine supply and exhaust air ducts are to be gastight and are to comply with the requirements of Pt C, Ch 1, Sec 10, [17].

6.2.3 The engine enclosure is to be maintained at a pressure below ambient pressure in the engine room. The differential pressure between the engine room and the enclosure is to be at least 50 Pa.

6.3 Sheltered machinery space

6.3.1 Sheltered machinery spaces are to comply with the provisions of Article [3].

6.3.2 In addition, access from a sheltered machinery space to the citadel is to be through an airlock complying with the requirements of Article [4].

6.3.3 Internal combustion machinery required to remain operational during CBRN operation is to be gastight or enclosed in a gastight enclosure and provided with a dedicated ducted air supply, in line with the requirements of [6.2.2].

6.4 Fire protection

6.4.1 Machinery spaces located outside of the citadel are to be provided with a fixed fire-extinguishing system complying with the relevant requirements of Pt C, Ch 4, Sec 13.

6.4.2 In case the engine is enclosed in a gastight enclosure, the enclosure is to be provided with a fixed fire detection and fire alarm system and with a fixed fire-extinguishing system suitable for category A machinery spaces and complying with the relevant requirements of Pt C, Ch 4, Sec 13.

6.5 Engine room cooling

6.5.1 A cooling system is to be provided in the engine room in order to keep the temperature at an acceptable level for personnel and to maintain safe equipment operation during CBRN operation.

7 Superstructure design

7.1 Precautions for decontamination

7.1.1 The shape of external decks and superstructures is to be such as to avoid local accumulation of water.

7.1.2 Surfaces that may be exposed to CBRN agents are to be made of easily decontaminable materials. This includes exposed interior surfaces in airlocks and cleansing stations and unprotected spaces, as well as external surfaces.

Alternatively, removable means of protection of interior surfaces of airlocks and cleansing stations may be provided for installation before CBRN operations, if specified by the Naval Authority in the CBRN operation specification.

7.2 Ventilation openings

7.2.1 The ventilation openings are to be arranged so as to prevent water ingress in the ventilating ducts when the pre-wetting and washdown system is in use.

8 Marking

8.1 Openings

8.1.1 All openings in the citadel and shelter boundaries are to be prominently marked. The marking is to indicate clearly (e.g. with a color code) in which situation the concerned opening may or may not be open.

8.2 Equipment

8.2.1 Equipment the setting of which needs to be modified locally for entering CBRN mode is to be prominently marked. The marking is to indicate clearly the relevant setting for each situation (CBRN operation or standard operation).

Section 3 CBRN Protection

1 Detection system

1.1 Detection

1.1.1 The ship is to be provided with a fixed CBRN detection system, consisting of detectors, cables, data treatment unit and control panel, adapted to the CBRN agents to be considered as per the CBRN operation specification.

A portable CBRN detection system may however be accepted when specified by the Naval Authority in the CBRN operation specification.

1.1.2 For fixed CBRN detection systems, detectors are to be provided as detailed in Tab 1.

Where portable CBRN detection system is provided, the number of portable detectors is to be in line with the requirements stated in the CBRN operation specification.

1.1.3 Detectors are to be of a type approved by the Society, complying with the requirements of Pt C, Ch 3.

Note 1: The performance of the detectors may be covered by military standards defined by the Naval Authority in addition to the type approval by the Society.

1.1.4 Radioactivity detectors are to remain accessible for maintenance purposes.

Table 1 : Minimum number and location of CBRN detectors

Hazard	Location				
	In the citadel	Filtering station **(1)**	Cleansing station **(2)**	Open air	Sea water below the waterline
Radioactivity	As a minimum, one detector per sub-citadel and one detector at the navigation bridge	1	1	2	1
Chemical agents				1 **(4) (5)**	
Biological agents **(3)**	To be agreed depending on concerned biological agent				

(1) The detector is to be located immediately downstream of the filters
(2) One detector per cleansing station is to be provided. The detector may be installed either in the cleansing station, or in the citadel close to the access to the cleansing station
(3) Biological agent detection is required only if and as specified by the Naval Authority in the CBRN operation specification
(4) Outside chemical detectors are to be located away from:
- ventilation and engine exhaust openings
- superstructures and physical obstacles

(5) Additional outside chemical detectors may be required by the Naval Authority depending on the ship type and configuration.

1.2 Alarm and monitoring

1.2.1 An audible and visual alarm is to be provided at the navigation bridge and at the damage control station in case CBRN contamination is detected. The alarms are to be distinct depending on the detected hazard. The location where contamination is detected is to be indicated.

In addition, an alarm is to be provided locally in case contamination values above thresholds are measured at any one detector.

1.2.2 For each hazard covered by the CBRN detection system, the detected agent or agent family and measured value at the location where contamination has been detected is to be displayed at the damage control station.

1.2.3 An alarm is to be provided throughout the citadel in case CBRN contamination is detected inside the citadel. The criterion for triggering an alarm in the whole citadel may be higher than that for triggering an alarm at the navigation bridge and damage control station, e.g. higher measured value, time delay or number of detectors impacted, to the satisfaction of the Society.

2 Ventilation and collective protection system

2.1 Citadel ventilation

2.1.1 The citadel, or each sub-citadel where provided, is to be provided with a dedicated ventilation system, which does not serve any other space not included in the citadel or sub-citadel. Arrangements may however be provided to interconnect the ventilation systems of two sub-citadels in degraded mode provided gastight means of segregation between the ventilation systems serving each sub-citadel are installed for use in normal CBRN configuration.

2.1.2 The citadel ventilation system is to be capable of maintaining an overpressure of at least 500 Pa relative to atmospheric pressure in all spaces within the citadel, except as specified in [2.2.2].

2.1.3 Means of monitoring the overpressure in the citadel with indication at the damage control station are to be provided and an alarm is to be activated at the damage control station and at the navigation bridge in case the overpressure drops below the required minimum level.

2.1.4 The ventilation system is to be sized so as to provide breathable air in the whole citadel during the expected duration of CBRN operation. The maximum number of people on board is to be taken into account for this purpose as well as the air consumption of any equipment located in the citadel and which may need to be used during CBRN operation.

Expected leakage through citadel boundaries, including sealed openings, is to be considered.

2.1.5 The sizing of the ventilation system is to be documented in a detailed calculation, in line with ANEP-25:1991 or with another recognized standard acceptable to the Society, supported by a drawing showing air flowrates and pressure levels in each part of the citadel.

2.1.6 Ventilation fans are to be located downstream of the CBRN filters.

2.1.7 Exhaust air from the citadel may be used for the ventilation of:

- other spaces in the citadel, including machinery spaces included in the citadel, or
- airlocks, or
- cleansing stations.

2.1.8 Where needed, non-return devices or dampers are to be fitted on ventilation ducts in order to maintain the required overpressure in the protected spaces and to prevent air flow from outside or decontamination spaces towards protected spaces or from machinery spaces towards other spaces.

2.1.9 Parts of the ventilation system not fully complying with the requirements of Pt C, Ch 4, Sec 5, [6] may be accepted provided that:

- they are used solely during CBRN operation, and suitably marked to this end, and
- they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and
- the ventilation system in use during normal operation is fully compliant with the requirements of Pt C, Ch 4, Sec 5, [6], and
- arrangements are made to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

2.1.10 Ventilation inlets for the citadel are to be widely separated from any ventilation outlets. As a reference, ventilation outlets located more than 1,5 m away from the citadel ventilation inlets are considered widely separated.

2.2 Ventilation of machinery spaces or hazardous spaces included in the citadel

2.2.1 This sub-article applies to machinery spaces or spaces where an explosive atmosphere may occur, when such spaces are included in the citadel. These spaces are referred to as machinery or hazardous spaces included in the citadel.

2.2.2 The ventilation system for machinery or hazardous spaces included in the citadel is to be capable of maintaining an overpressure of at least 200 Pa with respect to the atmospheric pressure. Machinery or hazardous spaces included in the citadel are to remain at an underpressure of at least 100 Pa with respect to other spaces included in the citadel.

2.2.3 During CBRN operation, machinery or hazardous spaces included in the citadel may be ventilated with exhaust air from other spaces in the citadel, subject to the provisions of [2.1.9] and provided that:

- the levels of CO_2 and oxygen remain acceptable for personnel to work in the space without breathing apparatus, and
- non-return valves are fitted in the ventilation ducts in order to maintain the differential pressure between machinery or hazardous spaces and other spaces included in the citadel.

2.3 CBRN protection plant

2.3.1 The CBRN protection plant is to include gas and particulate filters capable of efficiently removing all CBRN agents listed in the CBRN operation specification

- the CBRN gas filters are to be activated carbon filters capable of eliminating chemical agents and other gases
- the CBRN particulate filters are to be high efficiency particulate air (HEPA) filters realizing a collection efficiency as specified by the Naval Authority in the CBRN operation specification. Where no collection efficiency is specified by the Naval Authority, the particulate filters are to realize a collection efficiency H13 according to EN 1822-1 or a collection efficiency of 99.97% of particles of 0,3 μm or greater.

2.3.2 The air inlet for the protection plant is to be provided with devices preventing water, moisture, particulate and corrosive marine salts from entering the CBRN filtration system. In addition, pre-filters are to be provided so that the quality and humidity content of the air blown on the CBRN filter is in line with manufacturer's specification.

2.3.3 Filters are to be easy to change.

2.3.4 A damper is to be installed downstream of the CBRN filters. This damper is to be interlocked with the inlet fan and open only when the inlet fan is working and blowing air towards the citadel.

2.4 Airlocks and cleansing stations

2.4.1 Airlocks and cleansing station enclosures are to be provided with a mechanical ventilation capable of providing at least 40 air changes per hour.

2.4.2 Airlocks and cleansing stations are to be supplied with decontaminated air. Exhaust air from the citadel may be used for this purpose, provided non-return devices are installed as relevant.

2.4.3 Exhaust air from a cleansing station enclosure with a higher overpressure (i.e. closer to the citadel) may be used as supply for the adjacent enclosure with a lower overpressure (i.e. closer to the open deck), provided non-return devices or dampers are installed as relevant.

2.4.4 Ventilation exhausts from airlocks and cleansing stations are to be led to the adjacent cleansing station enclosure with a lower overpressure (i.e. closer to the open deck) or to the open deck, and provided with non-return devices or dampers as necessary to avoid airflow from the outside towards inside the airlock or cleansing station enclosures.

3 Air blast resistance

3.1 Application

3.1.1 The requirements of this article apply to ships to be assigned the additional class notation **CBRN-AIR BLAST RESISTANCE**.

3.2 Protection of ventilation openings

3.2.1 The ventilation openings of spaces included in the citadel are to be capable of withstanding a blast overpressure of 70 mbar.

3.2.2 Ventilation openings that need to remain open during CBRN operation are to be provided with means of closing controllable from the damage control station.

3.3 Protection of collective protection system air inlet

3.3.1 The air inlet for the CBRN protection plant is to be provided with an air blast protective device able to withstand 0,3 bar overpressure. The air blast protective device is to be installed upstream of the filters.

4 Pre-wetting and washdown system

4.1 System arrangement

4.1.1 The ship is to be provided with a pre-wetting and washdown system capable of providing continuous and complete coverage of all external horizontal and vertical surfaces of superstructures and weather decks.

Any equipment installed on open deck is to be covered by this system, unless specified otherwise in the CBRN operation specification.

4.1.2 The capacity of the pre-wetting and washdown system is to be not less than 60L/min for each square meter of horizontally projected protected area for the most demanding section.

Lower flowrates may be accepted if specified by the Naval Authority taking into account the ship’s operational profile.

4.1.3 Nozzles are to be so arranged that all parts of the protected surfaces can be covered by a film of water.

4.1.4 The pre-wetting and washdown system may be divided into sections capable of being operated independently.

4.2 System equipment

4.2.1 The pre-wetting and washdown system may share pumps and/or piping with other systems, including fire-fighting systems. In this case, the pump capacity is to be sufficient to supply either the pre-wetting and washdown system or the other system(s).

4.2.2 The pump and section valves are to be capable of local and remote operation from the damage control station. Indication of each section valve's open or closed position and of whether the pump is in operation is also to be provided at this location and at the navigation bridge.

4.2.3 Pipes, valves and nozzles are to be protected against corrosion and are to comply with the relevant requirements of Pt C, Ch 1, Sec 10.

4.2.4 Means are to be provided to flush the system with fresh water and drainage cocks are to be installed. Precautions are to be taken in order to prevent clogging of the nozzles by impurities contained in pipes, nozzles, valves and pumps.

5 Personal protective equipment (PPE)

5.1 General

5.1.1 A sufficient number of complete sets of protective equipment is to be carried on board, according to the scope defined in the CBRN operation specification.

5.1.2 A set of protective equipment is to consist of:

- CBRN suit
- CBRN gloves and shoes
- Breathing apparatus with adequate CBRN mask.

In addition, prophylactic kits adapted to the risks expected according to the CBRN operation specification are to be provided as relevant.

5.2 Self-contained breathing apparatus

5.2.1 The ship is to be equipped with at least one high pressure air compressor complete with all fittings necessary for refilling the bottles of air breathing apparatuses.

5.2.2 The aggregate capacity of the compressors is to be sufficient to allow the refilling of n bottles for air breathing apparatuses in no more than 10min. n is the number of persons that may be engaged simultaneously in a CBRN operation requiring wearing Personal Protective Equipment (PPE) as defined in the CBRN operation specification.

5.2.3 It is to be possible to supply the air compressors with clean air from the citadel.

5.2.4 If the main air intake for the compressors is located outside of the citadel, an interlock with the CBRN detection system is to be provided to avoid contamination of the breathable air system.

5.2.5 Air supply for the air compressors is to be taken into account for the sizing of the citadel ventilation system.

6 Monitoring and Controls

6.1 Monitoring and control centralisation

6.1.1 All monitoring and control equipment relevant for CBRN operation is to be provided at the damage control station.

6.1.2 Tab 2 summarizes monitoring and control requirements for CBRN systems.

Table 2 : Summary of monitoring and control requirements for CBRN systems (during CBRN operation)

System		Indication	Alarm	Control	Note
CBRN detection system	CBRN contamination detection outside	• Damage control station • Navigation bridge	Audible and visual alarm: • Navigation bridge • Damage control station	Damage control station	See [1.2]
	CBRN contamination detection in the citadel	• Damage control station • Navigation bridge	Audible and visual alarm: • Navigation bridge • Damage control station • Throughout the citadel	Damage control station	See [1.2]
CBRN collective protection ventilation system	Differential pressure between citadel and outside atmosphere	Damage control station	• Damage control station • Navigation bridge		See [2.1.3]
	Differential pressure between machinery space and other spaces in the citadel	Damage control station	• Damage control station • Navigation bridge		See [2.1.3]
	Differential pressure between enclosed engine casing and machinery space	Damage control station	• Damage control station • Navigation bridge		See [2.1.3]
	Position of liquid and gastight closing appliances in the citadel and shelter boundaries	Damage control station		Local and remote at the damage control station	See Ch 8, Sec 2, [1.4.5] and Ch 8, Sec 2, [3.2.1]
	Doors and hatches in citadel or shelter boundaries	Damage control station		Damage control station **(1)**	See Ch 8, Sec 2, [1.4.5] and Ch 8, Sec 2, [3.2.1]
	Airlock and cleansing station doors	Damage control station	Alarm at the damage control station in case more than one door is open		See Ch 8, Sec 2, [4.2.3] and Ch 8, Sec 2, [5.2.4]
	Isolation valves in piping system	Damage control station		Local and remote, inside the citadel	See Ch 8, Sec 4, [1.1]
Pre-wetting and washdown system	Pump	• Damage control station • Navigation bridge		Local and remote from the damage control station	See [4.2.2]
	Section valves	• Damage control station • Navigation bridge		Local and remote from the damage control station	See [4.2.2]

(1) Remote control is not required for doors and hatches that are required to be closed during CBRN operation.

Section 4 Piping and Electrical Equipment

1 Piping systems

1.1 General

1.1.1 Piping systems not serving the citadel are not to pass through the citadel unless:

- Open-ended lines crossing the citadel are fully welded, and
- Isolation valves are provided at penetrations of the boundaries of the citadel. These valves are to be operable from inside the citadel and indication of their position is to be provided at the damage control station, unless otherwise specified by the Naval Authority.

1.1.2 In general, separate piping systems are to be provided to serve:

- the citadel
- shelters, if any
- airlocks and cleansing stations
- other unprotected spaces.

On a case-by-case basis, the Society may accept other arrangements if needed for operational reasons, provided isolation valves are fitted where boundaries between the above spaces are penetrated. These valves are to be operable from inside the citadel. Indication of their position is to be provided at the damage control station, and they are to be marked in line with the requirements of Ch 8, Sec 2, [7.2].

1.1.3 Sea suctions serving the fire main, decontamination showers, cooling systems, and pre-wetting and washdown system where provided, are to be located as low as possible.

1.2 Scupper and bilge systems

1.2.1 Separate scupper and bilge systems are to be provided for:

- the citadel
- shelters, if any
- airlocks and cleansing stations
- other unprotected spaces

1.2.2 Scupper and bilge systems are to be sized taking into account decontamination systems, i.e. decontamination showers in cleansing stations and pre-wetting and washdown system.

1.2.3 Drainage from the cleansing stations and external decontamination showers is to be led directly overboard.

1.2.4 Scuppers from spaces within the citadel or the shelter, and from airlocks and cleansing stations are to be fitted with adequate devices, such as water traps, that will preserve the required overpressure in the protected spaces and prevent the ingress of external air.

1.2.5 Separate scupper and bilge systems are to be provided for spaces that are maintained at different overpressure during CBRN operation.

1.3 Air, sounding and overflow pipes

1.3.1 The potable water tank venting is to be led inside the citadel.

1.3.2 Vent pipes and filling connections of service tanks are to be arranged so that hazardous material cannot enter the tanks during CBRN operation.

2 Electrical installations

2.1 Environmental protection

2.1.1 Electrical equipment included in electrical installations for essential services and located in the citadel or shelter is to have environmental category (EC) of at least EC 31 C or EC 33 C as applicable. Environmental categories are defined in Pt C, Ch 2, Sec 1, [3.26.1].

2.1.2 Where needed, means of refrigeration are to be provided and systems are to withstand the maximum temperature expected in CBRN condition. If the local temperature around the equipment may be expected to rise above 55°C, specific testing may be required.

2.2 Emergency source of power

2.2.1 The following systems are to be supplied by the emergency source of power:

- CBRN detection system
- control and monitoring of openings in citadel boundaries.

Part E
Additional Class Notations

CHAPTER 9
MANOEUVRABILITY, STABILITY AND SEA-KEEPING

Section 1 Manoeuvrability (MANOVR)

Section 2 VLS

Section 3 Sea-Keeping Assessment (SEA-KEEP)

Section 1 Manoeuvrability (MANOVR)

1 General

1.1 Introduction

1.1.1 Ship manoeuvrability

The manoeuvrability of a ship include the stability of a steady state motion with “fixed controls” as well as the time dependent responses that result from the control actions used to maintain or modify steady motion, make the ship follow a prescribed path or initiate an emergency manoeuvre.

1.1.2 Manoeuvrability criteria

Some of the control actions are considered to be especially characteristic of ship manoeuvring performance and therefore are required to meet a certain minimum standard. The minimum standard is here considered to be the criteria given in IMO Resolution MSC.137(76) (Explanatory notes to this resolution are given in IMO MSC/Circ.1053). Based on compliance with these requirements, the Society can release the additional class notation **MANOVR-IMO**.

The additional class notation **MANOVR-IMO** cannot be granted for ships subject to high speed criteria. The high speed criteria are given as follows:

- Pt D, Ch 3, Sec 2, [1.1.2] for the service notation **corvette**
- Pt D, Ch 6, Sec 1, [1.2.1] for the service notation **military OPV**
- Pt D, Ch 7, Sec 2, [2.1.2] for the service notation **landing craft**.

In some cases the Naval Authority might wish to ensure a higher level of manoeuvring performance. In the following a different set of manoeuvring criteria, suitable for high performance military vessels, is given. By documenting compliance with these criteria the Society can release the additional class notation **MANOVR-MIL**.

1.1.3 Verification approach

It is a basic requirement that compliance with manoeuvrability criteria is to be demonstrated by full scale trials. The additional notations **MANOVR-IMO** and **MANOVR-MIL** can only be released when complete compliance with the relevant criteria has been demonstrated by means of full-scale trials.

