NR445 D DT R08 JANUARY 2024

RULES FOR THE CLASSIFICATION OF OFFSHORE UNITS

NR445 – JANUARY 2024

PART D
SERVICE NOTATIONS

OFFSHORE UNITS

BUREAU VERITAS

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RULES FOR THE CLASSIFICATION OF OFFSHORE UNITS

NR445 - JANUARY 2024

PART A
CLASSIFICATION AND SURVEYS
NR445 A DT R07 JANUARY 2024

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This version of the document takes precedence over previous revision. Unless otherwise specified, these rules apply to ships for which contracts are signed on or after January 1st, 2024. The Society may refer to the contents hereof before January 1st, 2024, as and when deemed necessary or appropriate.

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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.

BUREAU VERITAS MARINE & OFFSHORE

Tour Alto
4 place des Saisons
92400 Courbevoie - France
+33 (0)1 55 24 70 00

marine-offshore.bureauveritas.com/rules-guidelines

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NR445

RULES FOR THE CLASSIFICATION OF OFFSHORE UNITS

Part D
Service Notations

January 2024

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Part D
Service Notations

CHAPTER 1
PRODUCTION, STORAGE AND OFFLOADING SURFACE UNITS

Section 1 General

1 Application

1.1 General

1.1.1 The present Chapter deals with particular provisions applicable to floating units for production, and/or storage of hydrocarbons and intended to be assigned with one of the notations listed in [1.2.1].

1.1.2 Requirements of the present Chapter are complementary to the provisions of Part A, Part B and Part C which remain applicable, except where otherwise specified.

1.2 Class Notations

1.2.1 Structural type notations

Requirements of the present Chapter apply to surface units having one of the following structural type notations:

- **offshore barge** - which may be granted to surface type floating units, including the case of converted ships, when unable to perform non-assisted voyages.
- **offshore ship** - which may be granted to surface type floating units having a propulsion system and steering appliances for transit purpose, but not involved in the transport of cargoes, as defined in [3.2.14].

1.2.2 Service notations

This Chapter applies to units having at least one of the following service notations:

- **oil storage** - which may be granted to surface units engaged in the storage of oil products (in significant quantities).
- **oil production unit** - which may be granted to surface units designed and equipped for oil production and related activities.

For the definition of these notations, see Part A, Chapter 1.

1.2.3 Site, transit and navigation notations

Site, transit and navigation notations are granted in accordance with the provisions of Pt A, Ch 1, Sec 2, [7].

1.2.4 Additional service features

The following additional service features defined in Pt A, Ch 1, Sec 2 are mandatory for units covered by the present Chapter:

- **POSA**, **POSA HR** or **POSA JETTY**
- **INERTGAS** (mandatory for units with service notation **oil storage** and for units with service notation **oil production unit** having integrated process tanks)

1.2.5 Additional class notations

The following additional class notations are mandatory for units covered by the present Chapter:

- **AUTO**
- **INWATERSURVEY** (mandatory for permanent units)
- **VeriSTAR-HULL**

Other additional class notations defined in Part A may be granted to units covered by the present Chapter.

Besides, the additional class notations as given by the Ship Rules may be granted.

1.2.6 Comfort on board floating units

The additional class notations **COM HEALTH-NOISE-g** and **COMF HEALTH-VIB-g** defined in Pt A, Ch 1, Sec 2, [8.4.3], are relevant to the assessment of comfort and health on board floating units with regard to the level of noise and/or vibration.

1.3 Scope

1.3.1 Classification Society involvement

The scope of classification for units listed in [1.2.1] is based on an appraisal of the integrated unit covering, in general:

a) Hull, accommodation, helideck and hull attachments and appurtenances including:
   - riser support structure
   - structure to which the moorings are attached, and supports for mooring equipment
   - foundations for the support of topsides modules, the flare tower, and the hull mounted equipment
   - support structure for life saving appliances
   - passive fire protection and cathodic protection.

b) Intact and damage stability.

c) Marine equipment (with foundations) pertaining to the offloading facilities.

d) Accommodation quarters/

e) Mooring system:

- for the additional service feature **POSA**:
  mooring line components (anchors, chains, wire and accessories) and hull mounted equipment (fairleads, stoppers...)
- for the additional class notation **OHS**:
  mooring line handling equipment (winch, sheaves...).

f) Lifting appliances (for the additional class notation **ALM**).

g) Equipment and systems necessary for the safe operation of the hull and to the safety of personnel on board, as defined in the present Rules and related applicable Rules (taking into account the class notations **AUTO**, **INERTGAS** and **LSA**).

h) Equipment and systems installed in the hull, the failure of which may jeopardise the safety of the floating unit.

i) The fire and gas detection system for the hull as well as the definition of the hazardous areas of the hull.

j) The fire water and foam system for the protection of the hull.

k) Topsides process plant.

l) Propulsion plant.

Some of the systems and items mentioned in items g), h), i), j) and k) above are possibly positioned in topsides facilities and remain under the scope of classification, regardless of the additional class notation **PROC** (see also [1.8.2]).

For each project, the detailed boundaries for the classification of **offshore barge** or **offshore ship** are defined by the Society on a case-by-case basis and with reference to the requested structural type and service notations, additional class notations and additional service features.

1.3.2 Classification - Design Criteria Statement

Classification is based upon the design data or assumptions specified by the party applying for classification.

A Design Criteria Statement is to list the services performed by the unit and the design conditions and other assumptions on the basis of which class is assigned to the unit.

The Design Criteria Statement is to be:

- issued by the Society
- referred to on the unit classification certificate
- incorporated in the Operating Manual, as stated in Pt A, Ch 1, Sec 1, [3.4].

Additional details about the Design Criteria Statement are given in Pt A, Ch 1, Sec 1, [1.6].

1.3.3 Classification process

For units intended to have one of the notations given in [1.2.1], the classification process, prior to issuance of the final class certificate, includes towing from completion yard to site (see [1.10], hook-up operations and commissioning at site.

Procedures and detailed schedules for construction at each construction site together with towing/transit, installation, anchoring and production hook-up, and commissioning activities are to be submitted to the Society for information. These documents are also to indicate the possible interfaces between the parties involved. Basing on these documents, the Society prepares the survey program for inspection and drawing review.

1.3.4 Permanent installations

Surface units having one of the notations given in [1.2.1] are considered as permanent installations when performing their service either:

- at a single location, or
- on a single site for a duration not less than, typically, 5 years.

Two types of permanent installations are to be considered:

- disconnectable, when the unit has a means of disengaging from its mooring and riser systems in extreme environmental or emergency conditions
- non-disconnectable.

A permanent installation is assigned with a site notation consisting in the name of the unit operation field.

1.3.5 Non-permanent installations

In case of mobile units not considered as permanent installations, special requirements are to be met, based on the operating requirements. Such requirements are to be mentioned in the Design Criteria Statement and may influence not only the design but also the in-service inspections.

1.4 Applicable rules

1.4.1 General application of the Rules

The provisions of these Rules are applicable to the design and construction of newbuild surface units and to reassessment and conversion work of an existing unit or ship when converted to a unit covered by the present document (see also [1.5.3]).

When reference is made to “Ship Rules”, the applicable requirements are those for ships greater than 65 m in length. In case of converted ships, the Society reserves the right to refer to editions of the Ship Rules published prior the conversion stage.

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

1.4.2 Hull structure

The Sections to be applied for the hull scantling and arrangement are given in Tab 1.

1.4.3 Other structure

The Sections to be applied for the scantling and arrangement of specific structures are given in Tab 2.

1.4.4 Systems

The Sections to be applied for the design and arrangement of systems are given in Tab 3.

Table 1 : Sections applicable for hull scantling

<table>
<tr><th rowspan="2">Part</th><th colspan="2">Applicable Sections</th></tr>
<tr><th>General</th><th>Specific</th></tr>
<tr><td>Fore part</td><td rowspan="3">Ch 1, Sec 1
Ch 1, Sec 2
Ch 1, Sec 3
Ch 1, Sec 4
Ch 1, Sec 15</td><td>Ch 1, Sec 11</td></tr>
<tr><td>Central part</td><td>Ch 1, Sec 6
Ch 1, Sec 7
Ch 1, Sec 8
Ch 1, Sec 9
Ch 1, Sec 10</td></tr>
<tr><td>Aft part</td><td>Ch 1, Sec 12</td></tr>
</table>

Table 2 : Sections applicable for scantling of other structures

Item	Applicable Sections or Articles
Superstructures and deckhouses	Ch 1, Sec 13
Station keeping	Ch 1, Sec 14, [1]
Topside	Ch 1, Sec 14, [2]
Helicopter decks	Ch 1, Sec 14, [3]
Boat landing	Ch 1, Sec 14, [4]
Hull outfitting	Ch 1, Sec 14, [4]

Table 3 : Sections applicable to systems

Item	Applicable Sections
Access, openings, ventilation and venting of spaces in the storage area	Ch 1, Sec 16
Equipment and Safety Particulars	Ch 1, Sec 17
Piping	Ch 1, Sec 18
Use of process gas and crude oil as fuel	Ch 1, Sec 19
Swivels and risers	Ch 1, Sec 20

1.5 Structural requirements

1.5.1 Definition

Surface units are in principle similar to oil trading tankers, the main differences being in the following parameters:

- specific site as opposed to ocean trading
- towing or transit limited to voyage between the constructing shipyard and the intended site, and between different shipyards
- continuous loading and offloading operations at sea
- topsides facilities in continuous operations
- inspection, repair and maintenance at sea, with no dry-docking for the intended design life
- units permanently moored.

The related documentation is to be made available to the Society for reference.

1.5.2 Principles

Design loads and motions are to be evaluated, based on the following:

a) classification marks and notations

b) environmental conditions (transit/towing phases, site)

c) production effects (lightweight, loading cases).

When a navigation notation completes the site and/or transit notations (as defined in Pt A, Ch 1, Sec 2, [7]), the estimated loads and motions from the hydrodynamic analysis are to be compared to the rule values given for the granted navigation notation in order to determine the rule design loads and motions.

A Design Criteria Statement, as defined in [1.3.2], lists the services performed by the unit and the design conditions and other assumptions (including results of the hydrodynamic analysis) on the bases of which class is assigned to the unit.

Considering the design life with possible objective of no dry-docking during this period, accessibility for in-service inspections is to be considered during the detailed design phase.

1.5.3 Conversion, redeployment or life extension of existing units

As a rule, structural reassessment is mandatory in case of redeployment, life extension or conversion work of existing units or ships (see NI593).

A feasibility study is required for projects based on conversion of existing seagoing ships into units intended to have one of the notations given in [1.2.1].

As a minimum, complete re-measurements of the scantlings, including comprehensive surveys, are required to evaluate the condition of the unit.

1.5.4 Loads

The design of the structure is to consider the relevant loading conditions and associated loads, including:

a) still water conditions

b) extreme environmental conditions during unit operation (100-year wave)

c) offloading conditions

d) limiting conditions before the disconnection from a single point mooring, if relevant

e) conditions during maintenance or inspection operations

f) transit/towing conditions, from the construction/conversion location to offshore site and between the different construction shipyards, when relevant

g) loads induced by process and other equipment, in above conditions, as relevant

h) damaged conditions, in accordance with the provisions of Part B, Chapter 2 and Part B, Chapter 3, and taking into account the damage assumptions as given in Ch 1, Sec 2.

1.5.5 Hull attachments and appurtenances

Loads on the hull are to be clearly identified by the shipyard or the designer. All structures welded to the hull (such as major supports for topsides, flare tower, pipe rack and other hull appurtenances) should be considered regardless of the actual scope of Classification for these structures. Loads are to be indicated for operation, design, towing and damage conditions.

When attached structures and equipment are designed by an independent contractor, the Society may require the Owner to provide additional design analysis integrating the loads on attached structures and structure design of the hull, if not foreseen in design specification.

The attachments and appurtenances are within the scope of Classification if the supported equipment is either within the scope of Classification or essential for the safety of the unit. Otherwise, the interface between classed and non-classed parts is to be defined on a case-by-case basis.

1.5.6 Definition of ship areas

For the hull construction, and similarly to the approach for the design detailed in the present Rules, the shipbuilding practice, the industry and regulatory requirements and the Ship Rules (as defined in [3.2.6]) are the base references for the construction of the hull current parts, including materials, details, welding qualification, fabrication tolerances and inspection (see Ch 1, Sec 3, [2.3]). Any deviation from these standards is to be clearly documented on the construction drawings and in the specifications.

When the Ship Rules are applied for the design of the hull current parts, attention is to be paid to the loads specified in [1.5.4].

The Society reserves the right to require additional documentation for the design of ship structures like skeg, bilge, equipment supports, etc.

1.5.7 Definition of offshore areas

For the areas specific to offshore service, such as the elements listed in Ch 1, Sec 3, Tab 1, reference is made to Part B. More details are given in Ch 1, Sec 3, [2.2].

In case of conflict between the Ship Rules and the present Chapter, the latter one is to take precedence over the requirements of the Ship Rules.

1.6 Design life

1.6.1 The requirements about the design life, unit modifications and unit re-assessment are given in Pt A, Ch 1, Sec 1, [1.7].

1.7 Station keeping

1.7.1 General

The additional service features **POSA**, **POSA HR** and **POSA JETTY** cover the complete installation, from anchors or piles and their fixation in seabed to the fastening devices on the unit hull for mooring. The provisions for classification are given in NR493.

Note 1: Classification of the position mooring equipment is mandatory for permanent units.

The station keeping of the unit may be reached by different design configurations, which are subject to review, on a case-by-case basis:

a) The floating structure may use catenary, taut spread moorings and/or dynamic positioning systems. Mooring lines may be either combined into a turret base (SPM – Single Point Mooring) with a single point of contact to the hull of the floating unit, or connected to the hull in more than one position (spread mooring system).
b) The floating unit may be connected to a fixed tower using a pendulum link arrangement instead of the mooring hawser.
c) The mooring system may be based on use of the Catenary Anchor Leg Mooring (CALM) concept (pendulum link or rigid arm connection to the hull of the floating unit).
d) The floating structure may have an external or internal turret in the hull enabling the hull to weathervane (in particular for units positioned in severe environmental areas).
e) The floating structure may be moored permanently to a jetty.

The assessment of a mooring system requires evaluation of the unit motions, the resulting excursions and the line tensions, under specified environmental conditions.

The structural parts of the station keeping system are to comply with Part B, Chapter 2 and Part B, Chapter 3, in addition to the provisions of NR493.

When the station keeping of the unit is achieved by means of a turret, the turret structure and structures connecting the turret to the hull are to be designed in accordance with the provisions of Ch 1, Sec 14, [1.2].

When the station keeping of the unit is achieved by means of a spread mooring system, reference is made to Ch 1, Sec 14, [1.3].

1.7.2 Dynamic positioning systems

The mooring system may consist, either partly (combined with passive mooring systems as described in [1.7.1]) or entirely, in dynamic positioning systems, for which reference is made to the requirements given for additional class notation **DYNAPOS** in the Ship Rules, Pt F, Ch 11, Sec 6.

1.7.3 Mooring to buoy

The mooring of the floating unit may be realized through a buoy, which is a floating body, usually not manned, generally of a cylindrical shape, and fitted with mooring equipment as deemed necessary. Such buoy may also ensure the fluid transfer between the production and/or storage unit or the onshore installation and the moored floating unit.