1.1.4 Application

The following sections apply to all vessels. This is also the case when the **MANOVR-IMO** notation is requested; the IMO criteria should also be fulfilled for vessels with L<100m, where L is the rule length in m.

2 Manoeuvrability criteria

2.1 Standard manoeuvres

2.1.1 Terminology

The standard manoeuvres and associated terminology are as defined below:

a) Test speed (V) is a speed of at least 90% of the ship's speed corresponding to 85% of the maximum engine output.

b) Turning circle manoeuvre is the manoeuvre to be performed to both starboard and port with 35° rudder angle or the maximum rudder angle permissible at the test speed, following a steady approach with zero yaw rate.

c) Advance is the distance travelled in the direction of the original course of the midship point of a ship from the position at which the rudder order is given to the position at which the heading has changed 90° from the original course.

d) Tactical diameter is the distance travelled by the midship point of a ship from the position at which the rudder order is given to the position at which the heading has changed 180° from the original course. It is measured in a direction perpendicular to the original heading of the ship.

e) Zig-zag test is the manoeuvre where a known amount of helm is applied alternately to either side when a known heading deviation from the original heading is reached.

f) 10°/10° zig-zag test is performed by turning the rudder alternately 10° to either side following a heading deviation of 10° from the original heading in accordance with the following procedure:
   - After a steady approach with zero yaw rate, the rudder is put over to 10° to starboard/port (first execute)
   - When the heading has changed to 10° off the original heading, the rudder is reversed to 10° port/starboard (second execute)
   - After the rudder has been turned to port/starboard, the ship will continue turning in the original direction with decreasing turning rate. In response to the rudder, the ship should then turn to port/starboard. When the ship has reached a heading of 10° to port/starboard of the original course the rudder is again reversed to 10° to starboard/port (third execute).

g) The first overshoot angle is the additional heading deviation experienced in the zig-zag test following the second execute.

h) The second overshoot angle is the additional heading deviation experienced in the zig-zag test following the third execute.

i) 20°/20° zig-zag test is performed using the procedure given for the 10°/10° zig-zag test, using 20° rudder angles and 20° change of heading.

j) Full astern stopping test determines the track reach of a ship from the time of an order of full astern is given until the ship stops in the water.

k) Track reach is the distance along the path described by the midship point of a ship measured from the position at which an order for full astern is given until the ship stops in the water.

l) Inherent dynamic stability; a ship is dynamically stable on a straight course if it, after a small disturbance, soon will settle on a new straight course without any corrective rudder.

m) Pull-out manoeuvre determines the ships dynamic stability. After the completion of the turning circle test the rudder is returned to the midship position and kept there until a steady turning rate is obtained. If the ship is stable the rate of turn will decay to zero for turns to both port and starboard. If the ship is unstable then the rate of turn will reduce to some residual rate of turn.

2.2 Criteria

2.2.1 The criteria related to the **MANOVR-MIL** notation are given in Tab 1.

Table 1 : Manoeuvrability criteria

Test	Criteria
Turning circle manoeuvre • advance • tactical diameter	 4,5 L 5,0 L
Initial turning ability	With the application of 10° rudder angle to port/starboard, the ship should not have travelled more than 2,5L by the time the heading angle has changed by 10° from the original heading.
10°/10° zig-zag test	First overshoot angle should not exceed 10°; Second overshoot angle should not exceed the above by more than 15°.
20°/20° zig-zag test	First overshoot angle should not exceed 20°.
Stopping ability	The track reach in full astern **(1)** stopping test should not exceed 10 L.
Dynamic stability, pull-out test	After the completion of the turning circle test the rudder is returned to the midship position and kept there until a steady turning rate is achieved. This turning rate should be zero.
(1) Power corresponding to 85% of the maximum continuous power.	

3 Full scale trials

3.1 General

3.1.1 Scope of trials

Full scale trials must be carried out in order to demonstrate that a vessel complies with the manoeuvring criteria given in:

- [2.2] in cases where the **MANOVR-MIL** notation is considered
- IMO Resolution MSC.137(76) in cases where the **MANOVR-IMO** notation is considered.

3.2 Trials conditions

3.2.1 General

In order to evaluate the performance of a ship, manoeuvring trials should be conducted to both port and starboard and at conditions specified below:

a) deep, unrestricted water

b) calm environment

c) full or operational load, even keel condition

d) steady approach at the test speed.

The above conditions are further described in the following sections.

3.2.2 Deep, unrestricted water

Manoeuvrability of a ship is strongly affected by interactions with the bottom of the waterway, banks and passing vessels. Trials should therefore be carried out in deep, unconfined but sheltered waters. Following minimum requirement to the water depth applies:

- The water depth should exceed four times the mean draught of the vessel.

3.2.3 Environmental conditions

Trials should be carried out in the calmest weather conditions possible. Wind, waves and current can significantly affect trials results, having a more pronounced effect on smaller ships. Trials are to be conducted in conditions within the following limits:

a) Wind: not to exceed Beaufort 4 (< 7 m/s)

b) Wave: not to exceed sea state 3 (H_S < 1,25 m)

c) Current: uniform only.

The environmental conditions should be carefully recorded before and after trials so that corrections of the trials results can be applied. Corrections according to IMO MSC/Circ.1053, section 3.4.2, of 16 December 2002 may be applied. As a minimum following environmental data must be recorded:

a) Water depth

b) Waves: the sea state should be noted. If there is a swell, period and directions must be noted

c) Current: the trials should be conducted in a well surveyed area and the condition of the current noted from relevant hydrographical data. Correlation shall be made with the tide

d) Weather conditions, including visibility, should be observed and noted.

3.2.4 Loading condition

The manoeuvring trials should be carried out in following loading conditions:

- Auxiliary ships: full load condition
- Front and second line ships: at a displacement contained between the average operational displacement and the full load end of life displacement.

3.2.5 Steady approach

Prior to the start of the manoeuvring test the vessel must perform an approach run. The approach run means that below conditions must be fulfilled for at least two minutes preceding the test:

a) the ship speed must be steady and equal to the test speed, defined in [2.1.1]

b) the heading should be constant and preferably head to the wind

c) engine control setting to be kept constant.

3.3 Trials to be carried out

3.3.1 General

In order to demonstrate compliance with the manoeuvring criteria, following full scale trials are to be carried out:

- turning circle manoeuvre
- 10° zig-zag manoeuvre
- 20° zig-zag manoeuvre
- stopping test
- pull-out manoeuvre.

All trials must be carried out according to the descriptions in IMO MSC/Circ.1053, 16 December 2002.

3.4 Documentation to be submitted

3.4.1 The following documentation is to be submitted:

- for information, before the execution of the sea trials: sea trials specifications
- for approval, report on the sea trials results.

Section 2 VLS

1 General

1.1 Application

1.1.1 This Section applies to ships assigned the service notation **auxiliary naval vessel** as defined in Pt A, Ch 1, Sec 2, [4.5] and which are in compliance with the military criteria for hull arrangement and stability given in Part B.

Ships complying with the requirements of this Section are eligible for assignment of the additional class notation **VLS**.

2 Hull arrangement and stability

2.1 General arrangement design

2.1.1 Ships provided with the additional class notation **VLS** are to comply with the requirements of Part B for hull general arrangement and design.

Note 1: above listed requirement replace requirements of Part D, Chapter 4 where Part D, Chapter 4.

2.2 Stability

2.2.1 Intact stability

Ships provided with the additional class notation **VLS** are to comply with the requirements of Pt B, Ch 3, Sec 1 and Pt B, Ch 3, Sec 2 for intact stability.

Note 1: above listed requirement replace the requirements of Part D, Chapter 4 regarding intact stability.

2.2.2 Damage stability

Ships provided with the additional class notation **VLS** are to comply with the requirements of Pt B, Ch 3, Sec 3 for damage stability, as applicable for a ship of Category II as defined in Pt B, Ch 3, Sec 3, [2.4.2] a).2).

Note 1: above listed requirement replace the requirements of Part D, Chapter 4 regarding damage stability.

Section 3 Sea-Keeping Assessment (SEA-KEEP)

1 General

1.1 Introduction

1.1.1 Sea-keeping notations

The confidential additional class notation **SEA-KEEP** is assigned to ships whose specific sea-keeping performance levels are assured up to a certain limiting sea state.

The **SEA-KEEP** notation is completed, as applicable, by a combination of:

- notations specific to the type of ship capability:

  FLY, for flight operations, as given in [1.1.4]

  RAS, replenishment at sea, as given in [1.1.5]

  WEAP, for weapons systems operations, as given in [1.1.6]

  CREW, for crew capability, as given in [1.1.7]

  BOAT, for small craft operations, as defined in [1.1.8].

- notations detailing the specific capabilities and criteria assessed as per [2.1.2], [3.1.2], [4.1.2], and [6.1.2].
- a notation **X(L,M,H)** where **X** specifies the limiting sea state number and **L**, **M** and **H** further specify the degree of severity (Low, Medium, High) of the sea state considered among those characterized by the number, up to and including which the required sea-keeping performance is maintained.

E.g. the additional notation **SEA-KEEP-FLY_CTOL-3(H)** is assigned to a ship that can satisfy the flight operation limits for "Conventional Take-Off and Landing" in seas up to and including high sea state 3.

1.1.2 Operation limits

The operation limits depend on the specific operation the vessel must perform and are taken according to NATO STANAG 4154 Ed.4. For flight, replenishment at sea, weapons systems, crew performance and small boat operations, the limits ensure that:

- aircraft/helicopters can be launched and recovered
- replenishment at sea operations can be carried out safely and effectively
- weapons systems can be operated and handled safely and effectively
- crew members are capable of performing the tasks connected to transit missions
- small craft can be launched and recovered.

1.1.3 Verification approach

The additional notation **SEA-KEEP** is assigned to ships when the limiting sea state **X** for the specific operation has been determined by the use of sea-keeping computer calculations or small scale model tests in basin according to the procedure defined in [1.2].

1.1.4 Flight operations (FLY)

In terms of sea-keeping effects on performance, **FLY** notation covers operations including:

- conventional aircraft take-off and landing
- helicopter and STOVL (Short Take-Off Vertical Landing) aircraft take-off and landing
- near-ship operations (e.g. Helicopter In-Flight Refuelling (HIFR)
- on-deck handling (e.g. fuelling, folding wings or rotors, transit into hangar).

1.1.5 Replenishment at sea (RAS)

The **RAS** notation covers replenishment at sea operations which may represent a wide variety of resupply activities, including:

- connected replenishment (CONREP)
- fuelling at sea (FAS)
- vertical replenishment (VERTREP).

CONREP operations involve two (or more) ships that are connected by flexible umbilicals and/or constant tension wire rigging to exchange personnel and supplies such as munitions and general stores.

FAS operations involve two (or more) ships that are connected by flexible umbilicals to exchange fuel.

VERTREP operations cover operations where a helicopter is used to lower personnel and/or materials onto the ship.

1.1.6 Weapons systems operation (WEAP)

The **WEAP** notation covers weapons systems operations which represent the missions where the crew must operate or handle the on-board weapons systems, including:

- operation of radars and sonars
- operation of guns
- launching/handling of missiles
- launching/handling of torpedoes.

1.1.7 Crew performance (CREW)

The notation **CREW** covers crew performance which includes the tasks a crew may be required to perform during the TRAN mission as defined in Pt B, Ch 3, Sec 4, [1.1.4].

1.1.8 Small craft operations (BOAT)

The notation **BOAT** covers small craft operations which include the launch and recovery of small craft and depends upon the type of system implemented, as follows:

- stern and side (davit) launch and recovery
- stern ramp launch and recovery.

1.2 Assessment procedure

1.2.1 Parameters

The parameters to be considered for the assessment of the sea-keeping are defined in Articles [2], [3], [4], [5] and [6].

1.2.2 Evaluation

The values of the ship sea-keeping parameters are to be assessed by means of computer calculations and/or small scale model tests in a basin.

The computer calculations have to be performed as described in Pt B, Ch 3, App 6, and the following documentation must be provided:

- justification of the validity of the used software
- parameters to be calculated
- computation input data
- computation results
- model test results that verify and/or replace calculated results.

Concerning model tests the following documentation must be provided:

- parameters to be measured
- detailed test program
- analysis procedure of measured data
- sea- and ship loading condition during the tests
- test results and their analysis.

1.3 Environmental conditions

1.3.1 Sea state

Sea state is an expression used to categorize wave conditions and normally a sea state comprises a significant wave height Hs and a wave period.

Unless otherwise specified, the environmental conditions to be considered for sea-keeping analyses or model tests in basin are to be taken from NATO STANAG 4154 Ed.4.

Whenever computer calculations or model scale tests are used, i.e. when the environmental conditions are selectable, the sea states used for the verification of the criteria in [2.2]**,** [3.3], [4.2], [5.3] and [6.2] are to be defined as described in [1.3.2] and [1.3.3].

The limiting sea state denoted by **X(L,M,H)** defines the sea state up to and including which the sea-keeping criteria can be satisfied for any particular operation or capability. **X** specifies the sea state number and **L**, **M** and **H** further specify the degree of severity (Low, Medium, High) as per [1.3.2].

1.3.2 Wave height

Generally, the references to the wave height are to be taken as the significant wave height Hs, i.e. the average of the 1/3 largest wave heights in a sea state.

The description of sea states found in STANAG 4154 defines the significant wave height as ranges, not absolute values. For this reason sea states must be referred to not just by their number, but also whether it is a low, mid or high sea state (L, M or H). For example, for the sea states defined as per STANAG 4154, low sea state 6 has Hs = 4,0 m, mid sea state 6 has Hs = 5,0 m and high sea state 6 has Hs = 6,0 m.

The wave height to be considered for the verifications is to be the largest significant wave height relative to the specified sea state; for example, if a mid sea state 6 is specified, Hs is to be taken as 5,0 m but if only sea state 6 is specified, Hs is to be taken equal to 6,0 m.

1.3.3 Wave period

Generally, references to the wave period are to be taken as the modal wave period, as per STANAG 4154.

For the TRAN mission defined in Pt B, Ch 3, Sec 4, [1.1.4], at least three periods are to be considered, the values of which are to be taken from STANAG 4154. For other cases, one period value may be sufficient.

2 Flight operations (FLY)

2.1 General

2.1.1 Scope

The sea-keeping performance is to be evaluated in order to determine in what sea state the ship motions and accelerations become so severe that they prevent or obstruct the conduct of flight operations.

2.1.2 Requirements

It is to be ensured that relevant flight operations can be conducted by verifying that the parameters evaluated do not exceed the criteria defined in [2.2].

The limiting sea state **X(L,M,H)** is to be determined and included with each relevant **FLY** notations as follows:

- **_CTOL**: criteria specific to "Conventional Take-Off and Landing", as given in [2.2.1]
- **_FWAH**: criteria specific to "Fixed Wing Aircraft Handling", as given in [2.2.2]
- **_HELOL**: criteria specific to "Helicopter and STOVL aircraft launch and recovery" operations, as given in [2.2.3]
- **_HELOH**: criteria specific to "Helicopter and STOVL aircraft handling" operations, as given in [2.2.4].

2.2 Criteria

2.2.1 Fixed wing aircraft launch & recovery

Limits for Conventional Take-Off and Landing (CTOL) of fixed wing aircraft from aircraft carriers are listed in Tab 1, as RMS values of roll, pitch, vertical and lateral displacement and vertical velocity.

Table 1 : Fixed wing aircraft launch & recovery criteria limits

Governing factors	Performance limitations		
	Motion	Limit	Location
Aircraft handling	Roll	See roll criteria, Fig 1	
Sink off bow and OLS limits	Pitch	See pitch criteria, Fig 2	
Ramp clearance	Vertical displacement	0,8 m	Stern ramp at flight deck
Landing line-up	Lateral displacement	2,3 m	Stern ramp at flight deck
Landing gear	Vertical velocity	0,7 m/s	Touch down point
Note 1: All limits are given in terms of RMS amplitude			

Figure 1 : Roll limits

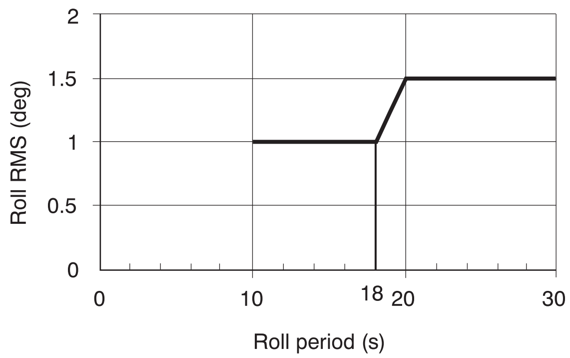
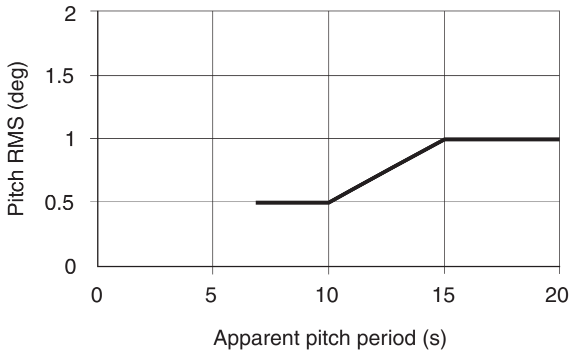


Figure 2 : Pitch limits



2.2.2 Fixed wing aircraft handling

Limits on support equipment for aircraft handling are given in Tab 2 as RMS values for pitch and roll motion. Support operations encompass a wide range of functions (e.g. ordnance handling, aircraft arming, fuelling, engine changing), hence the limits for support equipment are presented for the most restrictive of these.

Table 2 : Fixed wing aircraft handling criteria limits

Subsystem	Performance limitations		
	Motion	Limit	Location
Aircraft and handling equipment	Roll	See roll criteria, Fig 1	
	Pitch	See pitch criteria, Fig 2	
Elevators	Wetness	5/hr	Bottom inner leading elevator edge

2.2.3 Helicopter and STOVL aircraft launch & recovry

Limits for vertical and short take-off and vertical landing (VTOL and STOVL) aircraft are given in Tab 3 as RMS values of roll and pitch motion and vertical velocity.

Table 3 : Helicopter and STOVL aircraft launch & recovery criteria limits

Operation	Performance limitations		
	Motion	Limit	Location
Generic helicopter launch	Roll	2,5°	
	Pitch	1,5°	
Generic short takeoff	Roll	2,5°	
	Pitch	1,5°	
Generic helicopter recovery	Roll	2,5°	
	Pitch	1,5°	
	Vertical velocity	1,0 m/s	Landing point
Note 1: All limits are given in terms of RMS amplitude.			

2.2.4 Helicopter and STOVL aircraft handling

Limits for handling of helicopter and STOVL aircraft are given in Tab 4 as RMS values of roll and pitch motion.

Alternative performance limits specified by the Designer may be applied to specific helicopter types, subject to agreement with the Society and the Naval Authority. These alternative limits are to be consistent with the performance capabilities of the handling equipment and operations performed and are to be defined for the most restrictive functions for each type of handling equipment.

In all cases, when deck crew are involved in handling operations, the personnel criteria in Tab 14 are also to be applied.

Table 4 : Helicopter and STOVL aircraft handling criteria limits

Performance limitations	
Motion	Limit
Roll	1,8°
Pitch	1,8°
Note 1: All limits are given in terms of RMS amplitude.	

3 Replenishment at sea (RAS)

3.1 General

3.1.1 Scope

The sea-keeping performance is to be evaluated in order to determine in what sea state the ship motions and accelerations become so severe that they prevent or obstruct the replenishment at sea operations.

3.1.2 Requirements

It is to be ensured that the systems and crew are able to fulfil the functions related to relevant RAS operations by verifying that the parameters evaluated do not exceed the criteria defined in [3.3].

The limiting sea state **X(L,M,H)** is to be determined and included with each relevant **RAS** notation as follows:

- **_CONREP**: criteria specific to "Connected replenishment", as given in [3.3.1]
- **_FAS**: criteria specific to "Fuelling at sea", as given in [3.3.2]
- **_VERTREP**: criteria specific to "Vertical replenishment", as given in [3.3.3].

3.2 Parameters

3.2.1 Motion Induced Interruption (MII)

The motion induced interruption (MII) is defined in [5.2.1].