The buoy, mooring system included, is to be classed by the Society. The additional service feature **POSA** is to be granted to the buoy.

The arrangement of the buoy is to comply with NR494, Rules for the Classification of Offshore Loading and Offloading Buoys.

1.7.4 Single Point Mooring

For mooring to an existing Single Point Mooring (SPM) (possibly classed by another Classification Society), detailed documentation of the SPM is to be submitted to the Society for review. This documentation is to include certificate, design and maintenance. The Society reserves the right to require complete re-classification of the installation, including remeasurement of lines and anchors.

1.8 Scope of additional class notations

1.8.1 Classed topsides - Notation PROC

The structure of topside modules supporting entirely the classed equipment is covered by class and is to be designed and built in accordance with the relevant requirements of Part B, Chapter 2 and Part B, Chapter 3.

When the additional class notation **PROC** is granted, the structure of deck modules, flare boom and other structures housing production equipment, as well as related facilities, are to be designed and built in accordance with the relevant requirements of Part B, Chapter 2 and Part B, Chapter 3.

When not subjected to green waters, and subject to the Society agreement, topsides structures may be designed following other recognized standards, provided due consideration is given to inertial loads, overall deformations of the unit, differential displacements of support points and other relevant loadings, in accordance with the provisions of Part B, Chapter 2.

1.8.2 Notation PROC not requested

When the additional class notation **PROC** is not requested, the structure of deck modules, flare boom and other structures housing production equipment are not covered by the classification.

For equipment and piping installations, where classed systems within the hull have some part of their facilities located within the topsides, these facilities are covered by the classification. The Society reserves the right to include in the scope of classification the structure of the supporting skid and its connection to the topside structure, even if this structure is mainly supporting production facilities.

The classification covers the equipment necessary to the proper operation of these systems, as requested by the Rules and other related applicable rules or standards.

Classification excludes all the equipment only necessary to the operation of the topsides systems. For these systems, upon receipt of specific information and request, the Society endeavours to verify that failure of equipment and systems external to the scope of classification does not impair significantly the hull installation. For the structure supporting classed equipment, the attending Surveyor verifies the proper fitting of the local supporting elements, as indicated by the equipment manufacturer.

Particular attention is to be paid to the design of the pipe rack on the main deck, which remains within the scope of classification, regardless of the presence of pipes serving the topsides process plants.

Fig 1 and show examples of classification limits for different types of appurtenances.

1.8.3 Riser attachment - Additional class notation RIPRO

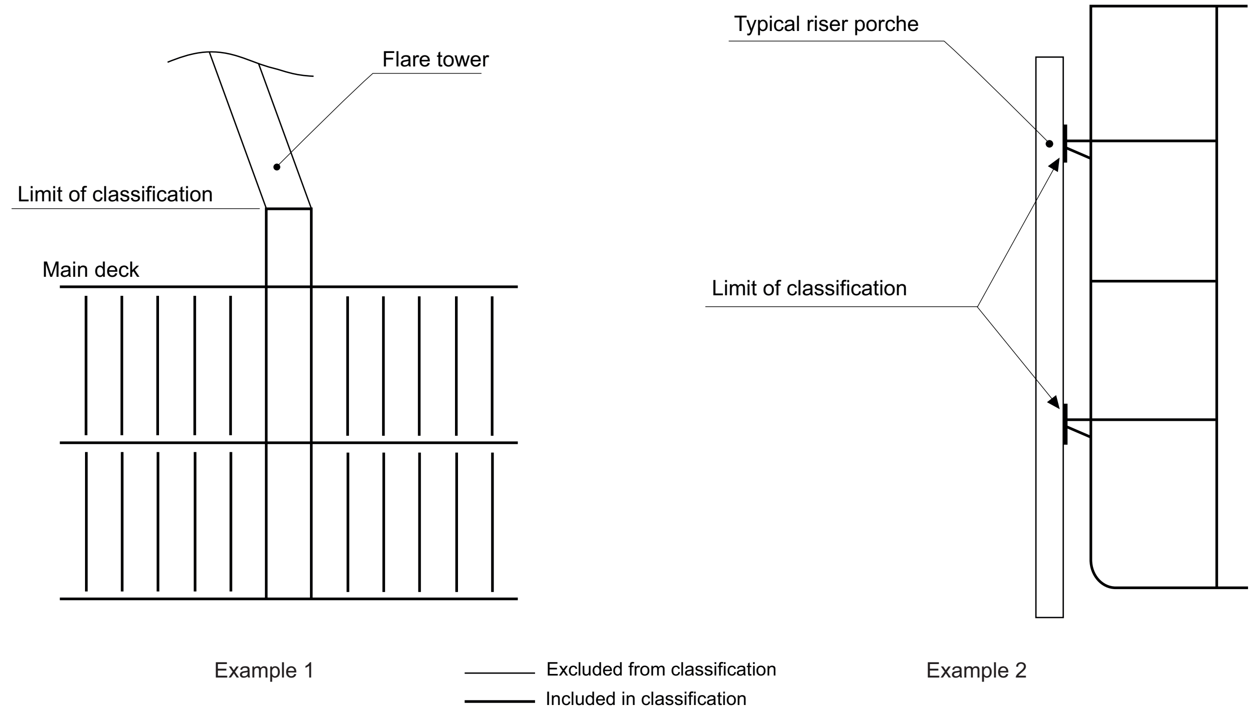
The additional class notation **RIPRO** may be assigned to units fitted with risers meeting the requirement of Ch 1, Sec 20, [2].

In case the additional class notation **RIPRO** is not requested by the Owner, the classification is limited to the riser foundations securing the risers to the floating unit. Documentation of the estimated design loads is to be submitted to the Society for information.

As risers influence the anchoring system of the hull, the Society reserves its right to require appropriate documentation for the installation, the additional class notation **RIPRO** being or not being requested.

Equipment fitted onboard for the installation of risers are considered as outside the scope of classification unless requested by the Owner or unless an additional class notation for the lifting appliances is requested. The attachment of all equipment to the hull structure is covered by classification and it is to be documented that the resulting loads on the hull are based on breaking strength of the wires used during installation.

Figure 1 : Examples of classification limits



1.8.4 Lifting appliances - Additional class notations ALP and ALM

The additional class notations **ALP** and **ALM** may be assigned to units equipped with cranes and other lifting appliances meeting the relevant requirements of NR526, Rules for the Certification of Lifting Appliances onboard Ships and Offshore Units.

When no additional class notation for lifting appliances is granted, the classification covers only the crane pedestal and its foundation welded to the hull, considering the loads specified by the designer.

When the crane pedestal and its foundation are welded to a classed topside structure covered by the notation **PROC**, they are covered by class for the specific loads provided by the designer.

When one of the additional class notations **ALP** and **ALM** is granted and the crane pedestal is partially or completely supported by a topside structure not covered by class (notation **PROC** not requested), the crane pedestal and its foundation are not covered by class. In case the pedestal is connected to the topside structure and extended over the hull, only the part of pedestal connected to the hull is classed for the specific loads provided by the shipyard.

The structure calculation for the crane pedestal and its foundation is to be submitted to the Society for information if not requested otherwise for classification.

Note 1: For the additional class notations **ALP** and **ALM**, the construction mark as defined in Pt A, Ch 1, Sec 2 is required.

1.9 Classification and temporary conditions during construction

1.9.1 In accordance with the provisions of classification, any temporary conditions during fabrication, load out, intermediate towing/transit between two construction sites before complete finalisation of the unit and final load out of topside modules are considered beyond the scope of classification, unless specific demand has been received from the party applying for classification.

1.9.2 Corrosion protection systems are to be arranged for the hull during the outfitting phase. The documentation is to be submitted to the Society for information. The Society may require thickness measurements to be carried out prior to the hull leaving the yard.

1.10 Classification and towing/transit

1.10.1 General

The towing or sailing by means of own propulsion system, between the construction shipyard and the intended site, is covered by classification requirements. To flag the unit is:

- Recommended for the towing.
- Mandatory in international waters and when people is onboard. Attention is to be paid to the compliance with international codes and standards as required by National Authorities.

The Society issues a provisional certificate upon completion of the hull, with design criteria for towing/transit condition clearly identified.

1.10.2 Temporary conditions

Provisions for the temporary conditions during construction and transit are defined in [1.9.1].

1.10.3 Environmental conditions for towing/transit

The Society may require:

- detailed documentation for the intended route between the construction shipyard and the intended site, and
- further investigation of slamming loads, green waters, bow impact and ice loads, if any, depending on the severity of the intended route, the planned period of the year and duration for the towing.

Extreme loads for towing/transit are to be taken by default for a return period of 10 years (typically referred to as a probability level of $10^{-7,7}$). Different values may be considered if specified by the party applying for classification.

Limitations on sea heading (for avoidance of beam seas) including possible seasonal limitations are to be defined by the Owner and/or the party applying for classification.

1.10.4 Fatigue strength during towing/transit

The Society reserves the right to require, for structural members, a direct fatigue analysis resulting from the towing/transit. Such fatigue analysis is to be combined with the overall fatigue verification of the unit in operation at intended site.

1.10.5 Temporary mooring during towing/transit

The floating unit is to be equipped with temporary mooring (anchoring) equipment during the towing/transit operation. This equipment may be removed when the unit is permanently moored at the operation site.

2 Statutory requirements

2.1 General

2.1.1 Project specification

Prior to commencement of the review of drawings, the complete list of Regulations, Codes and Statutory Requirements to be complied with is to be submitted for information:

- International Regulations
- Flag State requirements
- Coastal State requirements
- Owner standards and procedures
- Industry standards.

The project specification is also to specify the list of statutory certificates requested by the Owner.

2.1.2 Conflict of Rules

In case of conflict between the present Rules and any Statutory Requirements as given by Flag State or Coastal State, the latter ones are to take precedence over the requirements of the present Rules.

2.2 International Convention on Load Lines

2.2.1 Application

Compliance with the Load Line Convention may be required by the Owner, the Flag State and/or the Coastal State.

The Load Line Convention is in general applicable to units having structural type and service notations as given in [1.2.1] for the towing phase. In case the unit has a flag once in service at site, application of the Load Line Convention may result in issuance of a Load Line Certificate.

Application of ILLC has an impact on the stability requirements (see Ch 1, Sec 2).

2.2.2 ILLC at site

The Society verifies that the maximum draught of the unit is equal to, or less than, the draught derived from the Load Line Convention requirements, as applicable to tankers.

2.3 MARPOL 73/78

2.3.1 Application

The Society recommends to apply the “Guidelines for application of the revised MARPOL Annex 1 requirements to FPSOs and FSUs” issued by IMO as document MEPC 139(53) and MEPC 142 (54).

2.4 SOLAS

2.4.1 Application

Attention is drawn to the fact that SOLAS requirements may be applicable to the units covered by the present Rules, at the request of competent authorities.

The provisions of the present Rules do not cover all the SOLAS requirements.

2.5 IMO MODU

2.5.1 Application

Compliance with MODU may be required by the Owner, the Flag State and/or the Coastal State.

The Society reserves the right to refer to MODU requirements for fire-fighting equipment of the helideck installation.

3 Symbols and definitions

3.1 General

3.1.1 Unless otherwise specified, the units, symbols, definitions and reference co-ordinate system given in Pt B, Ch 1, Sec 3 of the Ship Rules remain applicable.

3.2 Definitions

3.2.1 Floating production units

A floating production unit (FPU) is a unit fitted with processing equipment necessary to perform basic treatment (de-watering, degassing, gas compression, etc.) of hydrocarbons received from wells.

3.2.2 Floating storage units

A floating storage unit (FSU) is a surface unit intended for the storage in bulk of liquid cargoes as defined in [3.2.14].

3.2.3 Floating storage and offloading units

A floating storage and offloading unit (FSO) is a unit fitted with equipment for offloading stored hydrocarbons by shuttle tankers, moored alongside or in tandem mode.

Note 1: Export may alternatively be performed by an export flowline leading to another offshore installation (e.g. a loading buoy).

3.2.4 Floating production, storage and offloading units

Production and storage installations may be combined into floating production and storage units (FPSU) or into floating production, storage and offloading units (FPSO).

3.2.5 Station keeping

A floating production and/or storage unit may be kept in position by means of either:

- a single point mooring at which the unit is moored or articulated, or
- an independent anchoring system, or
- a dynamic positioning system.

When provided, the anchoring system may consist in a spread mooring system or a turret system.

The mooring system may be a disconnectable system, e.g. for units located in typhoon areas, which have kept their ship propulsion and steering appliances and are able to sail the way in case of typhoon, or for units located in iceberg lanes.

An auxiliary propulsion system (thruster) may be fitted, e.g. to assist weathervaning or to provide a minimum manoeuvrability to the unit, when disconnected.

3.2.6 Rule length

For surface units, the rule length L is determined, for transit and site conditions, similarly to seagoing oil tankers (see the Ship Rules).

In case of units without rudder shaft, the rule length L is to be taken equal to 97% of the extreme length at the maximum draught.

The extreme length at the maximum draught is not to include external turret system or boat landing platforms possibly attached to the extreme ends.

3.2.7 Depth

The 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 beam at side on the uppermost continuous deck.

3.2.8 Fore and aft parts

The fore and aft parts are determined on a case-by-case basis, according to the main wave heading.

For units articulated around a single point mooring, the fore part is the part next to this single point mooring.

During transit, the fore part is the one orientated in the direction of towage.

3.2.9 Hull and superstructures

The hull is a barge shaped floating structure with overall dimensions in accordance with Pt B, Ch 1, Sec 2, [1.2] of the Ship Rules. The purpose is to store oil (if applicable), ballast and production liquids. In addition, dedicated machinery spaces are provided for essential generators, etc.

The hull includes:

- The living quarters, which are to be designed and built in accordance with the relevant requirements for “superstructures” given in Ch 1, Sec 13.
- The supports for pertinent features of hull structure design, named “attachments and appurtenances” in these Rules, as, for example, hull topsides supports and foundations. The interface point is the bearing and sliding supports of the topside modules.

3.2.10 Topsides

A topside structure is usually an independent structure located on the deck of the floating unit (typically the freeboard and strength deck). Depending on the supporting arrangement, provisions are to be taken for possible effects of longitudinal stress and deformation from hull girder in the topsides structure. Topsides equipment may contain essential marine systems which are within the scope of classification. The Society may require detailed documentation for information.

The topsides are usually arranged into modules to ease fabrication and installation, and to reduce impact from longitudinal stress in hull girder of the floating unit.

3.2.11 Site draughts

The draught is the distance, in m, from the base line to the waterline, measured amidships.

The maximum site draught is the deepest draught able to be observed during operation.

The minimum site draught is the lightest draught able to be observed during operation.

3.2.12 Transit draughts

For any transit phase, a maximum draught and a minimum draught are to be determined by the designer and reflected in the associated loading conditions.

3.2.13 Splash zone

The “splash zone” is the zone of the floating structure which is alternately in and out of water due to wind, waves and motions. Areas which are wetted only in case of major storms are excluded from the splash zone.

The exact location and vertical extent of the splash zone are to be determined at the design stage as a function of the environmental conditions at the intended site.

Unless otherwise indicated by the designer, the splash zone is usually considered as extending from 3 m below the lowest operational draught up to 5 m above the maximum loaded draught.

Corrosion in the splash zone during service is to be prevented by means of protective coating systems and/or corrosion margins and thickness increments of the plating.

3.2.14 Cargo

For the application of this Chapter, cargo means all the oil-like liquids in relation with the drilling and process (production) operations and includes also all the flammable liquids having a flash point of less than 60°C stored in bulk in cargo tanks of the unit.

3.2.15 Corrosion addition

The corrosion addition is the thickness to be added to the net thickness in view of corrosion allowance, as defined in Ch 1, Sec 3, [7].

3.2.16 Thickness increment

The thickness increment is the thickness that may be added to the gross thickness, in accordance with Ch 1, Sec 3, [8].

3.2.17 Manned end

The manned end is the end of the unit where accommodation is located.

3.2.18 Production equipment

Throughout the present Chapter, production equipment means equipment (piping and accessories, valves, pumps, pressure vessels, etc.) containing or liable to contain hydrocarbon products under treatment, excluding transfer from these production installations.

3.2.19 Cargo pump room

A cargo pump room is a space containing pumps and their accessories for the handling of cargo.

3.2.20 Pump room

A pump room is a space, possibly located in the storage area, containing pumps and their accessories for the handling of ballast and oil fuel, or other supplies, cargo being excluded.

3.2.21 Void space

A void space is an enclosed space in the storage area external to a cargo tank, except for hold space, cargo pump room, pump room, or any space normally used by personnel.

3.2.22 Other spaces

For definition of other spaces, refer to Part C, Chapter 4.

3.2.23 Independent piping system

An independent piping system is a piping system for which no potential connection to other piping systems is available.

3.2.24 Separate piping system

A separate piping system is a piping system which is not permanently connected to another piping system. This separation may be achieved by detachable spool pieces and valves and suitable blind flanges, or two spectacle flanges arranged in series with means between the two spectacles flanges to detect leakage.

Operational separation methods are normally not to be used within a cargo tank.

3.2.25 Process tank

A process tank is an internal tank used in the hydrocarbon production and processing systems which may contain a highly corrosive mixture of oil, gas, water, mud and chemicals.

3.2.26 Cargo area

The cargo area is that part of the unit which contains cargo tanks, slop tanks, process tanks, cargo pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks as well as deck areas throughout the entire length and breadth of the unit above the mentioned spaces.

For the purpose of the present Chapter, cargo area and storage area have the same meanings (see [3.2.27]).

3.2.27 Storage area

For the purpose of the present Chapter, storage area and cargo area have the same meanings (see [3.2.26]).

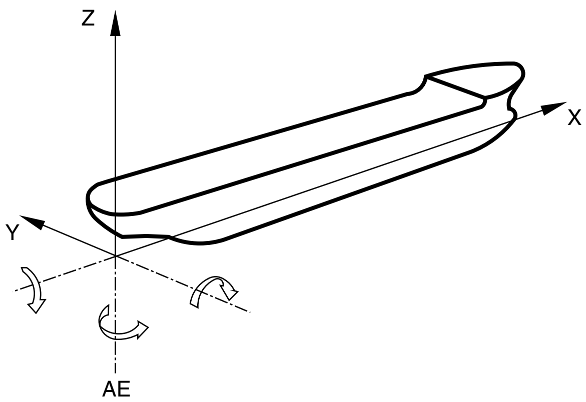
3.3 Reference co-ordinate system

3.3.1 The ship geometry, motions, accelerations and loads are defined with respect to the following right-hand co-ordinate system (see Fig 2):

- Origin: at the intersection between the ship longitudinal plane of symmetry, the aft end of L and the baseline
- X axis: longitudinal axis, positive forwards
- Y axis: transverse axis, positive towards portside
- Z axis: vertical axis, positive upwards.

Positive rotations are oriented in anti-clockwise direction about the X, Y and Z axes.

Figure 2 : Reference co-ordinate system



4 Calculations

4.1 Calculations to be submitted

4.1.1 Procedures

Procedures and assumptions used for structural and hydrodynamic calculations requested by the Rules are to be submitted to the Society for review prior to submission of final report with conclusions of the analysis.

The following calculations are to be submitted:

- Hydrodynamic calculations:
  - direct calculation report
  - model test report and calibration report, if relevant.
- Finite element calculations:
  - primary supporting members of cargo tanks
  - topside supports
  - turret supports
  - spread mooring seats
  - fatigue structural details
  - topsides, when **PROC** notation is granted
  - spectral fatigue when **Spectral Fatigue** notation is granted.
- Additional calculation reports are recommended and should be submitted for information when they are performed:
  - dropped object analysis procedure
  - collision analysis procedure
  - explosion analysis procedure.
- Calculation of design temperature of structural elements, if relevant (see Ch 1, Sec 3).

Detailed documentation of software used, demonstrating calculation accuracy, may be requested by the Society.

4.1.2 Calculation report

The calculation report is to follow the procedure as described and agreed to, prior to commencement of the study. Input data, considerations for decision of boundary conditions and detailed stress results are to be available.

Finite element models usually consist of plate elements. Normal and shear stresses are usually obtained in the centre of the element and stress plots are to show element stresses and not a node average.

Graphically, information for several loading conditions is to show deformation of structure and Von Mises stress values.

5 Design criteria and data

5.1 General

5.1.1 The party applying for classification is to provide the Society with the classification data and assumptions.

Relevant information is entered in the Design Criteria Statement.

5.2 Site data

5.2.1 The party applying for classification is to specify the site at which the unit will operate, and is to provide relevant design data and background information.

Note 1: Units intended to operate on several sites or units not being permanent installations are specially considered.

5.3 Operating loading conditions

5.3.1 General

The data on unit operation are to include the information required from [5.3.2] to [5.3.5].

5.3.2 Cargoes and processed products

Characteristics of processed hydrocarbons and cargoes intended to be stored (in particular H_2S content).

5.3.3 Environmental conditions

a) Extreme environmental conditions during unit operations.

b) Most severe environmental conditions, if relevant, during offloading operations towards a shuttle tanker, moored alongside or in tandem mode.

c) Limiting conditions before disconnection from the single point mooring, if relevant.

d) Most severe environmental conditions, if relevant, during maintenance operations such as dismantling of main bearings of connection with the single point mooring.

e) Environmental conditions during towing/transit from construction/conversion location to offshore site, when not covered by a navigation notation.

5.3.4 Loads

a) Loads induced by connection to a Single Point Mooring, if any, in all relevant conditions detailed in [5.3.3], including:
- loads in bearings, in case of arm and yoke connections
- loads on secondary bearings during maintenance operations.

b) Hawser loads, in case of connection by a hawser.

c) Maximum loads induced by shuttle tankers.

d) Loads induced by process and other equipment.

5.3.5 Loading conditions

The following loading conditions are to be considered:

a) loading conditions in normal operations, including distribution of stored hydrocarbon, ballast, stores and others, for the full sequence of loading-unloading of the unit

b) loading conditions in any other particular condition of operation, such as light ballast, or tank cleaning/inspection, and related limiting conditions for environment

c) loading condition for towing/transit.

Note 1: For control of loadings during operations, refer to Ch 1, Sec 5, [2.3].

6 Documentation to be submitted

6.1

6.1.1 The documentation to be submitted is to include the following information, in addition to the documentation required in Part A, Chapter 1:

a) Design criteria and data, as defined in Article [5]

b) Data for hydrodynamic analysis:
- lines plan and appendices on hull
- environmental data as required in Pt B, Ch 2, Sec 2
- properties of the unit related to the assessment of wind and current loads (areas, coefficients), when a heading analysis is performed (see Ch 1, Sec 4)
- properties of mooring system and relevant information
- loading manual with description of each loading condition

c) General drawings:
- general arrangement of the unit, showing, as relevant:
  - location of the storage tanks with their openings, ballast tanks, cofferdams and void spaces, accesses to hazardous and safe spaces, cargo storage, production piping and vent piping on the open deck, bow or stern transfer lines, etc.
  - general arrangement of process, utility and control spaces
  - general arrangement of risers, riser supports and manifolds
- general arrangement of hazardous areas
- flare radiation level plots
- arrangement of the fore and aft spaces
- general arrangement of the mooring system, or SPM connection

d) Structural drawings, specifications and supporting documents:
- booklet of loading conditions
- mooring systems foundations (fairleads, tensioners, winches, bollards, etc.), where applicable
- connections and supporting structure for floating units connected to a single point mooring by an arm or a yoke
- turret structural and mechanical drawings
- riser supports
- foundations of deck modules and flare, if any, together with the corresponding loads
- deck modules, as relevant
- flare structure
- specification of coatings and drawings of cathodic protection, including hull outside and tank inside, with drawings of anode securing devices

e) Machinery and piping drawings:
- oil and gas processing plant (general arrangement, PID)
- cargo offloading equipment
- gas disposal system
- diagram of cargo and gas piping systems, including offloading piping

- connections to risers
- diagram of stripping system for cofferdams, pump rooms and other spaces within the storage area
- diagram of cargo tank vent systems
- specification of pumps, valves, expansion joints and other cargo piping fittings
- drawing of cargo pump shaft stuffing boxes at bulkhead penetrations
- arrangement of gastight bulkhead penetrations
- bilge and drainage systems for hazardous areas
- ballast pumping within storage area
- remote control of cargo and ballast pumping systems
- specifications and drawings of cargo hoses
- cargo tank heating system
- crude oil tank washing systems, together with specification of equipment
- arrangements for gas-freeing of cargo tanks
- drawings of product swivels
- drawings of electrical swivels
- arrangements for venting cargo tanks, including specification of venting fittings
- pressure-vacuum valves
- arrangement and capacity of air ducts, fans and motors in storage area, together with justification of their anti-sparking properties
- rotating parts and casings of fans
- level-gauging arrangements, including drawings and specifications
- emergency shut-down system
- remote control and monitoring systems, including specifications of instrumentation
- arrangement of instrumentation in control stations

f) Inert gas installations:

- single-wire diagram of the installation, together with the following main characteristics: capacity, pressure, temperature, O_2 content, water content
- list of the components (with their characteristics) of: pipes, scrubber, blowers, non-return devices, valves, pumps, protective devices for overpressure and vacuum
- general arrangement plan of installations on board
- diagram of monitoring and alarm systems
- specifications of O_2 analyser, recorder and portable control instruments

g) Safety plans:

- drawing and specification of fire and gas detection systems
- fire protection details in accommodation areas
- pressure water fire main
- fire extinguishing systems in machinery and accommodation areas
- foam extinguishing systems within storage area: general arrangement diagram, calculation note, foam agent specification, characteristics of foam monitors and hoses
- fire-extinguishing system in cargo pump rooms: general arrangement plan and calculation note
- fire-extinguishing system in process areas

h) Others:

- documents relevant to contemplated additional class notations, as specified in the Rules.

Section 2 Subdivision and Stability

1 General

1.1 Application

1.1.1 The present Section defines the subdivision and stability requirements, with respect to risks of capsizing or risks of pollution of the sea for units covered by the present Chapter (see Ch 1, Sec 1, [1.2.1]) and intended to receive the service notation **oil storage**.

1.1.2 Units covered by the present Chapter but not intended to receive the service notation **oil storage** are to comply with the requirements of Part B, Chapter 1 instead of the present Section.

2 Stability

2.1 Free surface effect

2.1.1 General

The free surface effects of partially filled tanks are to be taken into account in the stability calculations. Filling restrictions entered in the operating manual are to be given special consideration by the Society.

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 nominally full, i.e. filling level is 98% or above.

Nominally full cargo tanks should be corrected for free surface effects at 98% filling level. In doing so, the correction to initial metacentric height should be based on the inertia moment of liquid surface at 5° of the heeling angle divided by displacement, and the correction to righting lever is suggested to be on the basis of real shifting moment of cargo liquids.

In calculating the free surfaces 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 are to be those where the effect of free surface is the greatest.

2.1.2 Gutter bars

Where gutter bars are provided on the cargo tank deck in order to avoid the spillage of flammable liquids, as required by Ch 1, Sec 16, [1.7], the free surface effect caused by containment of cargo spill, boarding seas or rain water is to be considered with respect to the vessel's available margin of positive initial stability (GMo).

Gutter bars are not to be accepted without an assessment of the initial stability (GMo) for compliance with the relevant intact stability requirement taking into account the free surface effect caused by liquids contained by the gutter bars.

2.1.3 Documentation to be submitted

A stability file is to be submitted by the Owner or its representative. It has to include line plans, capacity plans, justification of lightship characteristics, definitions of loading conditions, damage stability booklet, etc.

2.2 Intact stability

2.2.1 General

The requirements of Pt B, Ch 3, Sec 2 of the Ship Rules concerning the intact stability are to be complied with. In addition, the following requirements are applicable:

a) For inclining test and lightweight check:

   The unit is to comply with the requirements of Pt B, Ch 3, App 1 of the Ship Rules.

b) For trim and stability booklet:

   The information that is to be included in the trim and stability booklet is given in Pt B, Ch 3, App 2, [1.1] of the Ship Rules.

   The loading conditions to be checked are given in [2.2.2].

c) In addition to the requirements of Pt B, Ch 3, Sec 2 of the Ship Rules, the criteria of Pt D, Ch 7, Sec 3, [2.2] of the Ship Rules are to be complied with.

2.2.2 Loading conditions

The following conditions are to be submitted:

- Lightship condition.
- Transit/towing condition.

- Selected operational loading conditions covering foreseen fillings of the cargo tanks. One of the conditions must correspond to the maximum draught.

  For the assignment of a tropical freeboard, the corresponding loading condition has also to be submitted.
- Loading conditions for inspection of the cargo tanks, where one or two consecutive cargo tanks are empty (to be consistent with operational practice).

2.3 Damage stability

2.3.1 General

The unit is to comply with the requirements of Pt D, Ch 7, Sec 3, [2.3] of the Ship Rules which are similar to the ones in MARPOL.

However the extent of damage given in Pt D, Ch 7, Sec 3, Tab 1 of the Ship Rules is not fully applicable. The Table is to be replaced by the prescriptions given in [2.3.2].

2.3.2 Extent of damage

For the units covered in the present Chapter, the extent of damage on the bottom is disregarded.

The assumed extent of damage on the side shell is to be as follows:

- Longitudinal extent l_c:

  $l_c = 1/3\ L_{LL}^{2/3}$ or 14,5 m, whichever is the lesser

  where:

  L_{LL} : Load line length, in m, as defined in Pt B, Ch 1, Sec 3, [2.1.2] of the Ship Rules.
- Transverse extent t_c measured inboard from the side shell plating, at right angle to the centreline, at the level of summer load line:

  $t_c = B/5$ or 11,5 m, whichever is the lesser.

  B : Moulded breadth, in m, as defined in Pt B, Ch 1, Sec 3, [2.1.4] of the Ship Rules.
- Vertical extent v_c , from the moulded line of the bottom shell plating at centreline: upwards without limit.

2.3.3 Type A freeboard

For units assigned with a type A freeboard, the requirements of Pt B, Ch 3, App 4 of the Ship Rules, which are similar to the ones in ILLC 66, are also to be complied with.

3 General arrangement

3.1 General

3.1.1 The requirements of this Article are additional to, or replace, in case of conflict, those of Part C, Chapter 4.

3.2 Cargo tanks

3.2.1 Segregation requirements

Cargo tanks and slop tanks are to be segregated from accommodation, service and machinery spaces, drinking water and stores for human consumption by means of a cofferdam, or any other similar space.