3.3 Criteria

3.3.1 Connected replenishment (CONREP)

Limits for connected replenishment (CONREP) between two ships are listed in Tab 5 as RMS values of roll and pitch motion, and as human factor limits expressed in MII and vertical acceleration.

Table 5 : Connected replenishment criteria limits

Limiting factor	Performance limitations		
	Motion	Limit	Location
Equipment: Pallet truck slip angle	Roll	2,2°	
	Pitch	2,2°	
Personnel	MII	0,5/min	CONREP station
	Vertical acceleration	0,2g	CONREP station
	Wetness index	0,5/hr	CONREP station
Note 1: Roll, pitch and vertical acceleration limits are given in terms of RMS amplitude.			

3.3.2 Fuelling at sea (FAS)

Limits for (flexible connected) fuelling at sea (FAS) between two ships are listed in Tab 6 as human factor limits expressed in MII, vertical acceleration and wetness index.

Table 6 : Fuelling at sea criteria limits

Limiting factor	Performance limitations		
	Motion	Limit	Location
Personnel	MII	0,5/min	FAS station
	Vertical acceleration	0,2g	FAS station
	Wetness index	0,5/hr	FAS station
Note 1: The vertical acceleration limit is given in terms of RMS amplitude.			

3.3.3 Vertical replenishment (VERTREP)

Limits for vertical replenishment from helicopters (VERTREP) are listed in Tab 7 as RMS values of roll and pitch motion, vertical displacement and vertical velocity together with human factor limits expressed in MII and vertical acceleration.

Table 7 : Vertical replenishment criteria limits

Limiting factor	Performance limitations		
	Motion	Limit	Location
Helicopter-to-ship	Vertical displacement	0,7m	VERTREP station
	Vertical velocity	1,05m/s	VERTREP station
Equipment: Missile dolly slip angle	Roll	1,6°	
	Pitch	1,6°	
Personnel	MII	0,5/min	VERTREP station
	Vertical acceleration	0,2g	VERTREP station
	Wetness index	0,5/hr	VERTREP station
Note 1: Roll, pitch, vertical displacement and velocity limits are given in terms of RMS amplitude.			

4 Weapons systems (WEAP)

4.1 General

4.1.1 Scope

The sea-keeping performance is to be evaluated in order to determine in what sea state the ship motions and accelerations become so severe that weapons system performance may be unacceptably degraded.

4.1.2 Requirements

It is to be ensured that weapons system performance will remain acceptable by verifying that the parameters evaluated do not exceed the criteria defined in [4.2] for relevant systems.

The limiting sea state **X(L,M,H)** is to be determined and included with each relevant **WEAP** notation as follows:

- **_R** : criteria specific to “radar”, as given in [4.2.1]
- **_S** : criteria specific to “sonar”, as given in [4.2.2]
- **_TM** : criteria specific to “trainable missile”, as given in [4.2.3]
- **_VM** : criteria specific to “vertical launch system”, as given in [4.2.3]
- **_T** : criteria specific to “torpedo system”, as given in [4.2.4]
- **_E** : criteria specific to “support equipment”, as given in [4.2.5]
- **_G** : criteria specific to “guns”, as given in [4.2.6].

4.2 Criteria

4.2.1 Radars

For air search/surface surveillance radars with elevation-stabilised antennas, the maximum design roll angle is 25 degrees for 100% effective performance and 30 degrees for 0%. These values are rarely limiting. Mission performance will most likely depend upon motion limits on other subsystems.

4.2.2 Sonars

Degradation of hull mounted sonar performance will occur due to the emergence of the sonar housing, modification of the signal caused by beam bearing fluctuation, and phase and frequency shift of the signal.

Full performance may be expected within the motion limits defined in Tab 8.

Table 8 : Sonar criteria limits

Hull mounted sonar	Performance limitations		
	Motion	Limit	Location
Active sonar	Emergence	24/hr	Leading edge of dome with hull
	Roll	7,5°	
	Pitch	2,5°	
Passive sonar	Emergence	90/hr	Leading edge of dome with hull
Note 1: Roll and pitch limits are given in terms of RMS amplitude.			

4.2.3 Missile systems

Maximum design limits for both trainable and vertical launch systems are given in Tab 9 and Tab 10.

It must be noted that the launch criteria apply only to the missile launch systems. For launch, the missiles themselves have limits on structural strength and controllability until their air speed is sufficient for aerodynamic control. Typically, the missile is held in the launcher until motions are within specified lockout limits, then they are launched. The missile lockout criteria are not available in an unclassified format.

The roll, pitch and yaw limits listed in Tab 10 for vertical launch system operations are associated with minimum natural periods of 9 seconds, 9 seconds and 6 seconds, respectively. The limiting values will decrease below the minimum periods.

Table 9 : Trainable missile system criteria limits

Subsystems limitations	Performance limitations	
	Motion	Limit
Launcher	Roll or pitch	3,8°
Missile handling - automatic operation	Roll or pitch	3,8°
Missile handling - manual operation	Roll or pitch	2,5°
Missile reloading	Roll or pitch	1,3°
Note 1: Limits are given in terms of RMS amplitude.		

Table 10 : Vertical launch system criteria limits

Operation	Performance limitations		
	Motion	Limit	Location
Launch	Roll	8,8°	
	Pitch	1,5°	
	Yaw	0,8°	
	Longitudinal acceleration	0,15g	Launcher outboard corner
	Transverse acceleration	0,35g	Launcher outboard corner
	Vertical acceleration	0,30g	Launcher outboard corner
Reloading at 10 missiles per hour	Roll	1,3°	
	Pitch	0,5°	
	Yaw	0,3°	
	Longitudinal acceleration	0,05g	Launcher outboard corner
	Transverse acceleration	0,05g	Launcher outboard corner
	Vertical acceleration	0,1g	Launcher outboard corner
Reloading at 3 missiles per hour	Roll	3,8°	
	Pitch	1,0°	
	Yaw	0,5°	
	Longitudinal acceleration	0,1g	Launcher outboard corner
	Transverse acceleration	0,15g	Launcher outboard corner
	Vertical acceleration	0,15g	Launcher outboard corner
Note 1: Limits are given in terms of RMS amplitude. **Note 2:** 1,0 g acceleration due to gravity has been subtracted from the vertical acceleration limits.			

4.2.4 Torpedo systems

The criteria limits for torpedo system operation are defined in Tab 11. The torpedo itself is not limited by ship motion during launch. Typically heavier torpedoes and missiles must be loaded from dollies and thus the limits are somewhat more restrictive than for those that are loaded by hand.

Table 11 : Torpedo system criteria limits

Subsystems limitations	Performance limitations	
	Motion	Limit
Launcher	Roll or pitch	3,8°
Loading, torpedoes on dollies	Roll or pitch	1,3°
Loading by hand	Roll or pitch	1,5°
Automatic direct loading	Roll or pitch	3,8°
Note 1: Limits are given in terms of RMS amplitude.		

4.2.5 Support equipment

The criteria limits for support equipment operations are defined in Tab 12. Support operations encompass a wide range of functions (e.g. ordnance handling, arming, maintenance), hence the limits applicable to operation of support equipment are defined for the most restrictive of these.

Table 12 : Support equipment criteria limits

Performance limitations		
Motion	Limit	Location
Roll	1,8°	
Pitch	1,8°	
Motion Induced Interruption (MII)	1/min	Task location
Note 1: Roll and pitch limits are given in terms of RMS amplitude.		

4.2.6 Guns

Generic criteria for gun systems are provided in Tab 13. Accuracy of guns and fire control systems may be reduced because of ship motions.

Table 13 : Gun criteria limits

Representative gun system	Performance limitations		
	Motion	Limit	Location
5 inch/54	Roll	3,8°	Gun barrel tip
	Pitch	3,8°	Gun barrel tip
	Vertical velocity	0,5m/s	Gun barrel tip
Note 1: Limits are given in terms of RMS amplitude.			

5 Personnel performance (CREW)

5.1 General

5.1.1 Scope

The sea-keeping performance is to be evaluated in order to ensure that the ship motions and accelerations do not become so severe that they prevent the crew from carrying out their tasks related to operations conducted at specified locations, in weather conditions where the ship is expected to carry out the TRAN mission.

The evaluation excludes the impact of relative wind that may impact the ability of crew to work on open decks.

5.1.2 Requirements

It is to be ensured that the crew is able to carry out tasks related to the TRAN mission by verifying that the parameters evaluated do not exceed the criteria defined in [5.3], for all locations on board where crew may be present for both short and long durations.

The parameters evaluated are to comply with the criteria for a limiting sea state not less than mid sea state 5. Therefore, the **CREW** notation may only be assigned when the limiting sea state is not less than mid sea state 5. The limiting sea state **X(L,M,H)** is to be included with the **CREW** notation.

The Society may accept that the calculations consider the effect of active motion damping systems (anti-roll fins, T-foils etc.) if the suitability and efficiency of such systems can be demonstrated.

5.2 Parameters

5.2.1 Motion induced interruption (MII)

A motion induced interruption (MII) is an incident where ship motions cause a person to slide or lose balance, resulting in stumble. Motion induced interruption not only represents a danger to the crew, but also prevents the crew from carrying out their tasks.

In order to determine the MII index, the so-called Generalised Lateral Force Estimator for tipping port (GLFEp) or starboard (GLFEs) is to be evaluated according to the following definitions:

$$GLFE_p = \frac{1}{3}ha_R - a_T - g\phi - \frac{b}{h}a_V$$

$$GLFE_s = \frac{1}{3}ha_R - a_T - g\phi + \frac{b}{h}a_V$$

where b and h are defined in Fig 3.

The ratio b/h is called lateral tipping coefficient and a representative value of 0,25 with h taken equal to 1,20 m can be assumed based on typical human dimensions.

The formula above must be interpreted as a linear combination of the transfer functions (in-phase, pedex C, and out-of phase, pedex S, components) of roll motion ϕ, roll acceleration a_R, transverse acceleration a_T and vertical acceleration a_V, which can be safely considered as a standard output from frequency-domain codes.

By definition of generalised lateral force estimator, a tipping event occurs whenever the estimator exceeds the threshold level (b/h)g. In order to evaluate this occurrence frequency one has to rely upon standard spectral theory, which is routinely incorporated into frequency-domain sea-keeping codes.

The first step is to determine the in/out-of-phase components of the estimator, $GLEp,s_C$ and $GLEp,s_S$, and consequently its amplitude:

$$GLEp,s_a = \sqrt{(GLEp,s_C)^2 + (GLEp,s_S)^2}$$

The second step is the evaluation of its zero'th and second order spectral moments:

$$m_{0;p,s} = \int_{\omega_{min}}^{\omega_{max}} GLEp,s_a^2 \, S(\omega)d\omega$$

$$m_{2;p,s} = \int_{\omega_{min}}^{\omega_{max}} \left|\omega - \frac{\omega^2 V}{g}\cos\psi\right|^2 GLEp,s_a^2 \, S(\omega)d\omega$$

where $S(\omega)$ is the wave spectrum of the sea state, ω is the wave frequency in rad/s, V is the ship speed in m/s, ψ is the heading angle and g is the gravity acceleration in m/s^2.

The motion induced interruptions due to lateral tipping port/starboard $MII_{p,s}$ (in units of tipping events per minute) can thence be calculated as:

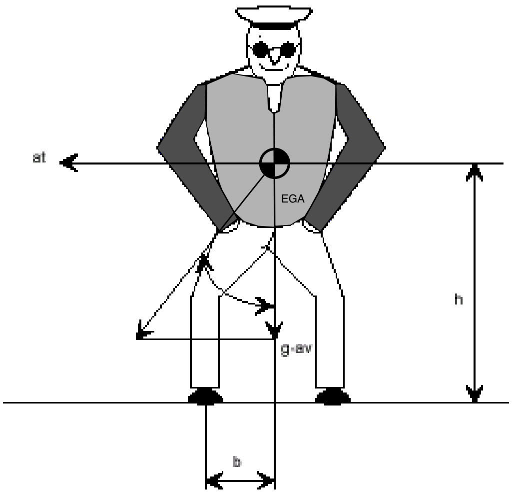
$$MII_{p,s} = \frac{60}{2\pi}\sqrt{\frac{m_{2;p,s}}{m_{0;p,s}}}\exp\left(-\frac{a^2}{2m_{0;p,s}}\right)$$

with a taken equal to (b/h)g

Finally, the MII can be determined as:

$MII = MII_p + MII_s$

Figure 3 : Definitions for generalised lateral force estimator



5.2.2 Motion sickness incidence (MSI)

MSI is a means of evaluating the incidence of seasickness among crew members, as measured by the percentage of the population who vomit. Seasickness has a direct influence on the capacity of crew to carry out their duties.

MSI is however susceptible to errors during evaluation and is difficult to apply as a sea-keeping criterion. For this reason a limit for RMS vertical acceleration is applied instead, as this presents good correlation with the incidence of seasickness.

5.3 Criteria

5.3.1 Recommended criteria

The recommended criteria for verifying crew performance are given Tab 14.

Table 14 : Recommended personnel criteria limits

Parameter	Limit	Location
Vertical acceleration	0,2g	bridge
Motion Induced Interruption (MII)	1/min	task location
Note 1: The vertical acceleration limit is given in terms of RMS amplitude.		

5.3.2 Default criteria

The default criteria for verifying crew performance are given in Tab 15.

Application of these criteria will only be accepted if it is not possible to calculate MII as per the recommended criteria in [5.3.1]. These criteria consist of the root mean square (RMS) amplitude value of the ship motions that contribute to MII.

Table 15 : Default personnel criteria limits

Parameter	Limit	Location
Pitch	4°	
Roll	1,5°	
Vertical acceleration	0,2g	Bridge
Lateral acceleration	0,1g	Bridge
Note 1: All limits given as RMS amplitude values.		

6 Small craft operations (BOAT)

6.1 General

6.1.1 Scope

The sea-keeping performance is to be evaluated in order to determine in what sea state the ship motions and accelerations become so severe that they prevent or obstruct the launch and recovery of small craft from the mothership.

6.1.2 Requirements

It is to be ensured that the crew is able to carry out their tasks related to the relevant type(s) of small craft launch and recovery operations by verifying that the parameters evaluated do not exceed the criteria defined in [6.2].

The limiting sea state **X(L,M,H)** is to be determined and included with each relevant **BOAT** notation as follows:

- **DECK**: criteria specific to "stern and davit (or side) launch and recovery of small craft"
- **RAMP**: criteria specific to "stern ramp launch and recovery of small craft"

6.2 Criteria

6.2.1 Stern and davit (or side) launch and recovery

Criteria for stern and davit (or side) launch and recovery of small craft are provided in Tab 16.

6.2.2 Stern ramp launch and recovery

Criteria for stern ramp launch and recovery of small craft are provided in Tab 16 and Tab 17.

Table 16 : Criteria for launch and recovery of small craft

Ship response	Limit	Location
Pitch	4°	
Roll	1,25°	
Vertical acceleration	0,1g	At launch and recovery station on mothership
Lateral acceleration	0,1g	At launch and recovery station on mothership
Note 1: All limits given as RMS amplitude values.		

Table 17 : Additional criteria for stern ramp launch and recovery of small craft

Parameter	Limit	Location
Vertical wave height	0,75m	At ramp entrance
Lateral displacement	0,75m	At stern
Ramp availability time	Average 8 seconds	
Note 1: Relative wave height and lateral displacement limits are given in terms of RMS amplitude. **Note 2:** For relative wave height, if it is not possible to accurately estimate this parameter due to the absence of modelled radiated and diffracted waves, the criteria may instead be applied to vertical motion calculated at the stern.		

Part E
Additional Class Notations

CHAPTER 10
SAFETY EQUIPMENT AND INSTALLATIONS

Section 1 Life-Saving Appliances (LSA)

Section 2 Towing (TOW)

Section 3 Enhanced Fire Protection FIRE

Section 1 Life-Saving Appliances (LSA)

1 General

1.1 Application

1.1.1 The additional class notation **LSA** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.13.1], to ships fitted with life-saving appliances and complying with the requirements of this Section.

1.2 Documents to be submitted

1.2.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	A/I(**1**)	Document
1	A	Safety Equipment Plan showing position and quantity of all life-saving equipment on board
2	I	Arrangement of life-saving appliances and relevant embarking and launching devices
3	A	Structure drawings with details of the hull/launching appliances interface
4	A	Calculations of the local structural reinforcements in way of the launching appliances
(1) A: to be submitted for approval; I: to be submitted for information		

1.3 Definitions

1.3.1 For the purpose of this additional class notation, unless expressly provided otherwise, definitions are as stated in SOLAS Convention Chapter III Regulation 3.

1.3.2 IMO LSA Code means the International Life-Saving Appliance (LSA) Code adopted by IMO Maritime Safety Committee by resolution MSC.48(66), as amended.

1.3.3 MSC.81(70) means the IMO Resolution "Revised recommendation on testing of life-saving appliances", as amended.

1.4 Approval of appliances and equipment

1.4.1 Where the words "of an approved type" are indicated, the equipment is to meet the requirements of the IMO LSA Code and MSC.81(70) and is to be approved by the Society, unless otherwise agreed with the Naval Authority. Other recognized references covering design and testing found acceptable by the Naval Authority and by the Society may be used for approval.

1.4.2 Unless expressly provided otherwise in this section, all life-saving appliances are to comply with the applicable requirements of the IMO LSA Code and MSC.81(70).

1.5 Alternative design and arrangements

1.5.1 When alternative design or arrangements deviate from the prescriptive provisions of the present Section, an engineering analysis, evaluation and approval of the design and arrangements are to be carried out in accordance with SOLAS regulation III/38.

Note 1: Refer to IMO Circular MSC.1/Circ.1212/Rev.1 "Guidelines on alternative design and arrangements for SOLAS chapters II-1 and III".

2 Survival craft

2.1 Number and location

2.1.1 Each ship is to carry:

a) On each side of the ship, one or more survival craft of an approved type complying with section 4.2 of the IMO LSA Code. The total number and size of these survival craft is to be sufficient to accommodate not less than 125% of the total number of persons on board.

b) Additional survival craft to ensure that at least 110% capacity will remain available in the event that all the survival craft on either side within the longitudinal damage extension (Pt B, Ch 3, Sec 3, [2.4.2]) are lost or unserviceable.

2.1.2 As far as practicable, survival craft are to be equally distributed on both sides of the ship.

2.1.3 If the survival craft cannot be readily transferred for launching on either side of the ship (i.e. of a mass of more than 185 kg or not stowed in a position providing for easy side-to-side transfer), the total capacity available on each side is to be sufficient to accommodate all persons on board.

2.1.4 Where the survival craft are stowed in a position which is more than 100 m from the extreme end of the stem or stern, each ship is to carry in addition to the survival craft as provided in [2.1.1], a survival craft with a carrying capacity of not less than six persons stowed as far forward or aft, or one as far forward and another as far aft, as is reasonable and practicable. Such survival craft may be securely fastened so as to permit manual release and need not be of the type which can be launched from an approved launching device.

2.1.5 A marine evacuation system (MES) or equivalent system complying with section 6.2 of the IMO LSA Code and associated liferafts complying with the requirements of paragraph 6.2.3 of the IMO LSA Code may be substituted for the equivalent capacity of survival craft required by [2.1.1].

2.2 Survival craft assembly and embarkation arrangements

2.2.1 Survival craft embarkation arrangements are to be so designed that:

a) davit-launched survival craft can be boarded and launched from a position immediately adjacent to the stowed position or from a position to which the survival craft is transferred prior to launching in compliance with [2.4.5], and
b) where necessary, means are to be provided for bringing the survival craft against the ship's side and holding it alongside so that persons can be safely embarked.

2.2.2 A MES complying with section 6.2 of the IMO LSA Code or an embarkation ladder complying with the requirements of paragraph 6.1.6 of the IMO LSA Code extending, in a single length, from the deck to the waterline in the lightest seagoing condition under maximum anticipated adverse list and trim for intact and damaged conditions is to be provided at each launching station. However, the Society may permit such ladders to be replaced by approved devices to afford access to the survival craft when waterborne, provided that there is to be at least one embarkation ladder on each side of the ship. Other means of embarkation enabling descent to the water in a controlled manner may be permitted for the survival craft required by [2.1.4].