3.2.2 Ends of storage area

A cofferdam or similar compartment is normally to be provided at both ends of the storage area. Such a cofferdam is to be bounded by oil-tight bulkheads 760 mm apart as a minimum and extending from keel to deck across the full breadth of the unit.

3.2.3 Double bottom

Double bottoms adjacent to cargo oil tanks are not to be used as oil fuel bunkers.

3.2.4 Arrangement of tanks

The size and arrangement of cargo tanks and ballast tanks located in the storage area are to comply with the applicable provisions of Article [2].

3.2.5 Fore and aft peaks

Cargo is not to be loaded in fore or aft peaks.

3.3 Location and arrangement of spaces adjacent to storage area

3.3.1 Machinery spaces

All machinery spaces are to be separated from cargo and slop tanks by cofferdams, cargo pump rooms, oil fuel bunkers or permanent ballast tanks.

However, the lower portion of the pump room may be recessed into the machinery spaces of category A to accommodate pumps provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel. In the case of units of not more than 25000 tonnes deadweight, where it can be demonstrated that for reasons of access and satisfactory piping arrangement this is impracticable, the Society may permit a recess in excess of such height, but not exceeding one half of the moulded depth above the keel.

Note 1: Pump-rooms intended solely for ballast transfer need not comply with the requirements of Ch 1, Sec 16, [1.2]. The requirements of Ch 1, Sec 16, [1.2] are only applicable to the pump-rooms, regardless of their location, where pumps for cargo, such as cargo pumps, stripping pumps, pumps for slop tanks, pumps for COW (Crude Oil Washing) or similar pumps are provided.

“Similar pumps” includes pumps intended for transfer of fuel oil having a flashpoint of less than 60°C. Pump-rooms intended for transfer of fuel oil having a flashpoint of not less than 60°C need not comply with the requirements of regulation Ch 1, Sec 16, [1.2].

3.3.2 Ballast pump rooms

Pump rooms containing pumps and their accessories for the handling of ballast for spaces adjacent to cargo tanks and slop tanks and pumps for fuel oil transfer may be considered as equivalent to a cargo pump room for the application of [3.3.1] and Ch 1, Sec 16, [1.4], provided that such pump rooms fulfil the safety requirements applicable to cargo pump rooms.

The lower portion of pump rooms may be recessed into category A machinery space to accommodate pumps, provided that the deck head of the recess is not more than one third of the moulded depth above the keel.

3.3.3 Process and utility

Process and utility spaces may be located above main deck in the storage area.

Utility and control spaces, and other enclosed spaces, which are not themselves hazardous areas, are to be separated from deck by a distance of 3 m minimum, or by a cofferdam.

3.3.4 Accommodation, control and service spaces

Accommodation spaces, main cargo oil control stations, control stations and service spaces (excluding isolated cargo handling gear lockers) are to be positioned outside the storage area and cofferdams or other spaces (crude oil pump rooms, oil fuel bunkers or permanent ballast tanks) considered as equivalent isolating cargo oil or slop tanks from machinery spaces.

Note 1: A recess provided in accordance with [3.3.2] need not be taken into account when the position of these spaces is being determined.

3.4 Cargo pump rooms

3.4.1 Glazed ports in bulkheads

a) The cargo pump rooms are to be separated from the other spaces of the unit by oil tight bulkheads and are not to have any direct access to the machinery spaces.

b) Glazed ports can be provided in the bulkhead separating the cargo pump room from machinery spaces provided they satisfy the following conditions:
   - they are to be sufficiently protected from mechanical damage
   - strong covers are to be permanently secured on the machinery compartment side
   - glazed ports are to be so constructed that glass and sealing are not damaged by any deformations of the unit
   - the glazed ports are to be so constructed as to maintain the structural integrity and the bulkhead resistance to fire and smoke.

3.4.2 Bulkhead penetrations

The number of penetrations through the bulkhead separating the cargo pump room from the machinery spaces is to be kept to a minimum.

Any penetration through bulkheads or decks bordering the cargo pump room is to be of a type approved by the Society.

3.5 Drainage arrangements and slop tanks

3.5.1 Drainage arrangements

Drainage arrangements for safe areas are to be entirely separate and distinct from drainage arrangements from hazardous areas.

3.5.2 Deck spills

Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by providing permanent continuous coaming of a suitable height extending from side to side.

3.5.3 MARPOL Convention

The attention of the Designer is drawn to the fact that the arrangements for the storage on board a unit, and the disposal of bilge and effluent from the production spaces are subject, outside the scope of classification, to requirements of the appropriate National Authority, in application of the MARPOL Convention.

3.5.4 Slop tanks

Slop tanks, where fitted in pump rooms, are to be of a closed type, air and sounding pipes being led to the open deck.

3.6 Ballasting of double bottom and narrow tanks

3.6.1 It is recommended to provide suitable arrangement for ballasting double bottom tanks and double hull tanks within storage area, if any, and cofferdams and other void spaces contiguous to storage tanks, in order to facilitate gas-freeing of such compartments.

3.7 Collision bulkhead

3.7.1 A collision bulkhead is to be provided, when necessary, to prevent flooding during transit and/or site conditions. The collision bulkhead is to comply with the requirements of the Ship rules.

3.7.2 Subject to the agreement of the flag Administration, if any, the Society may accept an exemption from having a collision bulkhead when the risk of collision is mitigated and duly justified (collision analysis, external turret, damage stability ...).

3.7.3 Subject to the agreement of the flag Administration, if any, the Society may , on a case by case basis, accept a distance from the collision bulkhead to the forward perpendicular FP_{LL} greater than the maximum specified in the Ship rules, provided that subdivision and stability calculations show that, when the unit is in upright condition on full load draft, flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or in any unacceptable loss of stability.

3.8 Aft peak bulkhead

3.8.1 General

As a rule, offshore units are to be provided with an aft peak bulkhead in accordance with the Ship rules, except when the risk of collision is mitigated and duly justified (collision analysis, external turret, damage stability...).

Section 3 Structure Design Principles

Symbols

b_f : Face plate width, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

D : Depth of the unit, in m, as defined in Ch 1, Sec 1, [3.2.7]

E : Young's modulus, in N/mm², to be taken equal to:

- for steels in general: $E = 2{,}06 \cdot 10^5$ N/mm²
- for stainless steels: $E = 1{,}95 \cdot 10^5$ N/mm²
- for aluminium alloys: $E = 7{,}0 \cdot 10^4$ N/mm²

h_w : Web height, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

I : Net moment of inertia, in cm⁴, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating, around its neutral axis parallel to the plating (see Fig 3, c), d))

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 3)

ℓ_b : Length, in m, of brackets (see Fig 11)

L : Rule length, in m, as defined in Ch 1, Sec 1, [3.2.6]

s : Spacing, in m, of ordinary stiffeners or primary supporting members, as the case may be

t_C : Rule corrosion addition, in mm, see Article [8]

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

t_w : Net web thickness, in mm, of an ordinary stiffener or a primary supporting member, as the case may be

w : Net section modulus, in cm³, of an ordinary stiffener or a primary supporting member, as the case may be, with attached plating of width b_p

w_G : Gross section modulus, in cm³, of ordinary stiffeners

w_N : Net section modulus, in cm³, of ordinary stiffeners.

1 Definition of ship areas and offshore areas

1.1 Principles

1.1.1 General

Following analysis of the stress level in the structure and design environment, the Society may categorize some of the areas as "ship areas" or as "offshore areas".

Elements and types of areas are listed in Tab 1.

The Society reserves its right, according to appropriate structural analyses, to declare other elements as belonging to offshore areas.

1.1.2 Offshore area requirements

Offshore areas listed in Tab 1 are to be in accordance with the requirements of Part B:

a) Concerned areas are to include the part of the ship structure affected by the loads on listed elements.

b) Structural elements contributing to the longitudinal strength of the hull girder are also to comply with strength requirements for ship areas (see [1.1.3]).

1.1.3 Ship area requirements

Ship areas listed in Tab 1 are to be in accordance with the present Chapter except where specific requirements of the Ship Rules are requested in it.

In case of conflict between the Ship Rules and the present Chapter, the most severe is to take precedence.

Table 1 : Types of areas

Elements	Area
Flare tower supports	Offshore area
Turret moon pool, casing, and surrounding area	
Topsides supports at main deck	
Crane pedestals and foundation into hull	
Helideck support structure	
Mooring supports	
Hose handling crane pedestal and foundation into hull	
Offloading equipment foundations	
Riser porches and their foundations to the hull	
Foundations of riser and mooring lines tensioning systems	
Towing brackets and their foundations	
Other elements	Ship area

1.1.4 Limits between ship areas and offshore areas

The offshore areas always include the following items:

- the foundations of modules and equipment defined in Tab 1 and their additional local structural members
- the inserts in primary supporting members, decks, bulkheads and side shell
- the reinforced longitudinal stiffeners
- the partial stringers, deck girders and web frames.

For other members and when the limits of offshore area is not obvious from engineering judgment, the offshore area is to be extended up to a distance where the equivalent membrane stress is lower than 30 MPa when only appurtenance forces are applied.

1.1.5 Structural categories for offshore areas

Offshore areas are divided into three categories (special, first and secondary) for the structural members.

These categories are defined in Pt B, Ch 3, Sec 2, [2].

Components in load transmission areas and contributing to the load path, including stiffener brackets, flanges etc., are to be categorized as first or special category area.

In principle, topside supports are to be categorized as first category elements with the highly stressed area as special category element.

The helideck structure is considered as first category element.

2 Materials and testing

2.1 Design temperature

2.1.1 For the purpose of steel grade requirements stated in [2.2] and [2.3], the design temperature of structural elements is to be calculated as required in Pt B, Ch 2, Sec 2, [6].

2.2 Offshore areas

2.2.1 General

The steel grade of elements belonging to offshore areas, as defined in [1.1.1], is to be determined in accordance with the requirements of Pt B, Ch 3, Sec 2.

2.2.2 Secondary category elements

The steel grades of structural elements categorized as secondary category are to comply with the most stringent between:

- Pt B, Ch 3, Sec 2 or
- Pt B, Ch 4, Sec 1 of the Ship Rules.

2.3 Ship areas

2.3.1 The steel grade of elements belonging to ship areas as defined in [1.1.1], is to be chosen in accordance with Pt B, Ch 4, Sec 1 of the Ship Rules.

2.4 Steels with specified through thickness properties

2.4.1 The steels with specified through thickness properties are to comply with the requirements in Pt B, Ch 3, Sec 2, [4]

2.5 Inspection and checks

2.5.1 General

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 Shipyard suitable to check compliance with the applicable requirements, approved plans and standards.

The manufacturer is to make available to the attending Surveyor a list of the manual welders and welding operators and their respective qualifications.

The manufacturer's internal organisation is responsible for ensuring that welders and operators are not employed under improper conditions or beyond the limits of their respective qualifications and that welding procedures are adopted within the approved limits and under the appropriate operating conditions.

The manufacturer is responsible for ensuring that the operating conditions, welding procedures and work schedule are in accordance with the applicable requirements, approved plans and recognized good welding practice.

2.5.2 Inspection of ship areas

For parts of the structure defined as ship areas, the requirements given in Pt B, Ch 13 of the Ship Rules are to be applied.

Prior to construction start, the constructing shipyard is to propose a recognized standard for approval.

The Society reserves the right to increase the number of non destructive examinations due to complexity of the structure compared to seagoing ships and with particular attention to the intended service.

2.5.3 Inspection of offshore areas

For parts of the structure defined as offshore areas, reference is to be made to NR426 Construction Survey of Steel Structures of Offshore Units and Installations.

The Society reserves the right to increase the number of non destructive examinations due to complexity of the structure and with particular attention to the intended service.

3 General structural principles

3.1 Accessibility for inspection during service

3.1.1 Principle

Accessibility for inspection, and also for maintenance, is required with respect to the durability and integrity of the structure.

3.1.2 Underwater parts

When the additional class notation **INWATERSURVEY** is granted to the units, special constructional features are to be provided as defined in Pt A, Ch 2, Sec 8, [2.2].

For underwater parts, marking and arrangements to facilitate inspections are to be provided. Marking is to be steel plate welded and painted.

Draught marks are to be provided at both sides at aft end, midship and bow.

Marks and identifying photographs shall be provided for orienting the diver (and submitted in copy to the Society for information). These shall include specific areas of plating, including locations of bulkheads and tanks, boundaries, sea chests (intake tubes), sea suction and discharge openings. Individual connections inside the sea chest (tube) are also to be identified.

Detailed drawings of the hull and hull attachments below the waterline are to be submitted to the Society for review.

3.1.3 Means of access

Each space within the unit is to be provided with permanent means of access in accordance with Pt B, Ch 3, Sec 1, [4].

The means of access in the hull are to allow inspection of the critical structure connections identified during the drawing review by the Society and/or the designer.

Inaccessible areas are to be clearly identified on structural drawings. The number of inaccessible areas is to be limited. The Society reserves the right to establish additional requirements related to corrosion protection of these areas. Special attention is to be paid to fatigue strength.

Web frame numbers shall be attached to structure or walkway inside of tanks to the satisfaction of the attending Surveyor.

Equipment on deck should be arranged to allow inspections of the deck plating and to avoid permanent concentration of dust and remaining water.

Complex areas like turret, riser porches, etc., must also be accessible for inspection.

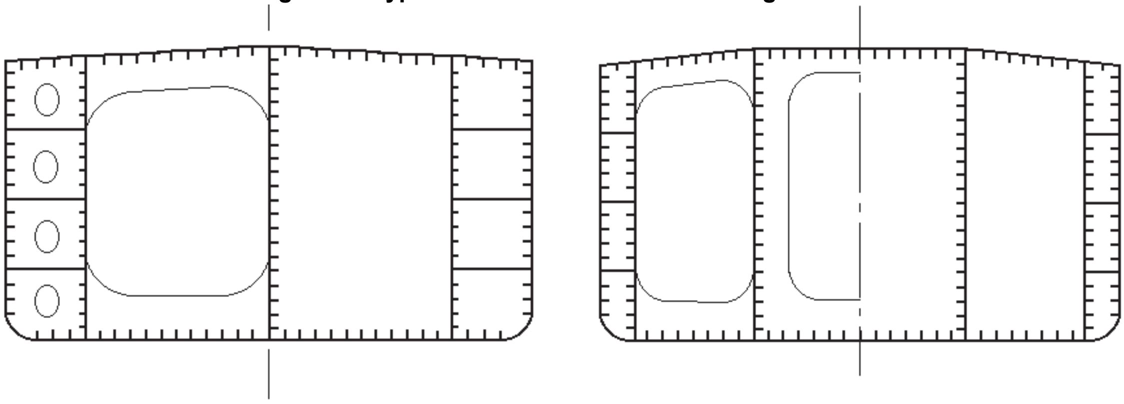
3.2 General construction

3.2.1 Typical arrangement

Large openings in web frames and stringers should be verified and necessary documentation / calculation notes are to be submitted to the Society.

As a guidance, two typical transverse structural configurations are shown in Fig 1.

Figure 1 : Typical transverse structural configurations



Typical arrangement with longitudinal bulkhead in centre line — Typical arrangement with two longitudinal bulkheads

3.2.2 Structural continuity

The variation in scantling between the midship region and the fore and aft parts is to be gradual.