2.3 Launching stations

2.3.1 Launching stations are to be in such positions that survival craft and rescue boats can be launched clear of all obstructions having particular regard to clearance from the propeller and steeply overhanging portions of the hull. As far as possible, survival crafts are to be launched down a straight side of the ship.

2.3.2 Launching stations are to be located abaft the collision bulkhead in a sheltered position and, if positioned forward, special consideration is to be given to the strength of the launching appliance.

2.4 Stowage of survival craft

2.4.1 Each survival craft is to be stowed:

a) so that neither the survival craft nor its stowage arrangement will interfere with the operation of any other survival craft, rescue boat or MES at any other launching station;
b) in such a position that the survival craft in the embarkation position is not more than 18m above the waterline with the ship in its lightest seagoing condition. Survival craft other than those intended for throw-overboard launching are to be stowed in a position such that the survival craft in the embarkation position is not less than 2 m above the waterline with the ship in the fully loaded condition under maximum anticipated adverse list or trim for damaged conditions, or to the angle at which the ship's weather deck edge becomes submerged, whichever is less;
c) as far as practicable, in a secure and sheltered position and protected from damage by fire and explosion not induced by hostile military action. In particular, survival craft, other than those required by [2.1.4], are not to be stowed near tanks or areas containing explosive or hazardous cargoes (Example: jettisonable fuel tanks or area of battery room ventilation);
d) fully equipped as required by the IMO LSA Code.

2.4.2 Survival craft for lowering down the ship's side are to be stowed as far forward of the propeller as practicable.

2.4.3 Every survival craft other than those mentioned in [2.1.4] are to be stowed with its painter permanently attached to the ship and with a float-free arrangement complying with the requirements of paragraph 4.1.6 of the IMO LSA Code so that each floats free and, if inflatable, inflates automatically when the ship sinks (i.e. automatic launching and inflating devices to be provided).

2.4.4 Survival craft are to be so stowed as to permit manual release of one raft or container at a time from their securing arrangements.

2.4.5 Davit-launched survival craft are to be stowed within reach of the lifting hooks, unless some means of transfer is provided which is not rendered inoperable within the limits of trim and list prescribed in Pt C, Ch 1, Sec 1, [2.4.1] for any damaged condition or by ship motion or power failure.

2.5 Survival craft launching and recovery arrangements

2.5.1 Launching appliances complying with the requirements of section 6.1 of the IMO LSA Code, as applicable, are to be provided for all davit-launched survival craft.

2.5.2 Launching arrangements are to be such that the appliance operator on the ship is able to observe the survival craft at all times during launching.

2.5.3 Only one type of release mechanism is to be used for similar survival craft carried on board the ship.

2.5.4 Preparation and handling of survival craft at any one launching station are not to interfere with the prompt preparation and handling of any other survival craft, rescue boat or MES at any other station.

2.5.5 Falls, where used, are to be long enough for the survival craft to reach the water with the ship in its lightest seagoing condition, under maximum anticipated adverse list and trim for intact and damaged conditions.

2.5.6 Means are to be available to prevent any discharge of water onto survival craft during abandonment.

2.5.7 All survival craft required to provide for abandonment by the total number of persons on board are to be capable of being launched with their full complement of persons and equipment within a period of 10 min from the time the abandon ship signal is given.

2.5.8 Launching and embarkation arrangements are to be so arranged as to enable stretcher cases to be placed in survival craft.

2.6 Stowage of marine evacuation systems

2.6.1 The ship's side is not to have any openings between the embarkation station of the marine evacuation system and the waterline in the lightest seagoing condition and means are to be provided to protect the system from any projections. The windows and side scuttles in the area in way of a marine evacuation system, if installed, are to be of the non-opening type.

2.6.2 Marine evacuation systems are to be in such positions as to ensure safe launching having particular regard to clearance from the propeller and steeply overhanging portions of the hull and so that, as far as practicable, the system can be launched down the straight side of the ship.

2.6.3 Each marine evacuation system is to be stowed so that neither the passage nor platform nor its stowage or operational arrangements will interfere with the operation of any other life-saving appliance at any other launching station.

2.6.4 Where appropriate, the ship is to be so arranged that the marine evacuation systems in their stowed positions are protected from damage by heavy seas.

3 Rescue boats

3.1 Number of rescue boats

3.1.1 Each ship is to carry at least one rescue boat complying with the requirements of section 5.1 of the IMO LSA Code.

3.2 Operational craft used as a rescue boat

3.2.1 Subject to acceptance of the Naval Authority, an operational craft may be accepted to replace the rescue boat and provide its function, provided that it is complying with the requirements of section 5.1 of the IMO LSA Code and with additional requirements for fast rescue boats, except that:

a) operational craft do not need to be fitted with retro-reflective material as required by paragraph 1.2.2.7 of the IMO LSA Code;
b) operational craft do not need to comply with paragraph 1.2.2.6 of the IMO LSA Code but are to be fitted with removable covers of orange colour (or equivalent highly visible colour) to increase visual detection. Such covers are to be fitted with retro-reflective material complying with paragraph 1.2.2.7 of the IMO LSA Code;
c) the length of operational craft is not to be less than 8.5m as required by paragraph 5.1.1.3 of the IMO LSA Code;
d) the radar reflector as required by paragraph 5.1.2.2.12 of the IMO LSA Code may be removable.

3.2.2 When operational craft are used as rescue boats, the following conditions are to be met:

a) sufficient number of operational craft are to be available in all operational scenarios;
b) sufficient number of operational craft are to be available to marshal all deployed survival craft that are not self-propelled;
c) means for rapidly recovering survivors from the water and transferring survivors to the ship are to be provided.

Note 1: Refer to IMO MSC./Circ.810 “Recommendation on means of rescue on Ro-Ro passenger ships”

3.2.3 The launching and recovery arrangements of the operational craft are to be also compliant with the requirements for a rescue boat as defined in [3.4].

3.3 Stowage of rescue boats

3.3.1 Rescue boats are to be stowed:

a) in a state of continuous readiness for launching in not more than 5 min

b) if of an inflated type, in a fully inflated condition at all times

c) in a position suitable for launching and recovery

d) so that neither the rescue boat nor its stowage arrangements will interfere with the operation of any survival craft at any other launching station.

3.4 Rescue boat embarkation, launching and recovery

3.4.1 Launching arrangements are to comply with the requirements of [2.5]. All rescue boats are to be capable of being launched, where necessary utilizing painters, with the ship making headway at speed up to 5 knots in calm water.

3.4.2 Recovery time of the rescue boat is to be not more than 5 minutes in moderate sea conditions when loaded with its full complement of persons and equipment.

3.4.3 Foul weather recovery strops are to be provided for safety if heavy fall blocks constitute a danger.

3.4.4 When the launching appliance of the rescue boat is fitted with a system to block radar detection or to protect the launching appliance, such system is to be operated manually or with a stored mechanical power device which is independent of the ship's power supplies to allow the launching of the rescue boat it serves in the fully loaded and equipped condition and also in the light condition.

4 Personal life-saving appliances

4.1 Lifebuoys

4.1.1 Total number

At least eight lifebuoys of an approved type, complying with paragraph 2.1.1 of the IMO LSA Code and located as per [4.1.3], are to be fitted. For ships of 100 m length or more, this number is to be increased up to the values given in Tab 2.

Table 2 : Lifebuoys

Length of ship (m)	Minimum number of lifebuoys
< 100	8
100 ≤ L < 150	10
150 ≤ L < 200	12
≥ 200	14

4.1.2 Types

a) Lifebuoys with buoyant lifeline:

At least one lifebuoy on each side of the ship is to be fitted with a buoyant lifeline complying with the requirements of paragraph 2.1.4 of the IMO LSA Code of length not less than twice the height at which it is stowed above the waterline in the lightest seagoing condition, or 30 m, whichever is greater.

b) Lifebuoys with self-igniting lights:

At least one-half of the total number of lifebuoys are to be provided with self-igniting lights complying with the requirements of paragraph 2.1.2. of the IMO LSA Code. Not less than two of these are to be also provided with self-activating smoke signals complying with the requirements of paragraph 2.1.3. of the IMO LSA Code. They are not to be the lifebuoys provided with lifelines in compliance with the requirements of item a).

4.1.3 Location

Lifebuoys are to be readily accessible from exposed locations on both sides of the ship with at least one placed in the vicinity of the stern. They are to be so stowed as to be capable of being cast loose and not permanently secured in any way.

Lifebuoys with lights and those with lights and smoke signals are to be equally distributed on both sides of the ship.

Lifebuoys fitted with self-igniting lights or self-activating smoke signals are to be located outside hazardous areas and be capable of quick release from the bridge or a location readily available to operating personnel.

4.2 Lifejackets

4.2.1 Lifejackets of an approved type complying with the requirements of section 2.2 of the IMO LSA Code are to be provided for at least 110% of the total number of persons on board.

4.2.2 Additionally, a sufficient number of lifejackets are to be carried for persons on watch and for use at remotely located survival craft stations. These lifejackets are to be stowed on the bridge, in the engine control room and at any other manned watch station.

4.2.3 Each lifejacket is to be fitted with a light complying with the requirements of paragraph 2.2.3 of the IMO LSA Code.

4.2.4 Each lifejacket is to be so placed as to be readily accessible and their position is to be plainly indicated.

4.3 Immersion suits and thermal protective aids

4.3.1 For ships carrying less than 60 persons on board, immersion suits of an approved type complying with the requirements of section 2.3 of the IMO LSA Code are to be provided for at least 110% of the total number of persons on board. Immersion suits are to be of an appropriate size for each person on board.

4.3.2 For ships carrying not less than 60 persons on board, a thermal protective aid complying with the requirements of section 2.5 of the IMO LSA Code is to be provided for every person to be accommodated in the survival craft and not provided with an immersion suit.

4.3.3 Each immersion suit is to be so placed as to be readily accessible and their position is to be plainly indicated.

4.3.4 Additionally, an immersion suit or an anti-exposure suit complying respectively with requirements of section 2.3 or 2.4 of the IMO LSA Code, of an appropriate size, is to be provided for every person assigned to crew the rescue boat or assigned to a marine evacuation system party.

5 Rescue arrangements

5.1 Line-throwing appliances

5.1.1 A line-throwing appliance complying with the requirements of section 7.1 of the IMO LSA Code is to be provided.

5.2 Communications

5.2.1 Two-way VHF radiotelephone apparatus

At least three two-way VHF radiotelephone apparatus are to be provided on each ship.

Such apparatus is to be approved according to IMO Resolution A.809(19) as amended by MSC.149(77), Performance standards for survival craft two-way VHF radiotelephone apparatus.

5.2.2 Search and rescue locating device

At least one search and rescue locating device is to be carried on each side of the ship. Such devices are to be stowed in such locations that they can be rapidly placed in any survival craft. Search and rescue locating devices are to be approved according to IMO Resolution A.802(19) as amended by MSC.247(83), Recommendation on performance standards for survival craft radar transponders for use in search and rescue operations and IMO Resolution MSC.246(83), Recommendation on performance standards for survival craft AIS search and rescue transmitters (AIS-SART) for use in search and rescue operations.

5.3 Distress flares

5.3.1 Not less than twelve rocket parachute flares, complying with the requirements of section 3.1 of the IMO LSA Code, are to be carried and be stowed on or near the navigation bridge.

Section 2 Towing (TOW)

1 Emergency towing arrangements

1.1 Definitions

1.1.1 Deadweight

Deadweight is the difference, in t, between the displacement of a ship in water of a specific gravity of 1,025 t/m^3 at the load waterline corresponding to the assigned summer freeboard and the lightweight of the ship (as defined in Pt B, Ch 1, Sec 2, [5.5.1].

1.2 Application

1.2.1 The requirements of this Article apply to equipment arrangement for towing ships out of danger in emergencies such as complete mechanical breakdowns, loss of power or loss of steering capability.

1.2.2 An emergency towing arrangement is to be fitted at the bow.

1.3 Documentation

1.3.1 Documentation for approval

In addition to the documents in Pt B, Ch 1, Sec 3, the following documentation is to be submitted to the Society for approval:

- general layout of the bow towing arrangement and associated equipment
- operation manual for the bow towing arrangement
- construction drawings of the bow strongpoints (towing brackets or chain cable stoppers) and fairleads (towing chocks), together with material specifications and relevant calculations
- drawings of the local ship structures supporting the loads applied by strongpoints, fairleads and roller pedestals.

1.3.2 Documentation for information

The following documentation is to be submitted to the Society for information (see Pt B, Ch 1, Sec 3):

- specifications of chafing gears, towing pennants, pick-up gears and roller fairleads
- deadweight, in t, of the ship at summer load line.

1.4 General

1.4.1 Scope

The emergency towing arrangements are to be so designed as to facilitate salvage and emergency towing operations on the concerned ship, primarily to reduce the risk of pollution.

1.4.2 Main characteristics

The emergency towing arrangements are, at all times, to be capable of rapid deployment in the absence of main power on the ship to be towed and easy connection to the towing ship.

To demonstrate such rapid and easy deployment, the emergency towing arrangements are to comply with the requirements in [1.12].

1.4.3 Typical layout

Fig 1 shows an emergency towing arrangement which may be used as reference.

1.4.4 List of major components

The major components of the towing arrangements, their position on board and the requirements of this Article which they are to comply with are defined in Tab 1.

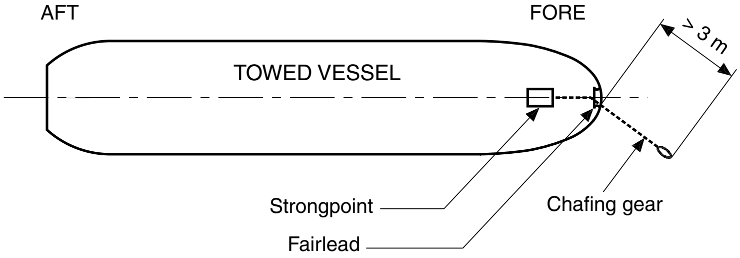
Table 1 : Major components of the emergency towing arrangement

Towing component	Forward	Reference of applicable requirements
Towing pennant	optional	[1.7]
Chafing gear	required	[1.8]
Fairlead	required	[1.9]
Strongpoint (inboard end fastening of the towing gear)	required	[1.10]
Pick-up gear	optional	no requirement
Pedestal roller fairlead	required	no requirement

1.4.5 Inspection and maintenance

All the emergency towing arrangement components are to be inspected by ship personnel at regular intervals and maintained in good working order.

Figure 1 : Typical emergency towing arrangement



1.5 Emergency towing arrangement approval

1.5.1 General

Emergency towing arrangements of ships are to comply with the following requirements:

- they are to comply with the requirements of this item
- they are to be type approved according to the requirements in [1.13]
- Certificates of inspection of materials and equipment are to be provided according to [1.13.2]
- fitting on board of the emergency towing arrangements is to be witnessed by a Surveyor of the Society and a relevant Certificate is to be issued
- demonstration of the rapid deployment according to the criteria in [1.12] is to be effected for each ship and this is to be reported in the above Certificate.

1.5.2 Alternative to testing the rapid deployment for each ship

At the request of the Owner, the testing of the rapid deployment for each ship according to [1.5.1] may be waived provided that:

- the design of emergency towing arrangements of the considered ship is identical to the type approved arrangements and this is confirmed by the on board inspection required in [1.5.1]
- the strongpoints (chain stoppers, towing brackets or equivalent fittings) are type approved (prototype tested).

In this case, an exemption certificate is to be issued.

In general, such dispensation may be granted to subsequent ships of a series of identical new buildings fitted with identical arrangements.

1.6 Safe working load (SWL) of towing pennants, chafing gears, fairleads and strongpoints

1.6.1 Safe working load

The safe working load (defined as one half of the ultimate strength) of towing pennants, chafing gear, fairleads and strongpoints is to be not less than that obtained, in kN, from Tab 2.

The strength of towing pennants, chafing gear, fairleads and strongpoints is to be sufficient for all pulling angles of the towline, i.e. up to 90° from the ship's centreline to port and starboard and 30° vertical downwards.

The safe working load of other components is to be sufficient to withstand the load to which such components may be subjected during the towing operation.

Table 2 : Safe working load

Ship deadweight DWT, in t	Safe working load, in kN
$DWT < 50000$	1000
$DWT \geq 50000$	2000

1.7 Towing pennant

1.7.1 Material

The towing pennant may be made of steel wire rope or synthetic fibre rope, which is to comply with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1.

1.7.2 Length of towing pennant

The length ℓ_P of the towing pennant is to be not less than that obtained, in m, from the following formula:

$\ell_P = 2 H + 50$

where:

H : Difference of height between the watertight deck and the waterline when ship is in ballast loading condition.

1.7.3 Minimum breaking strength of towing pennants when separate chafing gear is used

Where a separate chafing gear is used, the minimum breaking strength MBS_p of towing pennants, including their terminations, is to be not less than that obtained from the following formula:

$MBS_P = 2\ \mu\ SWL$

where:

μ : Coefficient that accounts for the possible loss in strength at eye terminations, to be taken not less than 1,1

SWL : Safe working load of the towing pennants, defined in [1.6.1].

1.7.4 Minimum breaking strength of towing pennants when no separate chafing gear is used

Where no separate chafing gear is used (i.e. where the towing pennant may chafe against the fairlead during towing operation), the minimum breaking strength of the towing pennants MBS_{PC} is to be not less than that obtained, in kN, from the following formula:

$MBS_{PC} = \varphi\ MBS_P$

where:

MBS_P : Minimum breaking strength, in kN, defined in [1.7.3]

φ : Coefficient to be taken equal to:

$$\varphi = \frac{2\sqrt{\rho}}{2\sqrt{\rho} - 1}$$

φ may be taken equal to 1,0 if tests carried out under a test load equal to twice the safe working load defined in [1.6.1] demonstrate that the strength of the towing pennants is satisfactory

ρ : Bending ratio (ratio between the minimum bearing surface diameter of the fairlead and the towing pennant diameter), to be taken not less than 7.

1.7.5 Towing pennant termination

For towing connection, the towing pennant is to have a hard eye-formed termination allowing connection to a standard shackle.

Socketed or ferrule-secured eye terminations of the towing pennant are to be type tested in order to demonstrate that their minimum breaking strength is not less than twice the safe working load defined in [1.6.1].

1.8 Chafing gear

1.8.1 General

Different solutions for the design of chafing gear may be used.

If a chafing chain is to be used, it is to have the characteristics defined in the following requirements.

1.8.2 Type

Chafing chains are to be stud link chains.

1.8.3 Material

In general, grade Q3 chain cables and associated accessories complying with the applicable requirements in NR216 Materials and Welding, Ch 4, Sec 1 are to be used.

1.8.4 Chafing chain length

The chafing chain is to be long enough to ensure that the towing pennant, or the towline, remains outside the fairlead during the towing operation. A chain extending from the strongpoint to a point at least 3 m beyond the fairlead complies with this requirement.

1.8.5 Minimum breaking strength

The minimum breaking strength of the stud link chafing chain and the associated links is to be not less than twice the safe working load defined in [1.6.1].

1.8.6 Diameter of the common links

The diameter of the common links of stud link chain cables is to be not less than:

- 52 mm for a safe working load, defined in [1.6.1], equal to 1000 kN
- 76 mm for a safe working load, defined in [1.6.1], equal to 2000 kN.

1.8.7 Chafing chain ends

One end of the chafing chain is to be suitable for connection to the strongpoint. Where a chain stopper is used, the inboard end of the chafing chain is to be efficiently secured in order to prevent any inadvertent loss of the chafing chain when operating the stopping device. Where the chafing chain is connected to a towing bracket, the corresponding chain end may be constructed as shown in Fig 2, but the inner dimension of the pear link may be taken as 5,30 d (instead of 5,75 d).

The other end of the chafing chain is to be fitted with a standard pear-shaped open link allowing connection to a standard bow shackle. A typical arrangement of this chain end is shown in Fig 2. Arrangements different than that shown in Fig 2 are considered by the Society on a case-by-case basis.

1.8.8 Storing

The chafing chain is to be stored and stowed in such a way that it can be rapidly connected to the strongpoint.

1.9 Fairleads

1.9.1 General

Fairleads are normally to be of a closed type (such as Panama chocks).

Fairleads are to have an opening large enough to pass the largest portion of the chafing gear, towing pennant or towline. The corners of the opening are to be suitably rounded.