Attention is to be paid to the structural continuity:

- in way of changes in the framing system
- at the connections of primary or ordinary stiffeners
- in way of the ends of the cargo area
- in way of ends of superstructures.

Longitudinal members contributing to the hull girder longitudinal strength are to extend continuously for a sufficient distance towards the ends of the unit.

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 of the cargo area and cofferdams. Alternative solutions may be examined by the Society on a case-by-case basis, provided they are equally effective.

Where stress concentrations may occur in way of structural discontinuities, adequate compensation and reinforcements are to be provided.

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. Particular attention is to be paid to the passage of secondary stiffeners through web plating in the stress vicinity of heavy loads, i.e. top side loads on deck supports.

Openings are to be generally well rounded with smooth edges.

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.

3.2.3 Connections with higher strength steel

The vertical extent of higher strength steel is to comply with the requirements of Ch 1, Sec 6, [3.3.5].

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.

3.2.4 Docking brackets

The Society recommends fitting of docking brackets considering the future topside weight.

3.2.5 Bilge keel

If a bilge keel is fitted, requirements are given in [10.6].

3.2.6 Sniped ends

As a rule, sniped ends of primary and secondary stiffeners are to be less than 30 degrees as indicated on Fig 12.

4 Structural principles for plating

4.1 General

4.1.1 A local increase in plating thickness is generally to be achieved through insert plates.

Insert plates are to be made of materials of a quality at least equal to that of the plates on which they are welded.

Plating under heavy concentrated loads shall be reinforced with doublers (only compression loads allowed) and/or stiffeners where necessary. Doublers in way of equipment and pipe rack supports are to be limited in size and avoided in areas of the deck with high stress. A detailed drawing showing location of the doublers is to be submitted to the Society for review.

5 Structural principles for ordinary stiffeners

5.1 General

5.1.1 Stiffener not perpendicular to the attached plating

Where the stiffener is not perpendicular to the attached plating, the actual net section modulus w, in cm^3, and net shear area A_{sh}, in cm^2, and net moment of inertia I, in cm^4, may be obtained, from the following formulae:

$w = w_0 \sin \varphi_w$

$A_{sh} = A_0 \sin \varphi_w$

$I = I_0 \sin^2 \varphi_w$

where:

A_0 : Actual net shear area, in cm^2, of the stiffener assumed to be perpendicular to the plating

I_0 : Net moment of inertia, in cm^4, of the stiffener assumed to be perpendicular to the attached plating

w_0 : Actual net section modulus, in cm^3, of the stiffener assumed to be perpendicular to the plating

φ_w : Angle, in degree, between the attached plating and the web of the stiffener, measured at midspan of the stiffener (see Fig 5).

5.1.2 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:

$$h_w = h'_w - \frac{h'_w}{9,2} + 2$$

$$t_w = t'_w$$

$$b_f = \varphi\left[t'_w + \frac{h'_w}{6,7} - 2\right]$$

$$t_f = \frac{h'_w}{9,2} - 2$$

where:

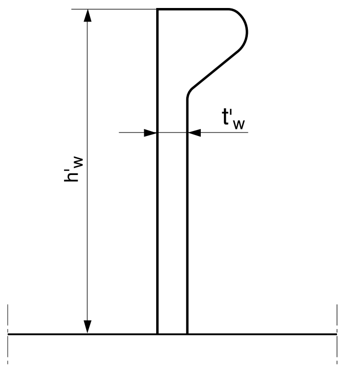
h'_w, t'_w : Height and net thickness of the bulb section, in mm, as shown in Fig 2.

φ : Coefficient equal to:

$$\varphi = 1,1 + \frac{(120 - h'_w)^2}{3000} \quad \text{for} \quad h'_w \le 120$$

$$\varphi = 1 \quad \text{for} \quad h'_w > 120$$

Figure 2 : Dimensions of a bulb section



5.2 Span of ordinary stiffeners

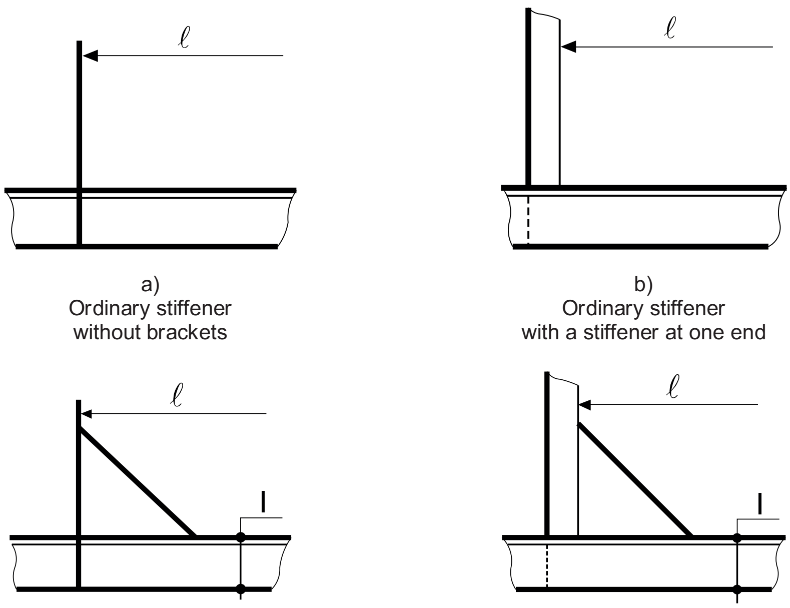
5.2.1 General

The span ℓ of ordinary stiffeners is to be measured as shown in Fig 3.

5.2.2 Ordinary stiffeners connected by struts

The span of ordinary stiffeners connected by one or two struts, dividing the span in equal lengths, may be taken equal to $0,7\ell$.

Figure 3 : Span ℓ of ordinary stiffeners



a) Ordinary stiffener without brackets

b) Ordinary stiffener with a stiffener at one end

c) Ordinary stiffener with end bracket

d) Ordinary stiffener with a bracket and a stiffener at one end

5.3 Width of attached plating

5.3.1 Yielding check

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):

  $b_P = 0,5s$

5.3.2 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 1, Sec 8.

5.4 Geometric properties

5.4.1 Built section

The geometric properties of built sections as shown in Fig 4 may be calculated as indicated in the following formulae.

These formulae are applicable provided that:

$A_a \geq t_f b_f$

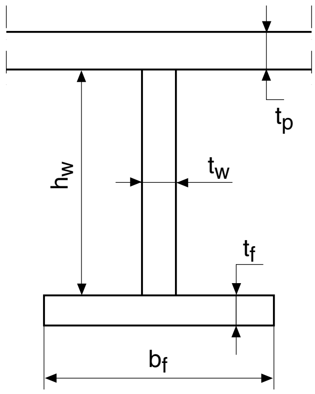
$\frac{h_w}{t_p} \geq 10$

$\frac{h_w}{t_f} \geq 10$

where:

A_a : Net sectional area, in mm^2, of the attached plating.

Figure 4 : 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 face plate to 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:

$I = w \cdot v$

The net shear sectional area of a built section with attached plating is to be obtained, in cm², from the following formula:

$$A_{Sh} = \frac{h_w t_w}{100}$$

5.4.2 Plastic section modulus

The actual net effective plastic section modulus Z_{pl} of a transverse or longitudinal ordinary stiffener, in cm³, is given by the formula in item a) or item b), depending on:

- the cross-sectional area of the attached plate A_p
- the net cross-sectional area of the ordinary stiffener $A_w' + A_f$

where:

A_p : Net cross-sectional area of the attached plate, in cm², taken equal to:

$A_p = 10\, t_p\, s$

A_f : Net cross-sectional area of the stiffener flange, in cm², taken equal to:

$$A_f = \frac{b_f\, t_f}{100}$$

A_w' : Net cross-sectional area of the stiffener web, in cm², taken equal to:

$$A_w' = \frac{h_w\, t_w}{100}$$

a) When $A_p \geq A_w' + A_f$, the plastic neutral axis PNA is assumed to be tangent to the uppermost edge of the attached plate:

$$Z_{pl} = \frac{A_p'\, x_p + A_w'\, x_w + A_f\, x_f}{10}$$

where:

A_p' : Net cross-sectional area of the stiffener, in cm², taken equal to:

$A_p' = A_w' + A_f$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = \text{Min}\left(\frac{A_w' + A_f}{20\, s}\,;\,\frac{t_p}{2}\right)$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$x_f = h_{fc} \sin \varphi_w - b_w \cos \varphi_w$

h_{fc} : Height, in mm, of the stiffener, measured up to the centre of the flange area, see Fig 5

b_w : Distance, in mm, from the mid-thickness plane of the stiffener web to the centre of the flange area, see Fig 5

x_w : Distance, in mm, between the centre of gravity of area A_w' and PNA, taken equal to:

$$x_w = \frac{h_w \sin\varphi_w}{2}$$

φ_w : As defined in [5.1.1]

b) When $A_p < A_w' + A_f$ the plastic neutral axis PNA is located at a distance z_a above the attached plate, in mm, given by:

$$z_a = \frac{(100\,A_f + h_w t_w - 1000\,t_p s)\ \sin\varphi_w}{2\,t_w}$$

$$Z_{pl} = \frac{(A_p x_p + A_{wa} x_{wa} + A_{wb} x_{wb} + A_f x_f)}{10}$$

where:

A_{wa} : Net cross-sectional area, in cm², of the part of the stiffener located above PNA, taken equal to:

$$A_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{t_w}{100}$$

A_{wb} : Net cross-sectional area, in cm², of the part of ordinary stiffener located below the PNA, taken equal to:

$$A_{wb} = \frac{t_w\ z_a}{100\ \sin\varphi_w}$$

x_f : Distance, in mm, between the centre of gravity of area A_f and PNA, taken equal to:

$x_f = h_{fc} \sin\varphi_w - b_w \cos\varphi_w - z_a$

x_p : Distance, in mm, between the centre of gravity of area A_p and PNA, taken equal to:

$$x_p = z_a + \frac{t_p}{2}$$

x_{wa} : Distance, in mm, between the centre of gravity of area A_{wa} and PNA, taken equal to:

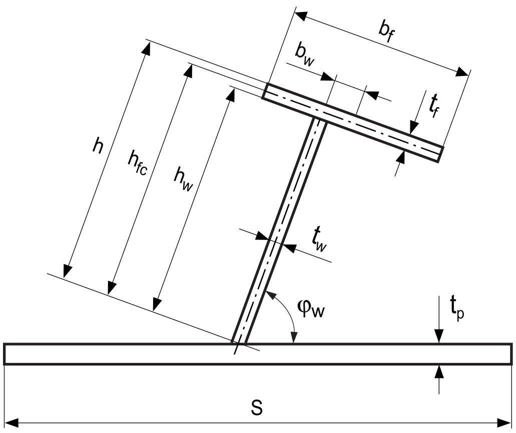
$$x_{wa} = \left(h_w - \frac{z_a}{\sin\varphi_w}\right)\frac{\sin\varphi_w}{2}$$

x_{wb} : Distance, in mm, between the centre of gravity of area A_{wb} and PNA, taken equal to:

$$x_{wb} = \frac{z_a}{2}$$

φ_w : As defined in [5.1.1].

Figure 5 : Dimensions of a built section



5.5 End connections

5.5.1 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 6 to Fig 9.

Connection details other than those shown in Fig 6 to Fig 9 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 6 : End connection of ordinary stiffener - Without collar plate

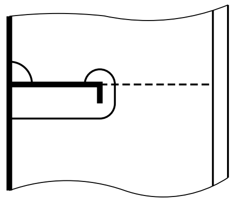


Figure 7 : End connection of ordinary stiffener - collar plate

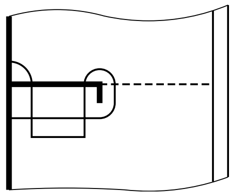


Figure 8 : End connection of ordinary stiffener - One large collar plate

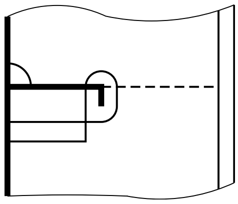
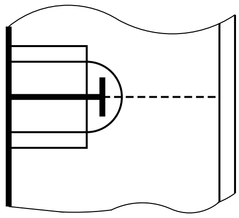


Figure 9 : End connection of ordinary stiffener - Two large collar plates

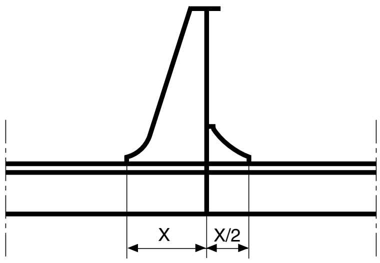


5.5.2 Where ordinary stiffeners are cut at primary supporting members, brackets are to be fitted to ensure the structural continuity. Their net section modulus and their net sectional area are to be not less than those of the ordinary stiffeners.

The net thickness of brackets is to be not less than that of ordinary stiffeners. Brackets with net thickness, in mm, less than $15L_b$, 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 net sectional area, in cm^2, of the flanged edge or face plate is to be at least equal to 10 L_b .

5.5.3 Where necessary, the Society may require backing brackets to be fitted, as shown in Fig 10, in order to improve the fatigue strength of the connection (see also [6.3.4]).

Figure 10 : End connection of ordinary stiffener - Backing bracket



6 Structural principles for primary supporting members

6.1 General

6.1.1 In the cargo area, the primary structure is composed of transverse web frames, stringers, buttress, deck girders, cross-ties, etc.

6.2 Bracketed end connections

6.2.1 The primary supporting members are generally connected through brackets. These brackets are to comply with the requirements [6.2.2] to [6.2.8].

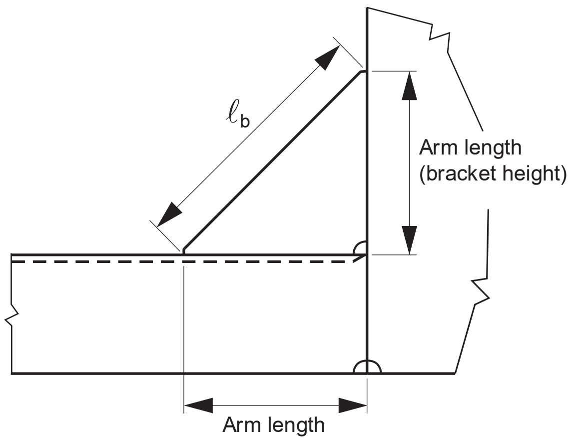
6.2.2 Arm lengths of end brackets are to be equal, as far as practicable, and are to comply with the following requirements:

a) For transversally frame single sides, the height of end brackets is to be not less than half the height of the primary supporting member.

b) For other structures, the arm length of brackets connecting primary supporting members, as shown in Fig 11, is not to be less than the web depth of the member and need not be taken greater than 1,5 times the web depth.

c) End brackets are generally to be soft-toed.

Figure 11 : Bracket dimensions



6.2.3 The net thickness of the end bracket web is generally to be not less than that than the thickness of the adjoining primary supporting member web plate.

6.2.4 The net scantlings of end brackets are generally to be such that the net section modulus of the primary supporting member with end brackets, excluding face plate where it is sniped, is not less than that of the primary supporting member at mid-span.