Where the fairleads are designed to pass chafing chains, the openings are to be not less than 600mm in width and 450mm in height.

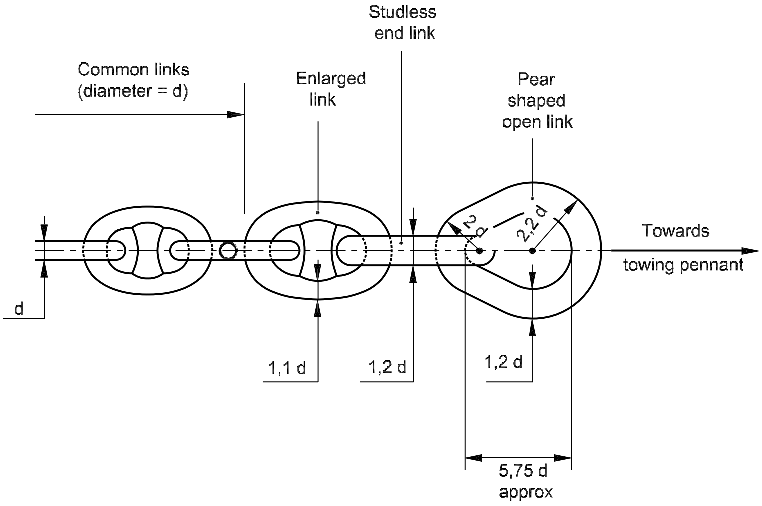
1.9.2 Material

Fairleads are to be made of fabricated steel plates or other ductile materials such as weldable forged or cast steel complying with the applicable requirements of NR216 Materials and Welding, Chapter 2.

1.9.3 Operating condition

The bow fairlead is to give adequate support for the towing pennant during towing operation, which means bending 90° to port and starboard side and 30° vertical downwards.

Figure 2 : Typical outboard chafing chain end



1.9.4 Positioning

The bow fairlead is to be located so as to facilitate towing from either side of the bow and minimise the stress on the towing system.

The bow fairlead is to be located as close as possible to the deck and, in any case, in such a position that the chafing chain is approximately parallel to the deck when it is under strain between the strongpoint and the fairlead.

Furthermore, the bow fairlead is normally to be located on the ship's centreline. Where it is practically impossible to fit the towing fairleads exactly on the ship’s centreline, it may be acceptable to have them slightly shifted from the centreline.

1.9.5 Bending ratio

The bending ratio (ratio between the towing pennant bearing surface diameter and the towing pennant diameter) is to be not less than 7.

1.9.6 Fairlead lips

The lips of the fairlead are to be suitably faired in order to prevent the chafing chain from fouling on the lower lip when deployed or during towing.

1.9.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm^2, induced in the fairlead by a load equal to the safe working load defined in [1.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the fairleads are analysed through fine mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

1.9.8 Alternative to the yielding check

The above yielding check may be waived provided that fairleads are tested with a test load equal to twice the safe working load defined in [1.6.1] and this test is witnessed by a Surveyor of the Society. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

1.10 Strongpoint

1.10.1 General

The strongpoint (inboard end fastening of the towing gear) is to be a chain cable stopper or a towing bracket or other fitting of equivalent strength and ease of connection. The strongpoint can be designed integral with the fairlead.

The strongpoint is to be type approved according to [1.13] and is to be clearly marked with its SWL.

1.10.2 Materials

The strongpoint is to be made of fabricated steel or other ductile materials such as forged or cast steel complying with the applicable requirements of NR216 Materials and Welding, Chapter 2.

Use of spheroidal graphite cast iron (SG iron) may be accepted for the main framing of the strongpoint provided that:

- the part concerned is not intended to be a component part of a welded assembly
- the SG iron is of ferritic structure with an elongation not less than 12%
- the yield stress at 0,2% is measured and certified
- the internal structure of the component is inspected by suitable non-destructive means.

The material used for the stopping device (pawl or hinged bar) of chain stoppers and for the connecting pin of towing brackets is to have mechanical properties not less than those of grade Q3 chain cables, defined in NR216 Materials and Welding, Ch 4, Sec 1.

1.10.3 Typical strongpoint arrangement

Typical arrangements of chain stoppers and towing brackets are shown in Fig 3, which may be used as reference.

Chain stoppers may be of the hinged bar type or pawl (tongue) type or of other equivalent design.

1.10.4 Position and operating condition

The operating conditions and the positions of the strongpoints are to comply with those defined in [1.9.3] and [1.9.4], respectively, for the fairleads.

1.10.5 Stopping device

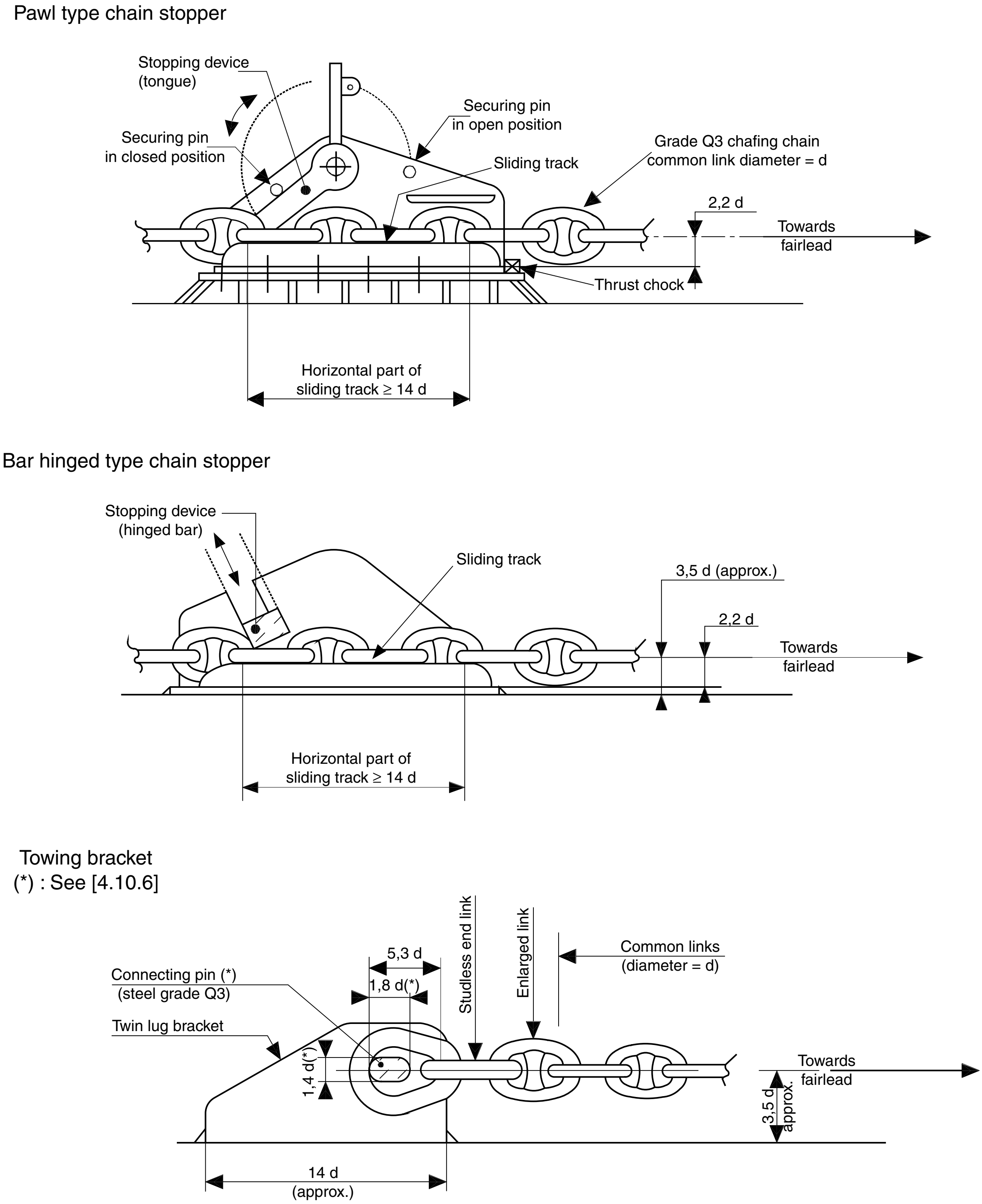
The stopping device (chain engaging pawl or bar) is to be arranged, when in closed position, to prevent the chain stopper from working in the open position, in order to avoid chain cable release and allow it to pay out.

Stopping devices are to be easy and safe to operate and, in the open position, are to be properly secured.

1.10.6 Connecting pin of the towing bracket

The scantlings of the connecting pin of the towing bracket are to be not less than those of a pin of a grade Q3 end shackle, as shown in Fig 3, provided that clearance between the two side lugs of the bracket does not exceed 2,0d, where d is the chain diameter specified in [1.8.6] (see also Fig 2).

Figure 3 : Typical strongpoint arrangement



1.10.7 Yielding check

The equivalent Von Mises stress σ_E, in N/mm², induced in the strongpoint by a load equal to the safe working load defined in [1.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

Areas subjected to stress concentrations are considered by the Society on a case-by-case basis.

Where the strongpoints are analysed through fine mesh finite element models, the allowable stress may be taken as 1,1 σ_{ALL}.

1.10.8 Alternative to the yielding check

The above yielding check may be waived provided that strongpoints are tested with a test load equal to twice the safe working load defined in [1.6.1] and this test is witnessed by a Surveyor. In this case, the Designer is responsible for ensuring that the fairlead scantlings are sufficient to withstand such a test load.

Unless otherwise agreed by the Society, components subjected to this test load are considered as prototype items and are to be discarded.

1.10.9 Bolted connection

Where a chain stopper or a towing bracket is bolted to a seating welded to the deck, the bolts are to be relieved from shear force by means of efficient thrust chocks capable of withstanding a horizontal force equal to 1,3 times the safe working load defined in [1.6.1] within the allowable stress defined in [1.10.7].

The steel quality of bolts is to be not less than grade 8.8 as defined by ISO standard No. 898/1.

Bolts are to be pre-stressed in compliance with appropriate standards and their tightening is to be suitably checked.

1.11 Hull structures in way of fairleads or strongpoints

1.11.1 Materials and welding

The materials used for the reinforcement of the hull structure in way of the fairleads or the strongpoints are to comply with the applicable requirements of NR216 Materials and Welding.

Main welds of the strongpoints with the hull structure are to be 100% inspected by adequate non-destructive tests.

1.11.2 Yielding check of bulwark and stays

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the bulwark plating and stays in way of the fairleads by a load equal to the safe working load defined in [1.6.1], for the operating condition of the fairleads defined in [1.9.3], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

1.11.3 Yielding check of deck structures

The equivalent Von Mises stress σ_E , in N/mm^2, induced in the deck structures in way of chain stoppers or towing brackets, including deck seatings and deck connections, by a horizontal load equal to 1,3 times the safe working load defined in [1.6.1], is to comply with the following formula:

$\sigma_E \leq \sigma_{ALL}$

1.11.4 Minimum gross thickness of deck plating

The gross thickness of the deck is to be not less than:

- 12 mm for a safe working load, defined in [1.6.1], equal to 1000 kN,
- 15 mm for a safe working load, defined in [1.6.1], equal to 2000 kN.

1.12 Rapid deployment of towing arrangement

1.12.1 General

To facilitate approval of towing arrangements and to ensure rapid deployment, emergency towing arrangements are to comply with the requirements of this item.

1.12.2 Marking

All components, including control devices, of the emergency towing arrangements are to be clearly marked to facilitate safe and effective use even in darkness and poor visibility.

1.12.3 Forward

The forward emergency towing arrangement is to be capable of being deployed in harbour conditions in not more than 1 hour.

The forward emergency towing arrangement is to be designed at least with a means of securing a towline to the chafing gear using a suitably positioned pedestal roller to facilitate connection of the towing pennant.

Forward emergency towing arrangements which comply with the requirements for aft emergency towing arrangements may be accepted.

1.13 Type approval

1.13.1 Type approval procedure

Emergency towing arrangements are to be type approved according to the following procedure:

- the arrangement design is to comply with the requirements of this Section
- each component of the towing arrangement is to be tested and its manufacturing is to be witnessed and certified by a Surveyor according to [1.13.2]
- prototype tests are to be carried out in compliance with [1.13.3].

1.13.2 Inspection and certification

The materials and equipment are to be inspected and certified as specified in Tab 3.

1.13.3 Prototype tests

Prototype tests are to be witnessed by a Surveyor and are to include the following:

- demonstration of the rapid deployment according to the criteria in [1.12]
- load test of the strongpoints (chain stoppers, towing brackets or equivalent fittings) under a proof load equal to 1,3 times the safe working load defined in [1.6.1].

A comprehensive test report duly endorsed by the Surveyor is to be submitted to the Society for review.

Table 3 : Material and equipment certification status

Component	Material		Equipment	
	Certificate	Reference of applicable requirements	Certificate	Reference of applicable requirements
Towing pennant	not applicable	[1.7.1]	COI **(1)**	[1.7]
Chafing chain and associated accessories	COI **(2)**	[1.8.3]	COI **(1)**	[1.8]
Fairleads	CW	[1.9.2]	COI	[1.9]
Strongpoint: • main framing • stopping device	 COI **(2)** COI **(2)**	 [1.10.2] [1.10.2]	COI **(3)**	[1.10]
Pick-up gear: • rope • buoy • line-throwing appliance	 not applicable not applicable not applicable	 – – –	 CW not required **(4)** not required **(4)**	no requirement
Pedestal roller fairlead	CW	–	not required **(4)**	no requirement

(1) according to NR216 Materials and Welding, Ch 4, Sec 1.
(2) according to NR216 Materials and Welding, Chapter 1.
(3) to be type approved.
(4) may be type approved.
Note 1:
COI : Certificate of inspection
CW : Works' certificate 3.1.B according to EN 10204.

Section 3 Enhanced Fire Protection FIRE

1 General

1.1 Application

1.1.1 The additional class notation **FIRE** may be assigned, in accordance with Pt A, Ch 1, Sec 2, [6.14.6], to ships complying with the requirements of this section. The additional class notation **FIRE** is to be completed, between brackets, by one, or by a combination, of the following notations:

- **F**, for ships equipped with a sprinkler system in accordance with Article [2]
- **T**, for ships on which the low flame-spread characteristics of surface materials have been tested according to Article [3]
- **S**, for ships on which fire doors located on smoke extraction paths are planned to be kept open in accordance with Article [4].

1.2 Documents to be submitted

1.2.1 The documents to be submitted are listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A**(1)**	Description
FIRE (**T**)		
1	A	Type approval certificates or specific test reports for low flame-spread characteristics of surface materials as per [3.2.1]
FIRE (**S**)		
2	I	General arrangement drawing showing the fire doors required to be kept open for smoke evacuation purposes
(1) A: To be submitted for approval ; I: To be submitted for information		

2 Fire-fighting

2.1 Application

2.1.1 This article applies to ships to be assigned the additional class notation **FIRE** completed by **F**.

2.2 Accommodation spaces, service spaces and control stations

2.2.1 The ship is to be equipped with a sprinkler system of an approved type complying with the requirements of Pt C, Ch 4, Sec 13, [8] in all service spaces, control stations and accommodation spaces, including corridors and stairways.

3 Fire growth potential

3.1 Application

3.1.1 This article applies to ships to be assigned the additional class notation **FIRE** completed by **T**.

3.2 Low flame-spread testing

3.2.1 The low flame-spread characteristics of the surface materials listed in Pt C, Ch 4, Sec 2, [2.2.2], item d) are to be assessed for the layer combinations installed on board.

4 Smoke control

4.1 Application

4.1.1 This article applies to ships to be assigned the additional class notation **FIRE** completed by **S**.

4.1.2 The requirements of the present article apply to:

- fire doors in stairway and corridor bulkheads, except doors leading to cabins
- other fire doors required to be kept open for smoke evacuation purposes, as specified by the Naval Authority.

They do not apply to:

- doors leading to the open deck
- manually operated watertight doors
- manually operated watertight hatches.

4.2 Doors located on smoke evacuation paths

4.2.1 Fire doors listed in [4.1.2] are to be of a self-closing type and capable of remote-release from the continuously manned central damage control station. They are also to be capable of individual release from a position near the door.

4.2.2 Release switches are to have an on-off function to prevent automatic resetting of the system. Means of re-activation of the release switches is to be provided for groups of doors corresponding to the smoke evacuation plan, independently of other fire doors.

4.2.3 Hold-back hooks not subject to remote control in the continuously manned damage control station release are prohibited.

4.2.4 Indication is to be provided at the fire door indicator panel in the continuously manned damage control station whether the door is opened or closed.

CHAPTER 11
OTHER NOTATIONS

Section 1	In-Water Survey Arrangements (INWATERSURVEY)
Section 2	Helicopter Deck (HELICOPTER)
Section 3	Refrigeration Installation (REF-STORE)
Section 4	Centralised Navigation Equipment (SYS-NEQ)

Section 1 In-Water Survey Arrangements (INWATERSURVEY)

1 General

1.1 Application

1.1.1 The additional class notation **INWATERSURVEY** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.15.1].

1.2 Documentation to be submitted

1.2.1 Plans

Detailed plans of the hull and hull attachments below the waterline are to be submitted to the Society for approval. These plans are to indicate the location and/or the general arrangement of:

- all shell openings
- stem
- rudder and fittings
- sternpost
- propeller, including the means used for identifying each blade
- anodes, if any, including securing arrangements
- bilge keels
- welded seams and butts.

The plans are also to include the necessary instructions to facilitate the divers' work, especially for taking clearance measurements.

Moreover, a specific detailed plan showing the systems to be adopted in order to assess, when the ship is floating, the slack between pintles and gudgeons is to be submitted to the Society for approval.

1.2.2 Photographs

As far as practicable, a photographic documentation, used as a reference during the in-water surveys, of the following hull parts is to be submitted to the Society:

- propeller boss
- rudder pintles, where slack is measured
- typical connections to the sea
- directional propellers, if any
- other details, as deemed necessary by the Society on a case by case basis.

1.2.3 Documentation to be put on board

The Owner is to put on board of the ship the plans and documents given in [1.2.1] and [1.2.2] and they are to be made available to the Surveyor and the divers when an in-water survey is carried out.

2 Structure design principles

2.1

2.1.1 Identification system

Identification system such as Ariadne thread, or any other systems accepted by the Society which permit to locate the diver under the hull of the ship is to be supplied to facilitate the in-water survey.

2.1.2 Rudder arrangements

Rudder arrangements are to be such that rudder pintle clearances and fastening arrangements can be checked as far as practicable.

2.1.3 Tailshaft arrangements

Tailshaft arrangements are to be such that clearances (or wear down by poker gauge) can be checked as far as practicable.

Section 2 Helicopter Deck (HELICOPTER)

1 General

1.1 Application

1.1.1 Ships complying with the requirements of this Chapter are eligible for the assignment of the additional class notation **HELICOPTER**, as defined in Pt A, Ch 1, Sec 2, [6.15.2].

1.1.2 Ships dealt with in this Chapter are to comply with the requirements stipulated in Parts A, B, C and D of the Rules, as applicable and with the requirements of this Chapter, which are specific to helideck.

2 Structure

2.1

2.1.1 For ships with the additional class notation **HELICOPTER**, the helicopter loads, as specified in this Article, are to be provided for information.

2.1.2 Design loads

a) In general, the design loads are to be calculated as specified in items c) or d), as applicable depending on the service notation assigned to the ship.

b) Other loads are to be considered when deemed necessary by the Society, depending on the operation that will be carried out on the ships (e.g. the loads induced by the helicopter engine test operations). In these cases, the design loads are to be provided by the Designer.

c) The loads transmitted by the helicopter to helideck structures are to be calculated according to Pt B, Ch 8, Sec 10, [5].

d) The still water loads transmitted by the helicopter to helideck structures, namely the landing and parking loads transmitted through the helicopter tyres, are to be provided by the Designer.

e) The inertial forces induced by ship motion and acceleration are to be calculated, on the basis of the above still water loads, according to Pt B, Ch 5, Sec 6.

2.1.3 Hull scantlings

In general, the helideck structures are to be checked according to Part B, Chapter 7, considering the design local loads and their combination with the hull girder loads as specified in the above Chapter.