6.2.5 The net cross-sectional area A_f, in cm^2, of bracket face plates is to be such that:

$A_f \geq \ell_b \, t_b$

where:

ℓ_b : Length of the bracket edge, in m (see Fig 10). For curved brackets, the length of the bracket edge may be taken as the length of the tangent at the midpoint of the edge

t_b : Minimum net bracket web thickness, in mm:

$$t_b \geq (2 + 0{,}2\sqrt{w})\sqrt{\frac{R_{eH,S}}{R_{eH,B}}}$$

with:

w : Net required section modulus of the primary supporting member, in cm^3

$R_{eH,S}$: Minimum yield stress, in N/mm^2, of the stiffener material

$R_{eH,B}$: Minimum yield stress, in N/mm^2, of the bracket material.

Moreover, the net thickness of the face plate is to be not less than that of the bracket web.

6.2.6 Where deemed necessary, face plates of end connecting brackets are to be symmetrical. In such a case, the following requirements are in general to be complied with:

- face plates are to be tapered at ends with a total angle not greater than 30°
- the breadth of face plates at ends is not to be greater than 25 mm
- face plates of 20 mm thick and above are to be tapered in thickness at their ends down to their mid-thickness
- bracket toes are to be of increased thickness
- an additional tripping bracket is to be fitted
- the radius R of the face plate is to be as large as possible
- collar plates welded to the plating are to be fitted in way of the bracket toes
- throat thickness of fillet welds is not to be less than t/2, where t is the thickness of the bracket toe.

In general, full penetration welds should be applied as shown on the example of bracket with symmetrical face plate indicated in Fig 12 and Fig 13.

Figure 12 : Bracket with symmetrical face plate

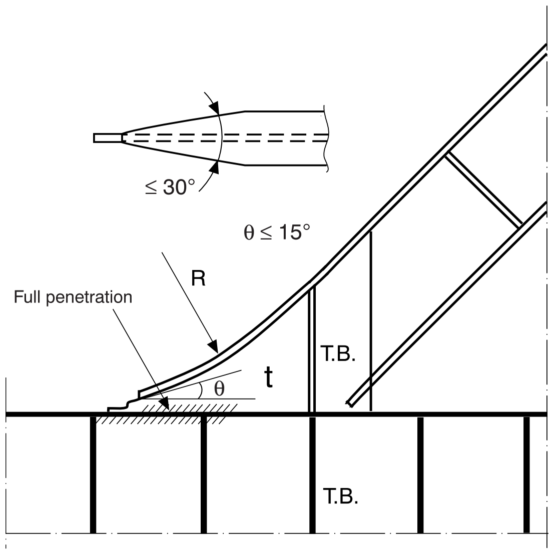
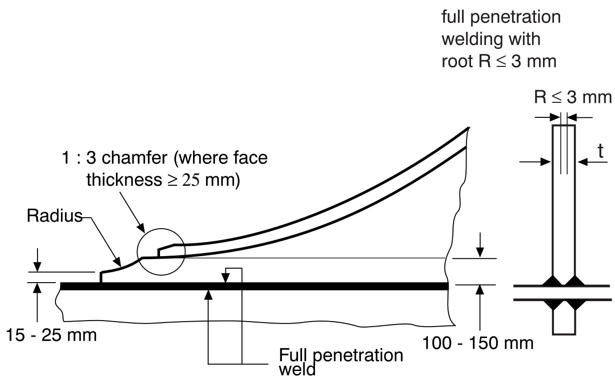


Figure 13 : Bracket with symmetrical face plate



6.2.7 Stiffening of end brackets is to be designed such that it provides adequate buckling web stability.

As 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.

For a ring system, where the end bracket is integral with the web of the members and the face plate is welded continuously onto the edge of the members and the bracket, the full area of the larger face plate is to be maintained close to the mid-point of the bracket and gradually tapered to the smaller face plate. Butts in face plates are to be kept well clear of the bracket toes.

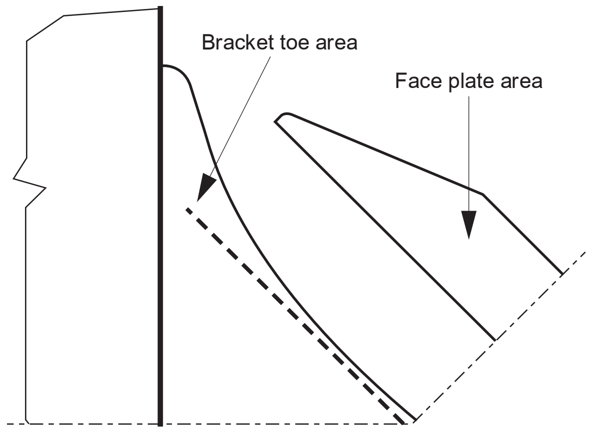
Where a wide face plate abuts a narrower one, the taper is not to be greater than 1 to 4.

The bracket toes are not to land on unstiffened plating. The toe height is not to be greater than the thickness of the bracket toe, but need not be less than 15 mm. In general, the end brackets of primary supporting members are to be soft-toed. Where primary supporting members are constructed of steel having a strength higher than the strength of the bracket steel, particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations.

Where a face plate is welded onto, or adjacent to, the edge of the end bracket (see Fig 14 the face plate is to be sniped and tapered at an angle not greater than 30°.

6.2.8 In addition to the above requirements, the end brackets are to comply with the applicable requirements given in Articles [10], [11] [12].

Figure 14 : Bracket face plate adjacent to the edge



Note: The details shown in this Figure are only used to illustrate items described in the text and are not intended to represent a design guidance or recommendations.

6.3 Stiffening arrangement

6.3.1 Webs

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.

6.3.2 Net sectional area

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 cm², 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:

- $k_1 = 0{,}30$ for connections without collar plate (see Fig 6)
- $k_1 = 0{,}225$ for connections with a collar plate (see Fig 7)
- $k_1 = 0{,}20$ for connections with one or two large collar plates (see Fig 8 and Fig 9)

γ_{S2}, γ_{W2} : Partial safety factors, defined in Ch 1, Sec 9 for yielding check (general)

p_S, p_W : Still water and wave pressure, respectively, in kN/m², acting on the ordinary stiffener, defined in Ch 1, Sec 5.

6.3.3 Net moment of inertia

The net moment of inertia, I, of the web stiffeners of primary supporting members is not to be less than the value obtained, in cm⁴, from the following formula:

- for web stiffeners parallel to the flange of the primary supporting members (see Fig 15):

$$I = C\ell^2 A \frac{R_{eH}}{235}$$

- for web stiffeners normal to the flange of the primary supporting members (see Fig 16):

$$I = 11{,}4\ st_w(2{,}5\ \ell^2 - 2s^2)\frac{R_{eH}}{235}$$

where:

C : Slenderness coefficient to be taken as:

- C = 1,43 for longitudinal web stiffeners including sniped stiffeners
- C = 0,72 for other web stiffeners

A : Net section area, in cm², of the web stiffener, including attached plate assuming effective breadth of 80% of stiffener spacing s

R_{eH} : Minimum specified yield stress of the material of the web plate of primary supporting member.

Figure 15 : Web stiffeners parallel to the flange

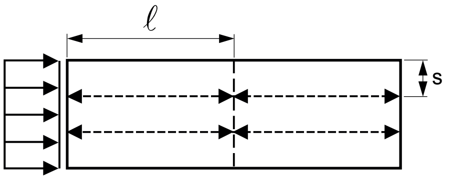
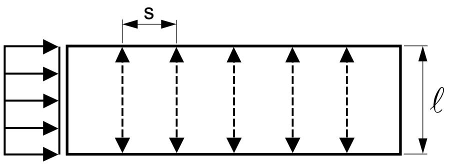


Figure 16 : Web stiffeners normal to the flange



6.3.4 Tripping brackets

Tripping brackets (see Fig 16) welded to the face plate are generally to be fitted:

- every fourth spacing of ordinary stiffeners, without exceeding 4 m
- at the toe of end brackets
- at rounded face plates
- in way of cross ties
- in way of concentrated loads.

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.

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 above.

The arm length of tripping brackets is to be not less than the greater of the following values, in m:

$$d = 0{,}38b$$

$$d = 0{,}85b\sqrt{\frac{s_t}{t}}$$

where:

b : Height, in m, of tripping brackets, shown in Fig 17

s_t : Spacing, in m, of tripping brackets

t : Net thickness, in mm, of tripping brackets.

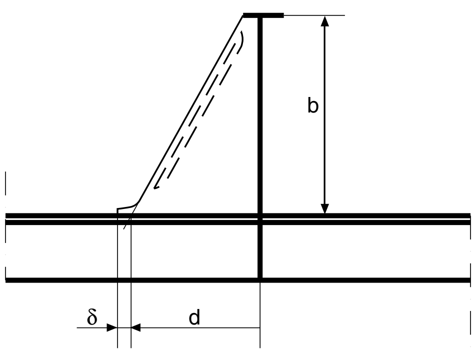
It is recommended that the bracket toe should be designed as shown in Fig 17.

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 $10L_b$, where L_b is the length, in m, of the free edge of the bracket.

Where the depth of tripping brackets is greater than 3 m, an additional stiffener is to be fitted parallel to the bracket free edge.

Figure 17 : Tripping bracket



6.4 Strength checks of cross-ties analysed through a three dimensional finite element model

6.4.1 The buckling capacity of cross-ties is to be carried out according to NR615, Buckling Assessment of Plated Structures. Buckling criteria is to be in accordance with Ch 1, Sec 9, [7.2].

6.5 Buttress

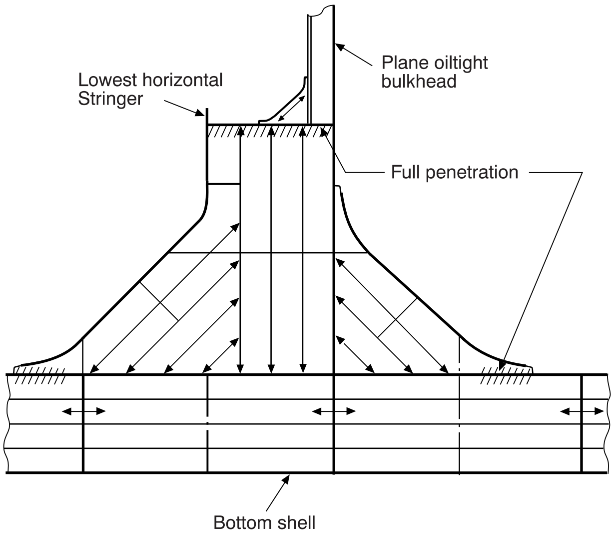
6.5.1 The buttress of transverse bulkhead is to be assessed through direct calculation, including fatigue.

The buttress is to be adequately stiffened, including tripping brackets according to [6.2]

The bracket ends are to be in accordance with [6.2].

In general, full penetration welds are to be applied as shown on the example of buttress arrangement (see Fig 18).

Figure 18 : Buttress



6.6 Stringers

6.6.1 Stringers on bulkheads are to be verified as swash bulkheads for sloshing. In case of risk of resonance, horizontal stringers are to be verified for the associated impact pressure on the adjacent bulkhead plating and stiffeners. Tripping brackets supporting the stringers are to be checked for loads as result of sloshing.

7 Net scantling approach

7.1 Principle

7.1.1 Except when otherwise specified, the scantlings obtained by applying the criteria specified in this Chapter 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:

- obtained from the yielding checks of the hull girder in Ch 1, Sec 6
- of rudder structures and hull appendages in Part B, Chapter 12 of Ship Rules
- of massive pieces made of steel forgings, steel castings or iron castings,

which are gross scantlings, i.e. they include additions for corrosion.

7.1.2 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 first moment for the hull girder.

7.1.3 The unit is to be built at least with the gross scantlings obtained by adding the corrosion additions, specified in Tab 2, to the net scantlings.

7.1.4 General

The net scantling plus the corrosion addition is equal to the gross thickness.

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.

If the party applying for classification specifies values of corrosion additions greater than those defined in [7.2], these values are to be taken into account for calculations and stated in the Design Criteria Statement.

7.2 Corrosion additions

7.2.1 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 equal to:

- for plating with a gross thickness greater than 10 mm, the sum of the values specified in Tab 2 for one side exposure to each compartment
- for plating with a gross thickness less than or equal to 10 mm, the smallest of the following values:
  - 20% of the gross thickness of the plating
  - 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.

7.2.2 Corrosion additions for stainless steel

For structural members made of stainless steel, the corrosion addition t_c is to be taken equal to 0.

7.2.3 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.

7.2.4 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

Compartment type		General **(1)**	Special cases
Ballast tank **(2)**		1,00	1,25 in upper zone **(3)**
Cargo oil tank and fuel oil tank	Plating of horizontal surfaces	0,75	1,00 in upper zone **(3)**
	Plating of non-horizontal surfaces	0,50	1,00 in upper zone **(3)**
	Ordinary stiffeners and primary supporting members	0,75	1,00 in upper zone **(3)**
Tanks for fresh water		0,5	
Accommodation space **(4)**		0,00	
Compartments other than those mentioned above **(4)** Outside sea and air		0,50	

(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) Ballast tank: does not include cargo oil tanks which may carry ballast according to Regulation 18 of MARPOL 73/78 as amended
(3) 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
(4) When not covered by any sheeting, AC Room, galleys, technical areas and crew staircases are to be considered as “other compartments”.

8 Thickness increments

8.1 General

8.1.1 Principle

A thickness increment of platings and, where relevant, of stiffeners may be added to the gross thickness in special areas subject to mechanical wastage due to abrasion or in areas of difficult maintenance.

$t_{net} = t_{gross} - t_c$

$t_{gross} = t_{as\text{-}built} - t_i$

where:

t_c : Corrosion addition as defined in Article [8]

t_{gross} : Gross thickness

t_i : Thickness increment

t_{net} : Net thickness.

The gross thickness plus the thickness increment is equal to the as-built thickness.

8.1.2 Checking criteria

For the checking criteria specified in this Chapter and in applicable requirements of the Ship Rules the thickness increments are not to be considered.

8.2 Thickness increment values

8.2.1 Units without the additional class notation STI

When the additional class notation **STI** is not assigned to the unit, the thickness increments are to be taken equal to zero.

8.2.2 Units with the additional class notation STI

When the unit is assigned the additional class notation **STI**, the thickness increments may be defined by the Owner or by the Society, as follows:

a) When the Owner specifies its own thickness increments, it is to be notified to the Society where thickness increments are provided. Thickness increments are to be stated in the Design Criteria Statement.

b) When the Owner does not provide its own thickness increments, the values to be considered are defined in Tab 3.

Adequate indications (location, value of thickness increments) are to be given in the relevant structural drawings.

Table 3 : Thickness increments

Structural element	Thickness increment, in mm
Strength deck	1
Bottom	1
Side shell above the maximum draught at site	1
Side shell below the minimum draught at site	1
Splash zone	5
Inner skin	1
Upper strake of longitudinal bulkhead	1
Lowest side stringer	1

9 Bulkhead structure

9.1 General

9.1.1 The requirements of the present Article [9] apply to longitudinal or transverse bulkhead structures.

Generally, plane bulkheads are to be applied. Longitudinal bulkheads are usually longitudinally stiffened and transverse bulkheads mainly vertically stiffened with horizontal stringers (primary structure).

The lower stringer on transverse bulkheads may be supported by buttress (see Fig 18).