2.1.4 Documents to be submitted

The documents listed in Tab 1 items 1 and 2 are to be submitted.

3 Fire protection, detection and extinction

3.1 General

3.1.1 The provisions of this Article are in addition of those given in Pt C, Ch 4, Sec 10.

3.1.2 The documents listed in Tab 1 are to be submitted.

3.1.3 Nozzles and rescue equipment

When not required by Pt C, Ch 4, Sec 10, [3.1.1], at least two nozzles of an approved type (jet/spray) each fed by two hose lengths complying with Pt C, Ch 4, Sec 6, [1.2.5] and Pt C, Ch 4, Sec 6, [1.4.3] shall be capable to reach any part of flying-deck.

All fire stations relevant to helideck shall be capable to delivery water or low expansion foam.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Documents **(2)** **(3)**
1	A	Drawings of helideck structural arrangements and scantlings
2	I	Details on the loads calculations
3	I	General plans shown the position of ship's spaces and helideck, refuelling and de-refuelling stations and JP5-NATO(F44) pump rooms, helicopter and aircraft positions, take off areas, landing areas, as well as spaces dedicated to fire-extinguishing units (as applicable)
4	A	Diagram of thick water fire-extinguishing systems for helideck
5	A	Diagram of twin media fire-extinguishing system for helideck including pressure containers
6	A	Diagram of JP5-NATO(F44) pump room fire-extinguishing systems (as applicable)
7	A	Plan(s) of fire appliances for helideck as well as refuelling and de-refuelling stations and drainage facilities (as applicable)

(1) A = to be submitted for approval
I = to be submitted for information.
(2) Diagram are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems
(3) Diagrams are to be schematic and functional and have to contain all information necessary for their correct understanding and verification

3.2 Additional fire safety measures for helideck

3.2.1 General

The helideck shall be provided with the following fire-fighting appliances from item a) to e) or from item f) to i):

a) in substitution to the requirements of Pt C, Ch 4, Sec 10, [3.1.1], item d), at least one semi-portable carbon dioxide extinguisher having capacity of at least 18 kg with necessary fittings to direct the carbon dioxide to the engine of helicopter when in the take off position; and

b) at least one semi-portable foam fire extinguisher of at least 45 l capacity with necessary fittings to direct the foam on deck area of crashed helicopter; and

c) a thick water helideck system; and

d) in substitution to the requirements of Pt C, Ch 4, Sec 10, [3.1.1], items a), b) and c), a twin media helideck system; and

e) in substitution to the requirements of Pt C, Ch 4, Sec 10, [3.1.1], items a), b) and c), at least two autonomous mobile twin media applicators; or

f) in substitution to the requirements of Pt C, Ch 4, Sec 10, [3.1.1], item d), at least one semi-portable carbon dioxide extinguisher having capacity of at least 18 kg with necessary fittings to direct the carbon dioxide to the engine of helicopter when in the take off position; and

g) at least two semi-portable foam fire-extinguishers of at least 45 l capacity with necessary fittings to direct the foam on deck area of crashed helicopter; and

h) a thick water system complying with the requirements of [3.2.2] for the protection of the door of the hangar only. This system is not required to provide continuous and complete coverage of the helideck with thick water; and

i) in substitution to the requirements of Pt C, Ch 4, Sec 10, [3.1.1], items a), b) and c), a twin media helideck system complying with the requirements of [3.2.3]. In addition, the monitors shall be capable of delivery the two media on any part of the helideck. The supply rate of the foam shall be not less than 5 l/min/m2 during at least 10 min discharge time. In any case, each monitor shall be capable of delivering foam at a supply rate of at least 2000 l/min during at least 10 min discharge time.

3.2.2 Thick water helideck system

a) The thick water helideck system shall provide continuous and complete coverage of the helideck and the door of the hangar with thick water.

b) The thick water is composed by sea water mixed with at least 3% of a type approved AFFF emulsifier (Agent Forming a Floating Film). The Society may authorize a lower concentration if the emulsifier media efficiency and the correct working of the system with lower concentrations are demonstrated.

c) The thick water shall be generated by generators units which shall include emulsifier container with a gauging system, proportioning mixer connected to the fire main.

d) Means shall be provided for washing the system with fresh water after use.

e) The nozzles provided for the system may be fitted directly on the helideck.

f) The system shall be capable of delivery thick water at a rate of not less than 5 l/m^2/min during not less than 5 minutes operation time.

g) The helideck thick water system may be divided into sections which shall be fed by the relevant sections of the fire main.

h) The system section valves and connection valves with the fire main shall be monitored from the damage control station. Such valves shall be located outside the protected area. The remote operation of such valves shall be possible from the control room of the helicopter operations. Local operation of the section valves shall be also possible.

i) For ships to be assigned the **CBRN** additional class notation, the thick water helideck system may be combined with the pre-wetting and washdown system provided for CBRN protection, if provided in accordance with Ch 8, Sec 3, [4], on the condition that the provisions for both systems are complied with.

3.2.3 Twin media helideck system

a) The two media shall be dry chemical powder, and foam solution. The powder and the foam forming liquid shall be of a type approved by the Society.

b) The two media shall be stored in pressure vessels which shall be pressurized by pressure air in dedicated pressurized bottles.

c) In addition the system shall be provided with means of control, fixed media pressurizing piping and fixed media delivering pipes to monitors.

d) The two media shall be delivered by in pairs monitors capable of simultaneous operation. In any case there shall be fitted at least two monitors.

e) The system shall be capable of delivery the two media on any part of the parcking area for helicopter which has caught fire.

Note 1: The parking area of the helideck is the area contained within a circle of diameter “D”, where “D” is the distance in meters across the main rotor and the tail rotor in the fore and aft line of an helicopter with a single main rotor and across both rotors for a tandem rotor helicopter.

f) The monitor throw in still air conditions shall not be less than 1,3 times the maximum distance of the monitor from any point of the area intended to be protected by this monitor.

g) The discharge rate is to be as follow:

- not less than 10, 25 and 45 kg/s for the maximum coverage distance of 10, 30 and 40 meters for the powder delivery
- not less than 20 l/s for the foam delivery.

h) The quantity of chemical powder and foam solution in the system containers for shall be not less than the quantity required for 45 seconds discharge time for the powder and the foam. The container volume shall be that required for housing the medium and that of the gap necessary for the pressurization of the container with air.

i) The helideck shall be provided with the twin media units necessary to comply with the provisions items. Such units shall be positioned as not to interfere with the helicopter operations.

j) Monitors shall have features for manual and remote control laying as well as for media discharge operations.

k) The expansion ratio of the foam shall not exceed 12 to 1.

3.2.4 Autonomous mobile twin media applicators

a) The two media shall be dry chemical powder, and foam solution. The powder and the foam forming liquid shall be of a type approved by the Society.

b) The two media shall be stored in pressure vessels which shall be pressurized by pressure air in dedicated pressurized bottles.

c) In addition the system shall be provided with means of control, fixed media pressurizing piping and fixed media delivering pipes to applicator nozzles fitted with hand hose lines.

d) The two media shall delivered by in pairs of applicator nozzles capable of simultaneous operation.

e) The system shall be capable of delivery the two media on any part of the helideck.

f) The hand hose lines shall not exceed 33 meters in length.

g) The discharge rate is to be as follow :

- not less than 100 kg/min for the powder delivery
- not less than 200 l/min for the foam delivery.

h) The quantity of chemical powder and foam solution in the system containers for each applicator nozzle shall be not less than the quantity required for 1 minute discharge time for the powder media and 10 minutes for the foam media. The container volume shall be that required for housing the medium and that of the gap necessary for the pressurization of the container with air.

i) The helideck shall be provided with the twin media units necessary to comply with the provisions items. Such units shall be positioned as not to interfere with the helicopter operations.

j) Applicator nozzles fitted with hand hose lines shall have features for one man operation.

k) The expansion ratio of the foam shall not exceed 12 to 1.

Section 3 Refrigeration Installation (REF-STORE)

1 General

1.1 Application

1.1.1 The additional class notation **REF-STORE** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.9], to ships with refrigerating installations related to preservation of ship’s domestic supplies, complying with the requirement of this Chapter.

1.1.2 The requirements of this Chapter apply to refrigerating installations on ships. These requirements are specific to permanently installed refrigerating installations and associated arrangements and are to be considered additional to those specified in Pt C, Ch 1, Sec 14, which are mandatory for all ships with refrigerating installations.

1.2 Definitions

1.2.1 Direct cooling system

Direct cooling system is the system by which the refrigeration is obtained by direct expansion of the refrigerant in coils fitted on the walls and ceilings of the refrigerated chambers.

1.2.2 Indirect cooling system

Indirect cooling system is the system by which the refrigeration is obtained by brine or other secondary refrigerant, which is refrigerated by a primary refrigerant, circulated through pipe grids or coils fitted on the walls and ceilings of the refrigerated chambers.

1.2.3 Refrigerant

Refrigerant is a cooling medium which is used to transmit and maintain the cool in the refrigerated chamber.

1.2.4 Brine

Brine is a refrigerant constituted by a solution of industrial salts, which is normally used to cool the chambers in the indirect cooling systems, as secondary refrigerant. In general, in this Chapter, the word brine is also used to cover other types of secondary refrigerants, as for instance refrigerants based on glycol.

1.2.5 Refrigerating unit

A refrigerating unit includes one or more compressors driven by one or more prime movers, one condenser and all the associated ancillary equipment necessary to form an independent gas-liquid system capable of cooling refrigerated chambers.

When the installation includes a secondary refrigerant (brine), the refrigerating unit is also to include a brine cooler (evaporator) and a pump.

1.2.6 Refrigerated chamber

A Chamber may be a ship’s store space or any other ship service space for preservation or de-freezing of ship's domestic victuals.

2 Design criteria

2.1 Reference conditions

2.1.1 Design arrangements and temperature

The design arrangements of refrigerated and conditioned spaces for transport, preservation, de-freezing, processing, distribution of victuals, including incompatibility victuals preservation as well as appropriate space temperature to stowed victuals, are to comply with hygienic-healthful requirement of Naval Authority.

The refrigerating plants are to be designed according to temperatures requested by the Naval Authority and in accordance with the Administration requirements.

2.1.2 Environmental conditions

Unless otherwise indicated in the ship specification, the following environmental conditions are to be considered for the heat transfer and balance calculations and for the running rate of the refrigerating machinery:

- Sea water temperature: 32°C
- Outside air temperature: 35°C
- Relative humidity of air at 35°C: 80%.

For the determination of heat transfer through outside walls liable to be exposed to sun radiation, the outside air temperature is to be taken as equal to 45°C.

2.1.3 Operating conditions

The refrigerating plant inclusive of all machinery, equipment and accessories is to operate satisfactorily under the conditions indicated in Tab 1.

Table 1 : Operating conditions

Length of ship (m)		< 100	< 200	≤ 300	> 300
Permanent list		15°	15°	15°	15°
Roll		± 22,5°	± 22,5°	± 22,5°	± 22,5°
Pitch		± 10°	± 7,5°	± 5°	± 3°
Trim	Aft	5,0°	2,5°	1,5°	1,0°
	Forward	2,0°	1,0°	0,5°	0,3°

3 Documentation

3.1 Refrigerating installations

3.1.1 Plans to be submitted

The plans listed in Tab 2 are to be submitted as applicable.

The listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

Plans of equipment which are type approved by the Society need not be submitted, provided the types and model numbers are made available.

3.1.2 Calculations to be submitted

The calculations listed in Tab 3 are to be carried out in accordance with criteria agreed with the Society and are to be submitted.

Table 2 : Documents to be submitted

No.	A/I **(1)**	Document
1	I	Detailed specification of the plant (refrigerating machinery and insulation) including the reference design and ambient conditions
2	I	General arrangement of refrigerated spaces including: • the intended purpose of spaces adjacent to refrigerated spaces • the arrangement of air ducts passing through refrigerated spaces • the arrangement of steelwork located in refrigerated spaces or in insulated walls • the arrangement of the draining system • the individual volume and the total volume of the refrigerated spaces
3	A	Drawings showing the thickness and methods of fastening of insulation on all surfaces in refrigerated spaces, including: • insulation material specification • hatch covers • doors • steel framing (pillars, girders, deck beams) • bulkhead penetrations • etc.
4	A	Cooling appliances in refrigerated spaces (coil grids, air coolers with air ducts and fans, etc.)
5	I	Characteristic curves of fans (capacity, pressure, power consumption)
6	A	Distribution of the thermometers and description of remote thermometer installation, if any, including: • detailed description of the apparatus with indication of the method and instruments adopted, measuring range, degree of accuracy and data regarding the influence of temperature variations on connection cables • electrical diagram of apparatus, with indication of power sources installed, characteristics of connection cables and all data concerning circuit resistance • drawings of sensing elements and their protective coverings and indicators, with specification of type of connections used
7	A	General arrangement and functional drawings of piping (refrigerant system, brine system if any, sea water system, defrosting system, etc.)
8	I	Characteristic curves of circulating pumps for refrigerant or brine (capacity, pressure, power consumption, etc.)
9	I	General arrangement of refrigerating machinery spaces (main data regarding prime movers for compressors and pumps, including source of power, are to be included in this drawing)

No.	A/I **(1)**	Document
10	A	Electrical wiring diagram
11	A	Compressor main drawings (sections and crankshaft or rotors) with characteristic curves giving the refrigerating capacity
12	A	Drawings of main items of refrigerant system and pressure vessels, such as condensers, receivers, oil separators, evaporators, gas containers, etc.
13	A	Remote control, monitoring and alarm system (if any)
14	I	Operation manual for the refrigerating plant and for refrigerated containers, as applicable
(1) A = for Approval, I = for Information.		

Table 3 : Calculations to be submitted

No.	A/I **(1)**	Item
1	I	Detailed calculation of the heat balance of the plant. The calculation is to take into account the minimum internal temperatures for which the classification is requested and the most unfavourable foreseen ambient conditions.
(1) I = for Information.		

4 General technical requirements

4.1 Refrigeration of chambers

4.1.1 Refrigerating systems

Refrigeration of the chambers may be achieved by one of the following systems:

- direct cooling system
- air cooling system.

4.1.2 Cold distribution

a) The chambers may be refrigerated either by means of grids distributed on their walls or by means of air circulation on air coolers.

b) Grids and/or air coolers may be supplied either by brine or by a direct expansion system depending on the type of refrigerating system.

4.2 Refrigerating unit

4.2.1 Availability

The total refrigerating capacity of the plant is to be such as, in the most unfavourable conditions of external temperatures, it is possible to maintain, in the insulated spaces loaded with refrigerated goods, the temperature(s) for which the plant has been designed, with all refrigerating units, except one, working 24 h a day, if necessary.

4.3 Defrosting

4.3.1 Means are to be provided for defrosting air cooler coils, even when the refrigerated chambers are loaded to their maximum. Air coolers are to be fitted with trays and gutterways for gathering condensed water.

4.3.2 Arrangements are to be made to drain away the condensate even when the refrigerated chambers are loaded to their maximum. See [5.8] for specific requirements.

4.4 Prime movers and sources of power

4.4.1 Number of power sources

The motive power for each refrigerating unit is to be provided by at least two distinct sources. Each source is to be capable of ensuring the service of the plant under the conditions stated in [2.1.1], [2.1.2] and [2.1.3], without interfering with other essential services of the ship.

4.4.2 Electric motors

Where the prime movers of refrigerating units are electric motors, the electrical power is to be provided by at least two distinct generating sets.

4.5 Pumps

4.5.1 Minimum number of condenser pumps

a) At least one standby condenser circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) One of the condenser circulating pumps may be one of the ship's auxiliary pumps, provided its capacity is sufficient to serve the refrigerating plant working at maximum power without interfering with essential services of the ship.

4.5.2 Plants with intermediate cooling media

a) Where an intermediate cooling medium is used, at least one standby brine circulating pump is to be provided; this pump is to be ready for use and its capacity is not to be less than that of the largest pump that it may be necessary to replace.

b) The same provision applies to any other type of plants in which the circulation of refrigerant is ensured by pumps.

4.6 Sea connections

4.6.1 Number and location of sea connections

a) The cooling water is normally to be taken from the sea by means of at least two separate sea connections.

b) The sea connections for the refrigerating plant are to be distributed, as far as practicable, on both sides of the ship.

4.6.2 Connections to other plants

Where the circulating pump(s) of the refrigerating plant is/are connected to the same circuit as other pumps, precautions are to be taken in the design and arrangement of piping so that the working of one pump does not interfere with another.

4.7 Refrigerating unit spaces

4.7.1 Arrangement

Refrigerating machinery spaces are to be provided with efficient means of ventilation and drainage and, unless otherwise allowed by the Society, are to be separated from the refrigerated spaces by means of gas-tight bulkheads.

Ample space is to be provided around the refrigerating machinery to permit easy access for routine maintenance and to facilitate overhauls, particularly in the case of condensers and evaporators.

4.7.2 Dangerous refrigerants in machinery spaces

Use of dangerous refrigerants in machinery spaces may be permitted in accordance with Part C, Chapter 1.

5 Refrigerated chambers

5.1 Construction of refrigerated chambers

5.1.1 Bulkheads surrounding refrigerated chambers

a) Generally, the bulkheads of refrigerated chambers are to be of metallic construction; however, the bulkheads between two refrigerated spaces intended to contain goods of the same nature or having no contaminating effect need not be metallic.

b) The bulkheads are to be gas-tight.

c) Steels intended to be used for the construction of refrigerated chambers are to comply with the applicable provisions of Pt B, Ch 4, Sec 1 for low temperature steels.

5.1.2 Prefabricated chambers

Prefabricated chambers are to be of a robust construction, capable of withstanding the usual movements of a sea going vessel (vibration, inclination, acceleration, etc.).

They are to be fitted with suitable pressure equalising devices; these devices are to be so designed to allow the passage of air in either direction and remain closed in the absence of pressure differential.

The inner and outer surfaces of the prefabricated panels are to be covered with a suitable lining.

5.1.3 Closing devices

a) The closing devices of the accesses to refrigerated chambers, such as doors, hatch covers and plugs for loading or surveying are to be as far as possible gas-tight.

b) The ventilators of refrigerated chambers, if any, are to be fitted with gas-tight closing devices.

5.2 Penetrations

5.2.1 Penetration of pipes and ducts

Penetrations of pipes through watertight, gas-tight or fire-resistant decks and bulkheads are to be achieved by fitting glands suitable for maintaining the tightness and fire-resisting characteristics of the pierced structure.

5.2.2 Penetration of electrical cables

Where electrical wiring passes through refrigerated chambers, the relevant requirements of Part C, Chapter 2 are to be complied with.

5.3 Access to refrigerated spaces

5.3.1 Access doors to refrigerated chambers are to be provided with means of opening from inside even where they have been shut from outside.

5.3.2 A calling mean is to be installed inside the refrigerated chambers, in an accessible place on the lower part of one of the walls.

5.4 Insulation of refrigerated chambers

5.4.1 The insulation of refrigerated chambers shall comply with the following requirements:

a) The insulating material is to be non-hygroscopic. The insulating boards are to have satisfactory mechanical strength. Insulating materials and binders, if any, are to be odourless and so selected as not to absorb any of the odours of the goods contained in refrigerated chambers. The materials used for linings are to comply with the same provisions.

b) Polyurethane and other plastic foams used for insulation are to be of a self-extinguishing type according to a standard acceptable by the Society. In general, these foams are not to be used without a suitable protective coating.

c) The insulation together with its coating is normally to have low flame spread properties according to an accepted standard.

d) Plastic foams of a self-extinguishing type, suitably lined, may also be used for insulation of piping and air ducts.

e) When it is proposed to use foam prepared in situ, the detail of the process is to be submitted for examination before the beginning of the work.

f) Prefabricated panels are to be of a design such that, when erected, the continuity of the insulation is ensured.

   Possible gaps are to be filled with insulation material.

5.5 Protection of insulation

5.5.1 Insulation extension

The insulation and the lining are to be carefully protected from all damage likely to be caused by the goods contained in the chamber or by their handling.

5.5.2 Insulation strength

The insulation lining and the air screens with their supports are to be of sufficient strength to withstand the loads due to the goods liable to be carried in the refrigerated chambers.

Insulation linings are to be constructed and fitted so that thay are airtight and provide an effective vapour barrier. The means of joining prefabricated panels are to have sufficient mechanical strength to maintain a vapour barrier on the inner and outer faces. All joints are to be sealed with a suitable gasket.