9.1.2 General arrangement

The number and location of watertight bulkheads are to be in accordance with the relevant requirements given in Ch 1, Sec 2.

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.

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.

The structural continuity of the bulkhead vertical and horizontal primary supporting members with the surrounding supporting structures is to be carefully ensured.

The web height of vertical primary supporting members of longitudinal bulkheads may be gradually tapered from bottom to deck. The maximum acceptable taper, however, is 80 mm per metre.

9.1.3 Watertight bulkheads of trunks, tunnels

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.

9.1.4 Openings in watertight bulkheads

a) Openings may not be cut in the collision bulkhead below the freeboard deck.

The number of openings in the collision bulkhead above the freeboard deck is to be kept to the minimum compatible with the design and proper working of the unit.

All such openings are to be fitted with means of closing to weathertight standards.

b) Certain openings below the freeboard 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 unit and to be provided with watertight doors having strength such as to withstand the head of water to which they may be subjected.

9.1.5 Watertight doors

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.

9.2 Plane bulkheads

9.2.1 The requirements for plane bulkheads are given in Pt B, Ch 4, Sec 5, [10.2] of the Ship Rules.

Horizontal stringers and associated brackets are subject to fatigue loading and are to be accessible for inspection. The structural analysis of these stringers must take into account any openings for ladders and pipes.

Attention is also to be paid to possible sloshing loads.

9.2.2 The upper part of plane bulkheads (longitudinal and transversal) are to be adequately reinforced in way of topside supports.

9.2.3 Vertical secondary stiffeners

For floating units with single bottom special attention is to be paid to the connection of vertical stiffeners on transverse bulkheads and bottom longitudinals. Direct calculation is to be submitted for information.

Attention is also to be paid to possible sloshing loads.

9.3 Swash bulkheads

9.3.1 General

The present [9.3] applies to transverse and longitudinal swash bulkheads whose main purpose is to reduce the liquid motions in partly filled tanks.

9.3.2 Openings

The total area of openings in a transverse swash 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 4.

In general, openings may not be cut within 0,15D from bottom and from deck.

Table 4 : Areas of openings in transverse swash bulkheads

Bulkhead portion	Lower limit	Upper limit
Upper	10%	15%
Central	10%	50%
Lower	2%	10%

9.4 Racking bulkheads

9.4.1 The Society may request racking bulkheads in the cargo area, if necessary.

The racking bulkheads are to be verified for design pressure indicated for the scantling of swash bulkheads.

The racking bulkheads are to be checked through direct calculations. Particular attention is to be paid to shear stress.

A racking bulkhead not complying with Tab 4 can not be considered as a swash bulkhead. In this case, the racking bulkhead is not to be taken into account in the sloshing calculation.

10 Bottom structure

10.1 General

10.1.1 Application

The requirements of this Article apply to longitudinally or transversely framed single and double bottom structures.

10.1.2 General arrangement

a) In units greater than 120 m in length, the bottom is, in general, to be longitudinally framed.

b) 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 unit.

c) The bottom is to be locally stiffened where concentrated loads are envisaged.

d) 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.

e) 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.

f) 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.

g) When solid ballast is fitted, it is to be securely positioned. If necessary, intermediate floors may be required for this purpose.

10.1.3 Keel

The width of the keel b is to be not less than the value obtained, in m, from the following formula:

$$b = 0,8 + 0,5\frac{L}{100}$$

10.1.4 Drainage and openings for air passage

a) 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.

b) Air holes are to be cut as near to the inner bottom and draining holes as near to the bottom shell as practicable.

10.2 Transversely framed single bottom

10.2.1 General

a) Single bottom units 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.

b) 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.

c) Centre and side girders are to be extended as far aft and forward as practicable.

d) 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.

e) Longitudinal girders are to be fitted in way of each line of pillars.

f) Floors are to be made with a welded face plate between the collision bulkhead and 0,25L from the fore end.

10.2.2 Floors

In general, the floor spacing is to be not greater than 5 frame spacings.

10.2.3 Longitudinal ordinary stiffeners

Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

10.3 Transversely framed single bottom

10.3.1 General

The requirements in [10.2.1] apply also to transversely framed single bottoms.

10.3.2 Floors

a) Floors are to be fitted at every frame.

b) The height, in m, of floors at the centreline is to be not less than $\ell/16$. In the case of units with considerable rise of floor, this height may be required to be increased so as to assure a satisfactory connection to the frames.

10.4 Longitudinally framed double bottom

10.4.1 General

The centre girder is to be continuous and extended over the full length of the unit and the spacing of adjacent longitudinal girders is generally to be not greater than 6,5 m.

10.4.2 Double bottom height

The double bottom height is given in Pt B, Ch 2, Sec 2, [3] of the Ship Rules or Pt D, Ch 7, Sec 2, [3] of the Ship Rules as applicable.

10.4.3 Floors

a) 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.

b) Plate floors are generally to be provided with stiffeners in way of longitudinal ordinary stiffeners.

c) 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.

10.4.4 Bottom and inner bottom longitudinal ordinary stiffeners

Bottom and inner bottom longitudinal ordinary stiffeners are generally to be continuous through the floors.

10.4.5 Brackets to centreline girder and margin plate

a) 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.

b) 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.

c) Where the side shell is transversely stiffened, margin plate brackets are to be fitted at every frame.

10.4.6 Duct keel

a) Where a duct keel is arranged, the centre girder may be replaced by two girders conveniently spaced, generally no more than 2 m apart.

b) The structures in way of the floors are to ensure sufficient continuity of the latter.

10.4.7 Bilge wells

a) Bilge wells arranged in the double bottom are to be 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.

b) Vertical extension of bilge wells is to comply with the requirements given in

- Pt B, Ch 2, Sec 2, [3.1.3] of the Ship Rules or
- Pt D, Ch 7, Sec 2, [3.2.3] of the Ship Rules as applicable.

c) Where there is no margin plate, well arrangement is considered by the Society on a case by case basis.

10.5 Transversely framed double bottom

10.5.1 General

The requirements in [10.4.1], [10.4.2], [10.4.5], [10.4.6] and [10.4.7] apply also to transversely framed double bottoms.

10.5.2 Floors

a) 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.

b) In general, plate floors are to be continuous between the centre girder and the margin plate.

c) Open floors are to be fitted in way of intermediate frames.

d) 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 $0,8\ L^{0,5}$.

10.5.3 Girders

a) 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.

b) 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 $0,8\ L^{0,5}$.

c) 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.

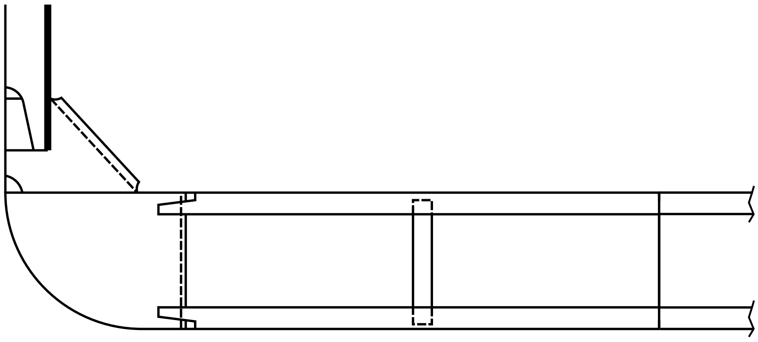
10.5.4 Open floors

a) 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 19).

b) 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.

c) Where frames and reverse frames are interrupted in way of girders, double brackets are to be fitted.

Figure 19 : Open floor



10.6 Bilge keel

10.6.1 Arrangement

Bilge keels may not be welded directly on the shell plating. An intermediate flat, or doubler, is required on the shell plating.

The ends of the bilge keel are to be sniped at an angle of 15° or rounded with large radius. They are to be located in way of a transverse bilge stiffener. The ends of the intermediate flat are to be sniped at an angle of 15°.

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 20). Where the butt weld has been subject to non-destructive examination, the crack arresting hole may be omitted.

The arrangement shown in Fig 20 is recommended.

The arrangement shown in Fig 21 may also be accepted.

10.6.2 Materials

The bilge keel and the intermediate flat are to be made of steel with the same yield stress and grade as that of the bilge strake.

10.6.3 Scantlings

The net thickness of the intermediate flat is to be equal to that of the bilge strake. However, this thickness may generally not be greater than 15 mm.

Figure 20 : Bilge keel arrangement

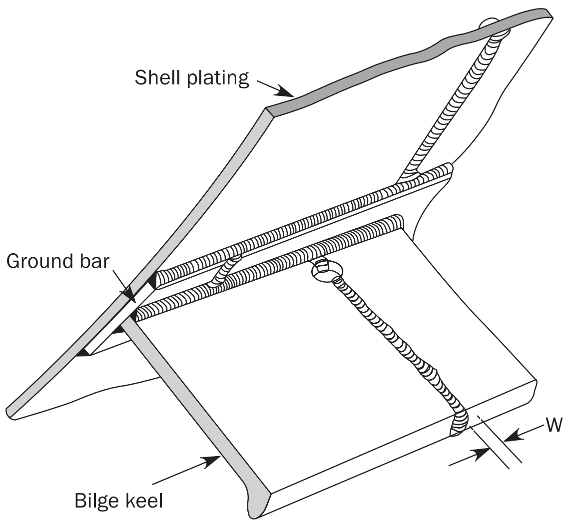
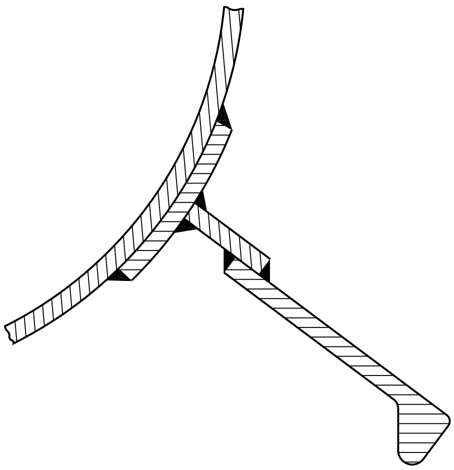


Figure 21 : Bilge keel alternative arrangement



10.6.4 Welding

The intermediate flat, through which the bilge keel is connected to the shell according to [10.6.1], is to be welded as a shell doubler by continuous fillet welds.

The butt welds of the doubler and bilge keel are to be full penetration and shifted from the shell butts.

The butt welds of the bilge plating and those of the doublers are to be flush in way of crossing, respectively, with the doubler and with the bilge keel.

Butt welds of the intermediate flat are to be made to avoid direct connection with the shell plating, in order that they do not alter the shell plating, by using, for example, a copper or a ceramic backing.

11 Side structure

11.1 General

11.1.1 Application

The requirements of this Section apply to longitudinally or transversely framed single and double side structures.

The transversely framed side structures are built with transverse frames possibly supported by side girders (see [5.3.1]).

The longitudinally framed side structures are built with longitudinal ordinary stiffeners supported by side vertical primary supporting members.

11.1.2 General arrangement

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.

11.1.3 Sheerstrake

a) The width of the sheerstrake, in m, is to be not less than 0,8 + L / 200, measured vertically, but need not be greater than 1,8 m.

b) The sheerstrake may be either welded to the stringer plate or rounded. If the sheerstrake is rounded, its radius, in mm, is to be not less than 17 ts , where ts is its net thickness, in mm.

c) The upper edge of the welded sheerstrake is to be rounded, smooth, and free of notches. Fixtures, such as bulwarks and eye plates, are not to be directly welded on the upper edge of the sheerstrake, except in fore and aft parts.

   Drainage openings with a smooth transition in the longitudinal direction may be permitted.

d) The transition from a rounded sheerstrake to an angled sheerstrake associated with the arrangement of the superstructures is to be designed to avoid any discontinuities.

   Drawings showing the details of this transition are to be submitted for approval to the Society.

e) The longitudinal seam welds of a rounded sheerstrake are to be located outside the bent area, at a distance not less than 5 times the maximum net thickness of the sheerstrake.

f) The welding of deck fittings onto rounded sheerstrakes is to be avoided within 0,6 L amidships.

11.1.4 Riser attachment

Equipment located on the side shell (e.g. risers, fenders) are to be fitted in way of primary supporting members.

11.2 Longitudinally framed single side

11.2.1 Longitudinal ordinary stiffeners

Longitudinal ordinary stiffeners are generally to be continuous when crossing primary members.

11.2.2 Primary supporting members

a) In general, the side vertical primary supporting member spacing may not exceed 5 frame spacings.

b) In general, the side vertical primary supporting members are to be bracketed to the double bottom transverse floors.

11.3 Transversally framed single side

11.3.1 Frames

a) Transverse frames are to be fitted at every frame.

b) 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.

c) In general, the net section modulus of 'tween deck frames is to be not less than that required for frames located immediately above.

11.3.2 Primary supporting members

a) 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.

b) 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.

c) The height of end brackets is to be not less than half the height of the primary supporting member.

11.4 Longitudinally framed double side

11.4.1 General

a) 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.

b) Knuckles of the inner side are to be adequately stiffened.

11.4.2 Primary supporting members

a) 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.

b) 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.

11.5 Transversally framed double side

11.5.1 General

a) The requirements in [11.4.1] also apply to transversely framed double side.

b) 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.

11.5.2 Frames

Transverse frames are to be fitted at every frame.

11.5.3 Primary supporting members

a) Unless otherwise specified, transverse frames are to be supported by side girders if $D \geq 6$ m.

These girders are to be supported by side vertical primary supporting members spaced no more than 3,8 m apart.

b) In the case of units having $4,5 < D < 6$ m, side vertical primary supporting members are to be fitted, in general not more than 5 frame spacings apart.

11.6 Frame connections

11.6.1 General

a) End connections of frames are to be bracketed.

b) 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.

c) Brackets are normally connected to frames by lap welds. The length of overlap is to be not less than the depth of frames.

11.6.2 Upper brackets of frames

a) 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 items b) and c) and depending on the type of connection

t : Bracket net thickness, in mm.

b) For connections of perpendicular stiffeners located in the same plane (see Fig 22) or connections of stiffeners located in perpendicular planes (see Fig 23), 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 22 and Fig 23.