5.5.3 Removable panels

a) A sufficient number of removable panels are to be provided in the insulation, where necessary, to allow inspection of the bilges, bilge suctions, bases of pillars, vent and sounding pipes of tanks, tops of shaft tunnels and other structures and arrangements covered by the insulation.

b) Where the insulation is covered with a protective lining, certain panels of this lining are to be provided with a suitable number of inspection openings fitted with watertight means of closing.

5.6 Miscellaneous requirements

5.6.1 Refrigerated chambers adjacent to oil or fuel tanks

a) An air space of at least 50 mm is to be provided between the top of fuel and lubricating oil tanks and the insulation, so designed as to allow leaks to drain to the bilges. Such air space may be omitted provided multiple sheaths of an odourless oil-resisting material are applied to the upper surface of tank tops. The total required thickness of sheathing depends on the tank construction, on the composition used and on the method of application.

b) In general, the sides of fuel and lubricating oil tanks are to be separated from refrigerated spaces by means of cofferdams. The cofferdams are to be vented, the air vents fitted for this purpose are to be led to the open and their outlets are to be fitted with wire gauze which is easily removable for cleaning or renewal. The cofferdams may be omitted provided that multiple sheaths of an odourless oil-resisting material are applied on the tank side surface facing the refrigerated chambers. The total required thickness of this sheathing depends on the composition used and on the method of application.

5.6.2 Refrigerated chambers adjacent to high temperature spaces

The insulation of the walls adjacent to coalbunkers or to any space where an excessive temperature may arise, by accident or otherwise, is to be made of mineral wool or any equivalent material; wood chips, if any, are to be fireproof and separated from the plates on which they are fitted by means of insulating sheets.

5.6.3 Wooden structures

Wooden beams and stiffeners are to be insulated and strips of suitable insulating material are to be fitted between them and the metallic structures.

5.6.4 Metal fittings

All metal fittings (bolts, nuts, hooks, hangers, etc.) necessary for fitting of the insulation are to be galvanised or made in a corrosion-resistant material.

5.6.5 Equipment below the insulation

Arrangements are to be made whilst building in order to facilitate the examination in service of parts such as bilge suctions, scuppers, air and sounding pipes and electrical wiring which are within or hidden by the insulation.

5.7 Installation of the insulation

5.7.1 The following requirements shall be fulfilled:

a) Before laying the insulation, steel surfaces are to be suitably cleaned and covered with a protective coating of appropriate composition and thickness.

b) The thickness of the insulation on all surfaces together with the laying process are to be in accordance with the approved drawings.

c) The insulating materials are to be carefully and permanently installed; where they are of slab form, the joints are to be as tight as possible and the unavoidable crevices between slabs are to be filled with insulating material. Bitumen is not to be used for this purpose.

d) Joints of multiple layer insulations are to be staggered.

e) In applying the insulation to the metallic structures, any paths of heat leakage are to be carefully avoided.

5.8 Drainage of refrigerated spaces

5.8.1 General

All refrigerated spaces and trays under air coolers are to be fitted with means suitable for their continuous and efficient drainage.

5.8.2 Drain pipes

a) Drain pipes from refrigerating space cooler trays are to be fitted with liquid sealed traps provided with non-return valves which are easily accessible, even when the chamber is fully loaded.

b) Threaded plugs, blank flanges and similar means of closing of drain pipes from refrigerated spaces and trays of air coolers are not permitted.

c) Where means of closing of drain pipes are required by the Owner, these are to be easily checked and the controls are to be located in an accessible position on a deck above the maximum ship draft.

6 Refrigerants

6.1 General

6.1.1 Prohibited refrigerants

For restrictions on the selection of refrigerants, see Pt C, Ch 1, Sec 14, [2.2.1] and Pt C, Ch 1, Sec 14, [2.2.2].

6.2 Rated working pressures

6.2.1 Pressure parts design pressure

a) The refrigerant design pressure is not to be less than the maximum working pressure of the installation or its parts, either in operation or at rest, whichever is the greater. No safety valve is to be set at a pressure higher than the maximum working pressure.

b) In general, the design pressure of the low pressure side of the system is to be at least the saturated vapour pressure of the refrigerants at 40°C. Due regard is to be paid to the defrosting arrangement which may increase the pressure on the low pressure system.

c) The design pressure of the high pressure side of the installation is to be based on the condenser working pressure while it operates with water cooling in tropical zones. In general, the rated working pressure is to be taken not less than the effective saturated vapour pressure at 50°C.

d) The design pressure of the system is also not to be lower than the values given in Tab 4.

Table 4 : Design working pressure

Refrigerant number	High pressure side	Low pressure side
R134a	1,3 MPa	1,1 MPa
R404a	2,0	1,7 MPa
R507	2,3	1,8 MPa
Note 1: Due to consideration is to be given to the values applicable to other refrigerants,		

7 Refrigerating machinery and equipment

7.1 Prime movers

7.1.1 General requirements

a) The diesel engines driving the compressors are to satisfy the relevant requirements of Pt C, Ch 1, Sec 2.

b) The electric motors driving the compressors, pumps or fans are to satisfy the relevant requirements of Pt C, Ch 2, Sec 4.

7.2 Common requirements for compressors

7.2.1 Casings

The casings of rotary compressors are to be designed for the design pressure of the high pressure side of the system indicated in Tab 4.

7.2.2 Cooling

a) Air-cooled compressors are to be designed for an air temperature of 45°C.

b) For sea water cooling, a minimum inlet temperature of 32°C is to be applied. Unless provided with a free outlet, the cooling water spaces are to be protected against excessive overpressure by safety valves or rupture safety devices.

7.2.3 Safety devices

a) Stop valves are to be provided on the compressor suction and discharge sides.

b) A safety valve or rupture disc is to be arranged between the compressor and the delivery stop valve.

c) When the power exceeds 10 kW, the protection may consist of a pressure control device which automatically stops the machine in the event of overpressure. Details of the design of this device are to be submitted to the Society.

d) Compressors arranged in parallel are to be provided with check valves in the discharge line of each compressor.

e) Means are to be provided to indicate the correct direction of rotation.

7.3 Reciprocating compressors

7.3.1 Crankcase

a) When subjected to refrigerant pressure, compressor crankcases are to be either:
   - designed to withstand the rated working pressure of the LP side; or
   - fitted with safety valves designed to lift at a pressure not exceeding 0,8 times the crankcase test pressure; in this case, arrangements are to be made for the refrigerant to discharge to a safe place; or
   - protected against overpressures by means of devices likely to ensure a similar protection.

b) An oil level sight glass is to be fitted in the crankcase.

c) Means are to be provided to heat the crankcase when the compressor is stopped if the power of the compressor technically required such an arrangement.

7.4 Pressure vessels

7.4.1 General

The general requirements of Pt C, Ch 1, Sec 14, [2.1.2] are applicable.

7.4.2 Refrigerant receivers

a) The receivers are to have sufficient capacity to accumulate liquid refrigerant during changes in working conditions, maintenance and repairing.

b) Each receiver is to be fitted with suitable level indicators. Glass gauges, if any, are to be of the flat plate type and are to be heat resistant. All level indicators are to be provided with shut-off devices.

c) Each receiver that may be isolated from the system is to be provided with an adequate overpressure safety device.

7.4.3 Evaporators and condensers

a) All parts of evaporators and condensers are to be accessible for routine maintenance; where deemed necessary, efficient means of corrosion control are to be provided.

b) Safety valves are to be fitted on the shells of evaporators and condensers when the pressure from any connected pump may exceed their anticipated working pressure.

7.4.4 Air coolers

a) Air coolers are to be made of corrosion-resistant material or protected against corrosion by galvanising.

b) Air coolers are to be provided with drip trays and adequate drains.

7.5 General requirements for piping

7.5.1 General

The general requirements of Pt C, Ch 1, Sec 14, [2.1.3] are applicable.

7.5.2 Piping arrangement

a) Pipelines are to be adequately supported and secured so as to prevent vibrations. Approved type flexible hoses may be used where necessary to prevent vibrations.

b) Provision is to be made for allowing thermal expansion and contraction of the piping system under all operating conditions. Approved type flexible hoses may be used where necessary for this purpose.

c) Where necessary, pipe insulation is to be protected from mechanical damage and is to be provided with an efficient vapour barrier which is not to be interrupted in way of supports, valves, fittings, etc.

7.6 Accessories

7.6.1 Oil separators

Oil separators with drains are to be fitted on the refrigerant lines. When a wire gauze is fitted, this is to be of material which cannot be corroded by the refrigerant.

7.6.2 Filters

a) Efficient filters are to be fitted at the suction of compressors and on the high pressure side of reducing valves. The filters of compressors may be incorporated in the crankcases, provided their filtering area is sufficient.

b) Filters are to be fitted with a wire gauze strainer which cannot be corroded by the refrigerant and allowing a sufficient flow area for the fluid. Small filters such as those of reducing valves are to be such that they can be easily removed without any disassembling of the pipes.

7.6.3 Dehydrators

An efficient dehydrator is to be fitted. The dehydrator is to be so designed and arranged that the drying product can be replaced without any disassembling of the pipes.

7.7 Refrigerating plant overpressure protection

7.7.1 General

a) The refrigerant circuits and associated pressure vessels are to be protected against overpressure by safety valves, rupture discs or equivalent arrangement. However, inadvertent discharge of refrigerant is to be prevented.

b) The safety devices are to be in such number and so located that there is no possibility that any part of the system may be isolated from a safety device. Where it is necessary to be able to isolate one of these devices from the system for maintenance purposes, the valves may be duplicated provided a change-over valve is arranged in such a way that when one device is isolated it is not possible to shut off the other.

c) Pressure vessels connected by pieces of pipe without valves may be considered as a single pressure vessel from the point of view of overpressure protection, provided that the interconnecting pipe does not prevent effective venting of the vessels.

7.7.2 Safety valves

a) Safety valve discharges are to be led to a safe place above the deck. Discharge pipes are to be designed in such a way that the ingress of water, snow, dirt or debris affecting the operation of the system can be prevented.

b) Refrigerant pumps are to be fitted with safety valves at the discharge side. The valves may discharge at the pump suction side or at another suitable location.

c) After setting, safety valves are to be suitably protected against the possibility of inadvertent change of setting.

d) Safety valves are to lift at a pressure not more than 0,80 times the test pressure of the parts concerned.

8 Specific requirements for direct refrigerating systems

8.1 Specific requirements for air cooling systems and distribution and renewal of air in refrigerated spaces

8.1.1 Rated circulation

The air circulation system is to be so designed as to ensure as uniform as possible a distribution of air in refrigerated spaces.

8.1.2 Refrigerated air circulation systems

a) For air coolers, see [7.4.4].

b) Air coolers are to be designed for a maximum temperature difference between cooling medium and cooling air at the air cooler inlet of about 5°C for fruit cargoes and about 10°C for deep frozen goods.

c) The coils are to be divided into two sections, each capable of being easily shut off.

d) Means for defrosting the coils of the air coolers are to be provided. Defrosting by means of spraying with water is to be avoided.

e) Fans and their motors are to be arranged so as to allow easy access for inspection and repair and/or removal of the fans and motors themselves when the chambers are loaded with refrigerated goods. Where duplicate fans and motors are fitted and each fan is capable of supplying the quantity of air required, it is sufficient that easy access for inspection is provided.

f) The air circulation is to be such that delivery and suction of air from all parts of the refrigerated chambers are ensured.

g) The air capacity and the power of the fans are to be in proportion to the total heat to be extracted from the refrigerated chambers, due regard being given to the nature of the service.

9 Instrumentation, alarm, monitoring

9.1 General

9.1.1 Automation safety equipment

The automation safety equipment is to be of the fail-safe type and is to be so designed and installed as to permit manual operation. In particular, manual operation of the compressors is to be ensured in the event that any of the equipment is inoperable.

9.1.2 Regulation devices

Regulation devices such as motor-operated valves or thermostatic expansion valves are to be such that they can be isolated, thus allowing the plant to be manually operated should the need arise.

9.2 Instrumentation, alarm and monitoring arrangement

9.2.1 Compressors

Tab 5 summarises the minimum control and monitoring requirements for refrigerating compressors.

9.2.2 Refrigerating systems

Tab 6 summarises the minimum control and monitoring requirements for refrigerating systems.

Table 5 : Refrigerating compressors

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Refrigerant suction	pressure	low		X	At saturated temperature and including intermediate stages
Refrigerant discharge	pressure	high		X	
Refrigerant suction	temperature				For installations over 25 kW only
Refrigerant discharge	temperature				
Lubricating oil	pressure	low		X	
Lubricating oil	temperature				For installations over 25 kW only
Cooling water	temperature				For installations over 25 kW only
Cumulative running hours	hours				All screw compressors and installations over 25 kW only
Note 1: Shutdown is also to activate an audible and visual alarm, locally or at remote position.					

Table 6 : Refrigerating systems

Item	Indicator	Function			Comments
			Alarm	Automatic shutdown	
Chamber temperature	temperature		X		
Bilge level in refrigerated space		high	X		
Note 1: Audible and visual alarm to be activated locally or at remote position.					

10 Material tests, inspection and testing, certification

10.1 Material testing

10.1.1 The materials for the construction of the parts listed below are to be tested in compliance with the requirements of NR216 Materials and Welding:

- compressor crankshafts, couplings, connecting rods and piston rods
- compressor liners, cylinder heads and other parts subjected to pressure
- steel and copper tubing for evaporator and condenser coils and for pressure piping in general
- oil separators, intermediate receivers and other pressure vessels included in the gas circuit
- condensers and evaporators of shell type (tube or welded plate).

10.2 Shop tests

10.2.1 Individual pieces of equipment

Shop tests are to be carried out on pumps, electric motors and internal combustion engines forming parts of refrigerating installations, following procedures in accordance with the requirements applicable to each type of machinery. The relevant running data (capacity, pressure head, power and rotational speed, etc.) are to be recorded for each item.

10.2.2 Refrigerating unit

a) At least one refrigerating unit of each type installed on board is to be subjected to shop tests in order to ascertain its refrigerating capacity in the most unfavourable temperature conditions expected, or in other temperature conditions established by the Society.

b) Where the complete unit cannot be shop tested (for instance, in the case of direct expansion installations), only the compressors are to be tested according to procedures approved by the Society.

10.3 Pressure tests at the workshop

10.3.1 Strength and leak tests

Upon completion, all parts included in the suction and delivery branches of the refrigerant circuit are to be subjected to a strength and leak test.

The strength test is a hydraulic test carried out with water or other suitable liquid. The leak test is a test carried out with air or other suitable gas while the component is submerged in water at a temperature of approximately 30°C.

The components to be tested and the test pressure are indicated in Tab 7.

10.3.2 Condensers

Circulating water sides of condensers are to be subjected to a hydrostatic test at a pressure equal to 1,5 times the design pressure, but in no case less than 0,1 N/mm^2.

10.4 Thermometers and manometers

10.4.1 The following requirements shall be fulfilled:

a) All thermometers recording the temperature of refrigerated spaces, the air temperature at the inlet and outlet of air coolers and the temperature at various points in the refrigerant circuit or in the brine circuit are to be carefully calibrated by the Manufacturer. The Society reserves the right to require random checks of the calibration.

b) The accuracy of manometers and other measuring instruments is also to be checked before the commencement of the tests required in [10.5].

Table 7 :

Component	Test pressure	
	Strength test	Leak test
Compressor cylinder blocks, cylinder covers, stop valves, pipes and other components (condensers, receivers, etc.) of the high pressure part of the circuit.	1,5 p_1	p_1
Compressor crankcases subjected to refrigerant pressure, stop valves, pipes and other components of the low pressure part of the circuit.	1,5 p_2	p_2
Where p_1 and p_2 are the design pressures indicated in [6.2] for high pressure and low pressure parts.		

10.5 Shipboard tests

10.5.1 Pressure tests

After installation on board, and before operating, the plant is to be subjected to a test at the maximum working pressure determined as indicated in [6.2.1].

However, all pressure piping portions which have welded joints made on board are to be subjected to a strength test at a pressure equal to 1,5 times the rated working pressure before being insulated.

After the pressure test, and before charging with refrigerant, a vacuuming and a drying out of the complete refrigerating plant is to be carried out.

Air tightness of the refrigerated chambers is to be checked.

10.5.2 Tests of the ventilation system

After installation, the ventilation system is to be tested. The distribution of air in the various refrigerated spaces is to be checked.

10.5.3 Operational tests

a) Upon completion of the installation, each refrigerating plant is to be subjected to an operational test on board in order to check the proper operation of the machinery and the refrigerating capacity of the unit.

b) Before starting the actual test, the Surveyor will check at random that thermometers, pressure gauges and other instruments are in working order, calibrated and arranged as directed in each case by the Society.

c) All the refrigerating machinery is to be put into service and all chambers, closed and empty, are to be simultaneously cooled to the minimum expected temperature, i.e. the temperature required to be entered in the notation, or a lower temperature determined so that a difference of at least 20 °C can be maintained between the average external temperature and the temperature in the refrigerated spaces. The expected temperature is to be maintained for a period of time sufficient to remove all the heat from the insulation.

d) The regulation of the refrigerating capacity of the plant may be effected by reducing the number of running compressors, by varying their rotational speed or even by running them intermittently.

e) The following data are to be recorded in the course of the test:
   - Temperatures in the refrigerated spaces, external air temperature and sea water temperature (in particular, at the outlet and inlet of the condensers).
   - Absorbed power and speed of the compressors and the temperatures and pressures which determine the running of the refrigerating machinery.
   - Absorbed power of the motors driving the fans F_V and brine pumps F_P
   - Temperatures and pressures at various locations along the refrigerant circuits
   - Air temperatures at the inlet and outlet of air cooler.

f) Particular cases, e.g. when the test is carried out with very low external atmospheric temperatures which would require the temperature within the refrigerated spaces to be brought down below the above specified values, or where tests with empty chambers are not deemed sufficient/significant, will be specially considered by the Society. In particular, the following may be required:
   - appropriate testing conditions, such as simulation with equivalent thermal loading or chamber heating, and/or
   - a copy of the log book of the refrigerated chambers, including the temperature reading, after the first loaded voyage.

10.6 Defrosting system

10.6.1 The defrosting arrangements are also to be subjected to an operational test.

Instructions regarding the procedure to be followed for the operational test of the refrigerating plant on board will be given by the Society in each case.

Section 4 Centralised Navigation Equipment (SYS-NEQ)

1 General

1.1 Application

1.1.1 The additional class notation **SYS-NEQ** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.6.1], to ships fitted with a centralised navigation control system so laid out and arranged that it enables normal navigation and manoeuvring operation of the ship by two persons in cooperation.

This notation is assigned when the requirements of Articles [1] to [5], [7] and [8] of this Section are complied with.

1.1.2 The additional class notation **SYSNEQ-1** is assigned, in accordance with Pt A, Ch 1, Sec 2, [6.6.1], when, in addition to [1.1.1], the installation is so arranged that the navigation and manoeuvring of the ship can be operated under normal conditions by one person for periodical one man watches. This notation includes specific requirements for prevention of accidents caused by the operator's unfitness.

This notation is assigned when the requirements of this Section are complied with.

1.1.3 The composition and the qualification of the personnel on watch remain the responsibility of the Owner and the Administration. The authorisation to operate the ship in such condition remains the responsibility of the Administration.

1.2 Operational assumptions

1.2.1 The requirements are framed on the following assumptions:

- Plans for emergencies are specified and the conditions under which a one man watch is permitted are clearly defined in an operations manual which is acceptable to the Administration with which the ship is registered.
- The manning of the bridge watch is in accordance with the national regulations in the country of registration and for the waters in which the ship is operating.
- The requirements of the International Convention on Standards of Training Certification and Watchkeeping for seafarers (STCW) and other applicable statutory regulations are complied with.

1.3 Regulations, guidelines, standards

1.3.1 The requirements are based on the understanding that the applicable regulations and guidelines issued by the International Maritime Organisation are complied with, in particular:

a) Regulations 15 to 28, Chapter V of the 1974 "International Convention for the Safety of Life at Sea" (SOLAS) and applicable amendments
b) The international Regulations for Preventing Collisions at Sea and all other relevant Regulations relating to Global Maritime Distress and Safety System (GMDSS) and Safety of Navigation required by Chapters IV and V of SOLAS 1974, as amended
c) the Provisional Guidelines for the Conduct of Trials in which the Officer of the Navigational Watch acts as the sole Lookout in Periods of Darkness (MSC Circular 566 of 2 July 1991)
d) IMO A.694: 1991, General requirements for shipborne radio equipment forming part of the global maritime distress and safety system (GMDSS) and for electronic navigational aids
e) MSC Circular 982, Guidelines on ergonomic criteria for bridge equipment and layout
f) Convention on the International Regulations for Preventing Collision at Sea, 1972 (COLREG)
g) IMO Performance Standards for navigational equipment applicable to:
    - magnetic compasses (Resolution A.382)
    - gyrocompasses (Resolution A.424)
    - performance standards for radar equipment (Resolution MSC.192(79))
    - speed and distance measuring equipment (Resolution A.478, A.824, MSC.96 (72))
    - echo sounding equipment (Resolution A.224, MSC.74 (69) Annex 4)
    - electronic navigational aids – general requirements (Resolution A.574)
    - VHF Radio installation (Resolution MSC.68 (68) Annex 1, A.524 (13), A.803 (19))
    - heading control systems (HCS) (Resolution A.342, MSC.64 (67) Annex 3)
    - rate-of-turn indicators (Resolution A.526)
    - VHF watchkeeping receiver (Resolution A.803 (19), MSC.68 (68) Annex 1)

- Performance standards for track control systems (Resolution MSC.74 (69) Annex 2)
- Performance standards for marine transmitting heading devices (THDs) (Resolution MSC.116 (73))
- Performance standards for electronic chart display and information systems (Resolution A.817 (19), MSC.86 (70) Annex 4, MSC.64 (67) Annex 5)
- Maintenance of electronic chart display and information system (ECDIS) software (IMO circ.266)
- Performance standards for shipborne global positioning system receiver equipment (Resolution A.819 (19))
- Adoption of the revised performance standards for shipborne global positioning system (GPS) receiver equipment (Resolution MSC.112 (73))
- Adoption of the revised performance standards for shipborne GLONASS receiver equipment (Resolution MSC.113 (73))
- Adoption of the revised performance standards for shipborne DGPS and DGLONASS maritime radio beacon receiver equipment (Resolution MSC.114 (73)).
- Performance standards for a universal automatic identification system (AIS) (Resolution MSC.74 (69) Annex 3)
- Performance standards for an integrated navigation system (INS) (Resolution MSC.86 (70) Annex 3)
- Performance standards for sound reception systems (Resolution MSC.86 (70) Annex 1)
- performance standards for the presentation of navigation-related information on shipborne navigational displays (Resolution MSC.191(79))
- performance standards for a bridge navigational watch alarm system (BNWAS) (Resolution MSC.128(75))
- performance standards for shipborne voyage data recorders (VDRs) (Resolution A.861(20) as amended by IMO Res. MSC.214(81))

1.3.2 The requirements and guidelines of ISO 8468 – ed. 3 “Ship’s bridge layout and associated equipment– Requirements and guidelines” are applicable.

1.3.3 Additional requirements may be imposed by the national authority with whom the ship is registered and/or by the Administration within whose territorial jurisdiction it is intended to operate.

1.4 Definitions

1.4.1 Terms used in the requirements are defined below:

- Acquisition: the selection of those target ships requiring a tracking procedure and the initiation of their tracking
- Alarm: a visual and audible signal indicating an abnormal situation
- ARPA: automatic radar plotting aid
- Backup navigator: any individual, generally an officer, who has been designated by the ship’s Master to be on call if assistance is needed on the navigation bridge
- Bridge: that area from which the navigation and control of the ship is exercised, including the wheelhouse and bridge wings
- Bridge wings: those parts of the bridge on both sides of the ship's wheelhouse which, in general, extend to the ship side
- CPA: closest point of approach, i.e. the shortest target ship-own ship calculated distance that will occur in the case of no change in course and speed data
- Conning position: the place in the wheelhouse with a commanding view and which is used by navigators when monitoring and directing the ship mouvements
- Display: means by which a device presents visual information to the navigator, including conventional instrumentation
- Ergonomics: application of the human factor in the analysis and design of equipment, work and working environment
- Field of vision: angular size of a scene that can be observed from a position on the ship's bridge
- Lookout: activity carried out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision
- Navigation: all tasks relevant for deciding, executing and maintaining course and speed in relation to waters and traffic
- Navigator: person navigating, operating bridge equipment and manoeuvring the ship
- NAVTEX: an international maritime radio telex system sponsored by IMO and IHO, which automatically receives the broadcast telex information such as navigational, meteorological warnings and search and rescue (SAR) alerts on a 24-hour watch basis
- Normal conditions: when all systems and equipment related to navigation operate within design limits, and environmental conditions such as weather and traffic do not cause excessive workload to the officer of the watch
- Officer of the watch: erson responsible for safe navigating, operating of bridge equipment and manoeuvring of the ship
- OMBO: one man bridge operation
- OMBO ship: one man bridge operated ship

- Radar plotting: the whole process of target detection, tracking, calculation of parameters and display of information
- Seagoing ship: ship navigating on the high seas, i.e. areas along coasts and from coast to coast
- TCPA: time to closest point of approach
- Tracking: process of observing the sequential changes in the position of a target, to establish its motion
- Vigilance system: system provided to verify the officer of the watch's alertness
- Watch alarm: alarm that is transferred from the bridge to the Master and the backup navigator in the event of any officer of the watch deficiency (absence, lack of alertness, no response to another alarm/warning, etc.)
- Wheelhouse: enclosed area of the bridge
- Workstation: position at which one or several tasks constituting a particular activity are carried out.

2 Documentation

2.1 Documents to be submitted

2.1.1 In addition to the documents mentioned in Pt C, Ch 3, Sec 1, Tab 1, and the requirement in Pt C, Ch 3, Sec 1, [2.1.1], documents according to Tab 1 are to be submitted.

2.1.2 Additional plans and specifications are to be submitted for approval, if requested by the Society.

3 Bridge layout

3.1 General

3.1.1 The bridge configuration, the arrangement of consoles and equipment location are to enable the officer of the watch to perform navigational duties and other functions allocated to the bridge as well as maintain a proper lookout from a convenient position on the bridge, hereafter referred to as a 'workstation'.

3.1.2 A workstation for navigation and traffic surveillance/manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions. All relevant instrumentation and controls are to be easily visible, audible and accessible from the workstation.

3.1.3 The bridge layout design and workstations are to enable the ship to be navigated and manoeuvred safely by two navigators in cooperation.

3.1.4 The requirements and guidelines of the ISO 8468 Standard are to be regarded as a basic reference for the design of bridge layout.

4 Bridge instrumentation and controls

4.1 General

4.1.1 The instrumentation and controls at the workstation for navigation and traffic surveillance/manoeuvring are to be arranged to enable the officer of the watch to:

a) determine and plot the ship's position, course, track and speed
b) analyse the traffic situation
c) decide on collision avoidance manoeuvres
d) alter course
e) change speed
f) effect internal and external communications related to navigation and manoeuvring, radio communication on the VHF
g) give sound signals
h) hear sound signals
i) monitor course, speed, track, propeller revolutions (pitch), rudder angle and depth of water
j) record navigational data (may be manually recorded from data available at the workstation).

4.1.2 Irrespective of their size, gross tonnage and date of construction, all ships assigned the additional class notation **SYS-NEQ** are to be equipped with the instrumentation and controls described in [4.2] to [4.4] and as referred to in Tab 2.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	A	General arrangement of bridge and wheelhouse showing the position of the control console and panels
2	A	Plans showing the field of vision from each workstation
3	A	List and specification of navigational equipment fitted on the bridge and references (Manufacturer, type, national authority approval...)
4	A	Functional block diagram indicating the relationship between the items of navigational equipment and between them and other equipment
5	A	List of alarms and instrumentation fitted on the bridge
6	A	Diagram of electrical supply to the navigational equipment
7	A	Diagram of the system linking the bridge alarms with the other operational locations **(2)**
8	A	Diagram of the navigation officer's call system **(2)**
9	A	Diagram of the communication systems **(2)**
10	A	Diagram of the vigilance systems **(2)**
11	A	Test program including test method
12	I	List of the intended area of operation of the ship

(1) A : to be submitted for approval
I : to be submitted for information.
(2) Documents to be submitted only when a **SYSNEQ-1** notation is requested.

Table 2 : List of mandatory equipment

Equipment	Additional class notations	
	SYS-NEQ	**SYS-NEQ 1**
Multifunction displays - according to MSC.191(79)	optional	optional
Radar **(1)**	CAT 1/2/3	CAT 1
Gyrocompass	one	one
Magnetic compass	yes	yes
Spare magnetic compass or second gyrocompass fed by main and emergency power supply and in addition by a transitional power supply (e.g. battery)	yes	yes
Transmitting Heading Device (THD)	yes	yes
Heading Control System (HCS), formerly autopilot	yes	yes
ECDIS with backup	yes	yes
Position receiver (GNSS ...)	one	one
Bridge Navigation Watch Alarm System (BNWAS)	yes	yes
Call system (back-up Officer)	yes	yes
Alarm transfer system	yes, at least to master's cabin	yes, at least to master's cabin
Central alarm panel	yes	yes
Echo sounder	yes	yes
Speed Distance and Measuring Equipment (SDME)**(2)**	yes	yes
Sound reception (if totally enclosed bridge)	yes	yes
VHF at conning position	one	one
NAVTEX	yes	yes
Weather chart facsimile	yes	yes
Wind speed and direction	yes	yes
AIS	yes	yes
VDR	yes	yes

(1) According to [4.2.1]
H: when approched for high speed application
(2) Speed of the ship through the water and over the ground

Table 3 : Categories of ship with their radar performance requirements

	Category of ship		
	CAT 3	CAT 2	CAT 1
Size of ship/craft	<500 gt	500 gt to < 10000 gt	≥ 10000 gt
Minimum operational display area diameter	180 mm	250 mm	320 mm
Minimum display area	195 mm x 195 mm	270 mm x 270 mm	340 mm x 340 mm
Auto acquisition of targets	-	-	yes
Minimum acquired radar target capacity	20	30	40
Minimum activated AIS target capacity	20	30	40
Minimum sleeping AIS target capacity	100	150	200
Trial manoeuvre	-	-	yes

4.2 Safety of navigation: collision-grounding

4.2.1 The ship is to be equipped with an RADAR/ARPA system meeting the requirements of IMO Resolution MSC.192(79)).

The categories of ship with their radar performance requirements are specified in Tab 3.

4.2.2 An heading control system (HCS) is to be provided and monitored by a heading alarm addressed to the navigator, in case of malfunction. This alarm is to be derived from a system independent from the automatic steering system. An overriding control device is to be provided at the navigating and manoeuvring workstation.

4.3 Position fixing

4.3.1 Ships are to be provided with the following position systems:

a) position fixing systems appropriate to the intended service areas

b) at least two independent radar, one of which is to operate within the X-band

c) a gyrocompass system

d) a speed log system

e) an echo sounding system.

f) an ECDIS with backup arrangement.

4.4 Controls - Communication

4.4.1 Ships are to be provided with the following control and communication:

a) a propulsion plant remote control system, located on the bridge

b) a whistle control device

c) a window wipe and wash control device

d) a main workstation console lighting control device

e) steering pump selector/control switches

f) an internal communication system

g) a VHF radiotelephone installation

h) a wheelhouse heating/cooling control device

i) a NAVTEX automatic receiver and recorder.

Note 1: The systems or controls under a) to g) are to be fitted within the reach of the officer of the watch when seated or standing at the main navigating and manoeuvring workstation.

5 Design and reliability

5.1 General

5.1.1 Where computerised equipment is interconnected through a computer network, failure of the network is not to prevent individual equipment from performing its individual functions.

5.2 Power supply

5.2.1 Power supply for AC equipment

a) Power to navigation equipment is to be supplied by two circuits, one fed directly from the main source of electrical power, and one fed directly from the emergency source of power. Power to radio equipment is also to be supplied by two circuits as described above and is additionally to be supplied by a reserve source of energy.

b) The power supplies to the distribution panels are to be arranged with automatic change-over facilities between the two sources.

c) The distribution of supplies to navigation equipment is to be independent of those for radio equipment. The circuits from the power sources is to be terminated either in one or two distribution panels. When one distribution panel is used, the two circuits supplying power to the panel are to be provided with split feeds into two separate bus bars, one for the radio equipment and one for the navigation equipment. The panel(s) is(are) to be sited on the navigation bridge or other suitable position on the bridge deck.

d) The circuits supplying the board(s) are, as far as practicable, to be separated from each other throughout their length. Facilities are to be provided in each distribution board for changing over between the main source of power and the emergency source of power. It is preferable that change over be initiated automatically. When a single distribution board is used for both radio and navigation equipment, separate change-over switches are to be provided for each service.

e) Where radio equipment requires an uninterrupted input of information from the ship’s navigational equipment or other equipment, it is necessary for the equipment providing the data to be supplied from the same distribution board bus serving the radio equipment rather than the bus bar serving the navigation equipment.

f) Failure of any power supply to the panel is to initiate and audible and visual alarm at the navigation bridge.

g) Each consumer is to be individually connected to the distribution panel bus bar and individually provided with short-circuit protection.

h) An indicator is to be mounted in a suitable place to indicate when batteries of the reserve source of energy are being discharged.

5.2.2 Power supply for DC equipment

a) The requirements of [5.2.1] are applicable.

b) Where the equipment is fed via converters, separate converters are to be provided and these are to be located on the supply side of change-over facility.

c) The radio equipment and the navigation equipment are to be provided with separate converters.

5.2.3 Power supply for equipment operated either AC or DC

a) Each consumer is to be individually connected to the main source of electrical power and to a distribution bus bar of the panel which is fed from the emergency source of electrical power and also, in case of the radio equipment, from the reserve source of energy (radio batteries). These two circuits are to be separated throughout their length as fas as practicable.

b) The radio equipment and the navigation equipment are to be provided with separate converters.

c) An indicator is to be mounted in a suitable place visible for responsible member of the crew to indicate when batteries of the reserve source of energy are being discharged.

5.2.4 Following a loss of power which has lasted for 30 seconds or less, all primary functions are to be readily reinstated. Following a loss of power which has lasted for more than 30 seconds, as many primary functions as practical are to be readily reinstated.

5.3 Environmental conditions

5.3.1 Shipborne navigational equipment specified in IMO Publication 978-88-04E “PERFORMANCE STANDARDS FOR NAVIGATIONAL EQUIPMENT” is to be capable of continuous operation under the conditions of various sea states, vibration, humidity, temperature and electromagnetic interference likely to be experienced in the ship in which it is installed.

5.3.2 Equipment which has been additionally specified in this notation is to comply with the environmental conditions specified in Pt C, Ch 2, Sec 2 for control and instrumentation equipment, computers and peripherals for shipboard use.

6 Prevention of accidents caused by operator’s unfitness

6.1 Bridge safety system

6.1.1 A vigilance system is to be provided to indicate that an alert officer of the navigational watch is present on the bridge.

6.1.2 Any system used for verification of the officer of the navigational watch's alertness is not to cause undue interference with the performance of bridge functions.

6.1.3 The system is to be so designed and arranged that it cannot be operated in an unauthorised manner, as far as practicable.

6.1.4 Any system used for periodical verification of the officer of the navigational watch's alertness is to be adjustable up to 12 minutes intervals and constructed, fitted and arranged so that only the ship's Master has access to the component for setting the appropriate intervals.

6.1.5 The system is to provide for the acknowledgement by the officer of the navigational watch at the navigating and traffic surveillance/manoeuvring workstation and other appropriate locations in the bridge from where a proper lookout may be kept.

6.1.6 Such system is to be connected to the alarm transfer system described in [6.3].

6.1.7 An alarm is to operate on the bridge in the event of a failure of the bridge safety systems.

6.1.8 The requirements of [6.1.1] to [6.1.7] do not prevent the Society from accepting any technical systems that adequately verify or help maintain the alertness of the officer of the watch at intervals up to 12 minutes.

6.2 Field of vision

6.2.1 For the purpose of performing duties related to navigation, traffic surveillance and manoeuvring, the field of vision from a workstation is to be such as to enable observation of all objects which may affect the safe conning of the ship. The field of vision from a workstation is to be in accordance with the guidelines on navigation bridge visibility, as specified in IMO Resolution A.708, MSC Circular 982 and ISO 8468 ed.3 as it applies to new ships.

6.3 Alarm/warning transfer system - Communications

6.3.1 Any alarm/warning that requires bridge operator response is to be automatically transferred to the Master and, if he deems it necessary, to the selected backup navigator and to the public rooms, if not acknowledged on the bridge within 30 seconds.

Such transfer is to be carried out through the systems required by [6.3.3] and [6.3.7], where applicable.

6.3.2 Acknowledgement of alarms/warnings is only to be possible from the bridge.

6.3.3 The alarm/warning transfer is to be operated through a fixed installation.

6.3.4 Provision is to be made on the bridge for the operation of a navigation officer call-alarm to be clearly audible in the spaces of [6.3.1].

6.3.5 The alarm transfer system is to be continuously powered and have an automatic change-over to a standby power supply in the case of loss of normal power supply.

6.3.6 At all times, including during blackout, the officer of the watch is to have access to facilities enabling two-way speech communication with another qualified officer.

The bridge is to have priority over the communication system.

Note 1: The automatic telephone network is acceptable for this purpose, provided that it is automatically supplied during blackouts and that it is available in the locations specified in [6.3.1].

6.3.7 If, depending on the shipboard work organisation, the backup navigator may attend locations not connected to the fixed installation(s) described in [6.3.1], he is to be provided with a portable wireless device enabling both the alarm/warning transfer and the two-way speech communication with the officer of the watch.

6.3.8 External sound signals from ships and fog signals that are audible on open deck are also to be audible inside the wheelhouse; a transmitting device is to be provided to reproduce such signals inside the wheelhouse (recommended frequency range: 70 to 700 Hertz).

6.4 Bridge layout

6.4.1 The bridge configuration, the arrangement of consoles and equipment location are to enable the officer of the watch to maintain a proper lookout from a convenient workstation.

6.4.2 A workstation for navigation and traffic surveillance/manoeuvring is to be arranged to enable efficient operation by one person under normal operating conditions.

7 Ergonomical recommendations

7.1 Lighting

7.1.1 The lighting required on the bridge should be designed so as not to impair the night vision of the officer on watch. Lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision adaptation is not impaired, e.g. red lighting. Such lighting is to be arranged so that it cannot be mistaken for a navigation light by another ship. It is to be noted that red lighting is not to be fitted over chart tables so that possible confusion in colour discrimination is avoided.

7.2 Noise level

7.2.1 The noise level on the bridge should not interfere with verbal communication and mask audible alarms.

7.3 Vibration level

7.3.1 The vibration level on the bridge should not be uncomfortable to the bridge personnel.

7.4 Wheelhouse space heating/cooling

7.4.1 Unless otherwise justified, wheelhouse spaces are to be provided with heating and air cooling systems. System controls are to be readily available for the officer of the watch.

7.5 Navigator's safety

7.5.1 There are to be no sharp edges or protuberances on the surfaces of the instruments and equipment installed on the bridge which could cause injury to the navigator.

7.5.2 Sufficient handrails or the equivalent are to be fitted inside the wheelhouse or around instruments and equipment therein for safety in bad weather.

7.5.3 Adequate means are to be made for anti-slip of the floor, whether it is dry or wet.

7.5.4 Doors to the bridge wings are to be easy to open and close. Means are to be provided to hold the doors open at any position.

7.5.5 Where provision for seating is made in the wheelhouse, means for securing are to be provided, having regard to storm conditions.

8 Testing

8.1 Tests

8.1.1 Documentary evidence in the form of certification and/or test results is to be submitted to the satisfaction of the Society. Where acceptable evidence is not available, the requirements of Pt C, Ch 3, Sec 6 are applicable.

8.1.2 Shipboard tests and sea trials are to be carried out in accordance with the test procedures submitted for approval in advance to the Society. Tests and trials are to be performed under the supervision of a Surveyor of the Society.

8.1.3 After fitting on board, the installations are to be submitted to tests deemed necessary to demonstrate correct operation. Some tests may be carried out at quay side, while others are to be effected at sea trials.

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