Figure 22 : Connections of perpendicular stiffeners in the same plane

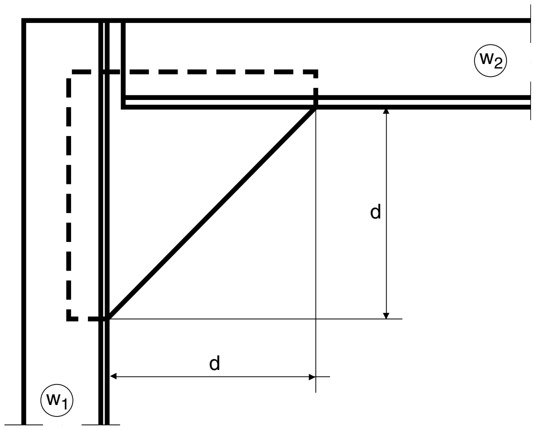
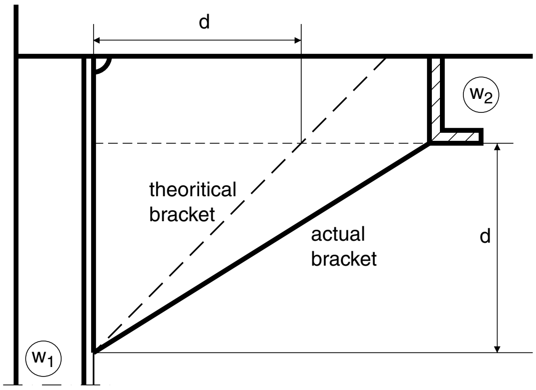


Figure 23 : Connections of stiffeners located in perpendicular planes



c) For connections of frames to deck beams (see Fig 24), the required net section modulus is to be taken equal to:

- for bracket "A":

  $w_A = w_1$ if $w_2 \leq w_1$

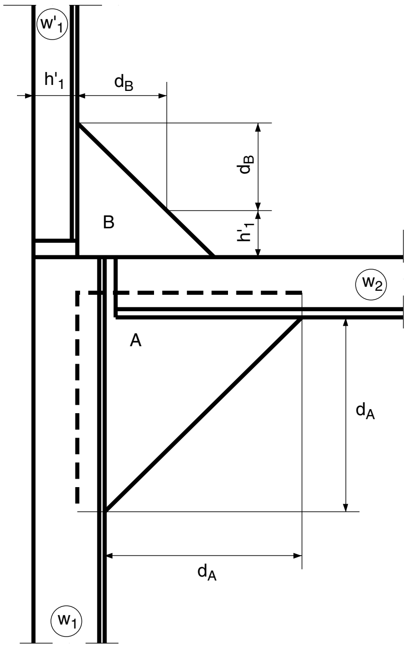
  $w_A = w_2$ if $w_2 > w_1$

- 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 24.

Figure 24 : Connections of frames to deck beams



11.6.3 Lower brackets of frames

a) In general, frames are to be bracketed to the inner bottom or to the face plate of floors as shown in Fig 25.

b) 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: $\varphi = 45$

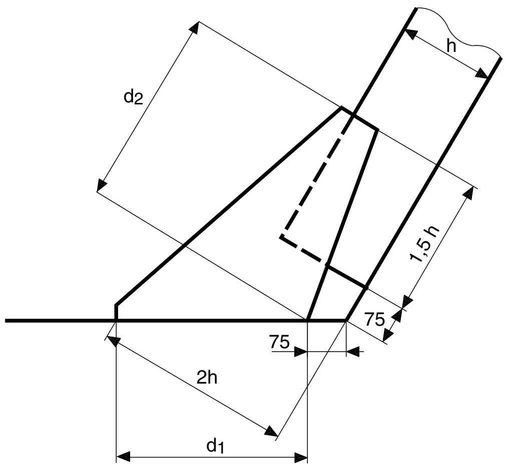
w : Required net section modulus of the frame, in cm^3

t : Bracket net thickness, in mm.

c) Where the bracket net thickness, in mm, is less than $15\ L_b$, 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 $10\ L_b$.

Figure 25 : Lower brackets of main frames



11.7 Openings in the side shell

11.7.1 Position of openings

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 Fig 26.

11.7.2 Local strengthening

a) Openings in the unit 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.

b) 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 that of the local shell plating, but in no case less than 12 mm.

c) Openings in item a) and item b) 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 [11.1.3], 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.

12 Deck structure

12.1 General

12.1.1 Application

The requirements of this Section apply to longitudinally or transversely framed deck structures.

12.1.2 General arrangement

a) 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.

b) In units 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 units, it is considered by the Society on a case by case basis.

c) Adequate continuity of strength is to be ensured in way of:
   - stepped or knuckled strength decks
   - changes in the framing system.

   Details of structural arrangements are to be submitted for review to the Society.

d) Where applicable, deck transverses of reinforced scantlings are to be aligned with floors.

e) Deck supporting structures under deck machinery, cranes and king posts are to be adequately stiffened.

f) Pillars or other supporting structures are generally to be fitted under heavy concentrated cargoes.

g) Special arrangements, such as girders supported by cantilevers, are considered by the Society on a case by case basis.

h) Where devices for 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.

i) Stiffeners are also to be fitted in way of the ends and corners of deck houses and partial superstructures.

j) The topside supports are to be fitted in way of bulkheads or beams.

12.1.3 Construction of watertight decks

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.

12.1.4 Stringer plate

a) The width of the stringer plate, in m, is to be not less than 0,8 + L / 200, measured parallel to the deck, but need not be greater than 1,8 m.

However, the stringer plate is also to comply with the requirements of the Ship Rules, Pt B, Ch 4, Sec 1, [2.3] and Pt B, Ch 4, Sec 1, [2.4.5].

Rounded stringer plates, where adopted, are to comply with the requirements of [11.1.3] for rounded sheerstrakes.

b) Stringer plates of lower decks not extending over the full unit's length are to be gradually tapered or overlapped by adequately sized brackets.

12.2 Longitudinally framed deck

12.2.1 General

a) 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.

b) In general, the spacing of deck transverses is not to exceed 5 frame spacings.

c) In case of deck transverses located above the deck, longitudinal girders are to be fitted above the deck, in addition of tripping brackets.

12.2.2 Longitudinal ordinary stiffeners

a) In units 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.

b) Frame brackets, in units with transversely framed sides, are generally to have their horizontal arm extended to the adjacent longitudinal ordinary stiffener.

12.3 Transversely framed deck

12.3.1 General

In general, deck beams are to be fitted at each frame.

12.4 Pillars

12.4.1 Pillars are to be fitted, as far as practicable, in the same vertical line.

12.4.2 In general, pillars are to be fitted below winches, cranes, windlasses and steering gear, in the engine room and at the corners of deckhouses.

12.4.3 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.

12.4.4 Tight or non-tight bulkheads may be considered as pillars, provided that each vertical stiffener complies with the applicable buckling requirement in Ch 1, Sec 8, [4], taking into account:

- a width of associated plating equal to 35 times the plating net thickness
- the axial load supported by the analysed stiffener
- a resistance partial safety factor, γ_R, equal to 1,15 for column buckling and 1,05 for torsional and local buckling.

12.5 Openings in the strength deck

12.5.1 Position of openings and local strengthening

a) 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 avoided in way of the connection between deck and side.

The dashed areas in Fig 22 are those where openings are generally to be avoided. The meaning of the symbols in Fig 22 is as follows:

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 26), 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

b) 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 27
- elliptical with the major axis in the longitudinal direction and the ratio of the major to minor axis not less than 2.

c) If the openings arrangements do not comply with the requirements of the present Sub-Article, the hull girder longitudinal strength assessment is to be carried out by subtracting such opening areas.

Figure 26 : Position of openings in the strength deck

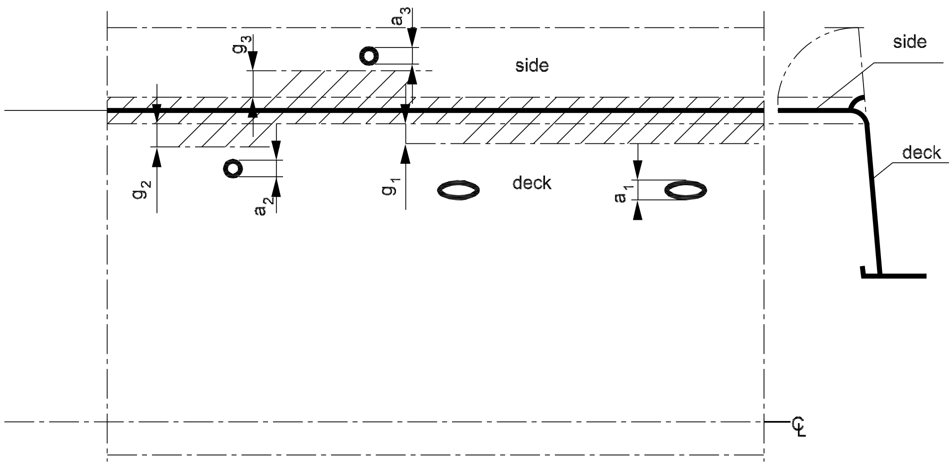
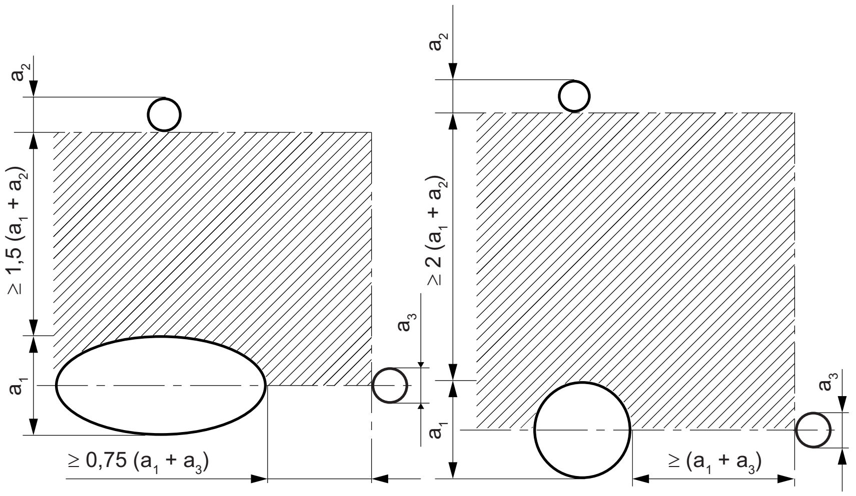


Figure 27 : Circular openings in the strength deck



12.5.2 Corners of hatchways

a) For hatchways located out of the cargo area, 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.

b) Where insert plates are required, their thickness and arrangement may be considered by the Society in a case by case basis.

12.6 Openings in decks other than the strength deck

12.6.1 The requirements for such openings are similar to those in [12.5.1] for the strength deck. However, circular openings need not to be compensated.

12.6.2 Corners of hatchway openings are to be rounded, as specified in [12.5.2] for the strength deck; insert plates may be omitted, however, when deemed acceptable by the Society.

13 Reinforcements in way of supporting structures for hull attachments

13.1 Local arrangement

13.1.1 Generally, the supports for attachments and appurtenances are to be fitted in way of longitudinal and transversal bulkheads or in way of deck beams. Other supports are to be fitted in way of large primary supporting members.

The main structure may be locally reinforced by means of insert plates.

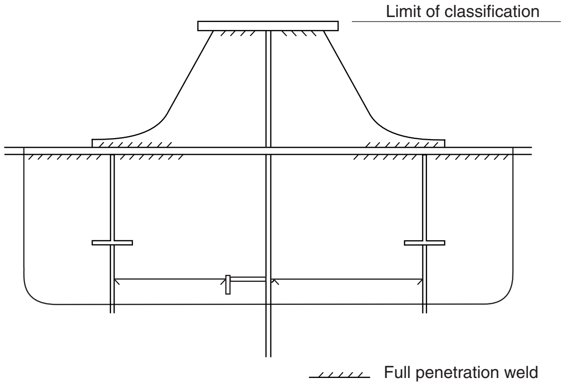
When the supports are only located on transverse web beam, the longitudinal structure is to be adequately reinforced.

The cut out in the deck transverse for the passage of ordinary stiffeners are to be closed in way of supports.

Particular attention is to be paid to buckling below supports.

An example of local supporting structure for hull attachment is indicated in Fig 28.

Figure 28 : Example of local reinforcements in way of supporting structure



14 Welding and weld connections

14.1 General

14.1.1 The standards applicable for offshore areas and for ship areas are different, as stated in [14.2]and [14.3].

14.2 Offshore areas

14.2.1 NR426, Construction Survey of Steel Structures of Offshore Units and Installations, is to be applied for offshore areas.

14.2.2 For size of fillet welds, reference may be made to AWS D1.1M:2020 Structural Welding Code - Steel.

14.3 Ship areas

14.3.1 Pt B, Ch 13, Sec 1 to Pt B, Ch 13, Sec 3 of the Ship Rules are to be applied for ship areas.

14.3.2 For the members, the web is to be connected to the face plate by means of double continuous fillet welding.

It is recommended to use continuous fillet welding to connect the web to its associated shell plating. The throat thickness of such a welding is neither to be less than the value specified in Pt B, Ch 13, Sec 3, Tab 4 of the Ship Rules nor greater than 0,45 t.

Discontinuous welds and scallop welds are generally not allowed in the cargo tank area.

14.3.3 The welding factors for some hull structural connections are specified in Tab 5. These welding factors are to be used, in lieu of the corresponding factors specified in Pt B, Ch 13, Sec 3, Tab 1 of the Ship Rules to calculate the leg length of fillet weld T connections according to Pt B, Ch 13, Sec 3, [3.2] of the Ship Rules. For the connections of Tab 5, continuous fillet welding is to be adopted.

Table 5 : Welding factor w_F

Hull area	Connection		Welding factor w_F
	of	to	
Double bottom in way of cargo tanks	girders	bottom and inner bottom plating	0,48
		floors (interrupted girders)	0,48
	floors	bottom and inner bottom plating	0,48
		inner bottom in way of bulkheads or their lower stools	0,63
		girders (interrupted floors)	0,48

14.3.4 Leg length of fillet welds for transverse web frames and horizontal stringers on transverse bulkheads are to be reinforced as shown in Fig 29 and Fig 30.

As a rule, full penetration welds are to be applied as shown in Fig 29 and Fig 30. The length of full penetration welds is not to be less than the greater of the following values:

a) length of the area where the tension stress normal to welds is above 0,3 times the tensile strength of the filler metal

b) 400 mm.

The tension stress and shear stress required in a) and b) are to be calculated based on the provisions of Ch 1, Sec 9, using a fine mesh finite element model. The size of elements is not to be above 100 mm x 100 mm. Values of stresses calculated at element centroid are to be used.

The length of areas defined in a) and b) is to include an entire number of 100 mm x 100 mm elements.

14.3.5 The minimum leg length of continuous fillet welding is not to be less than 6 mm for assemblies of high tensile steel.

Figure 29 : Reinforcement of leg length of a web frame

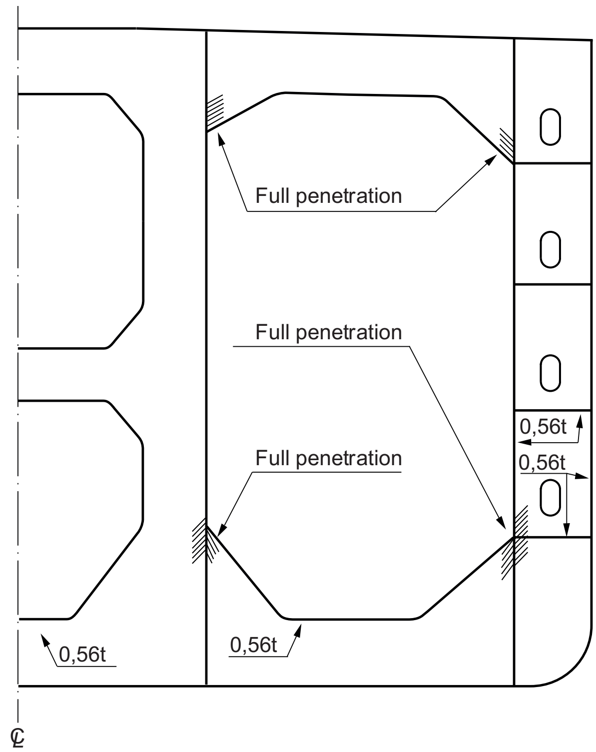
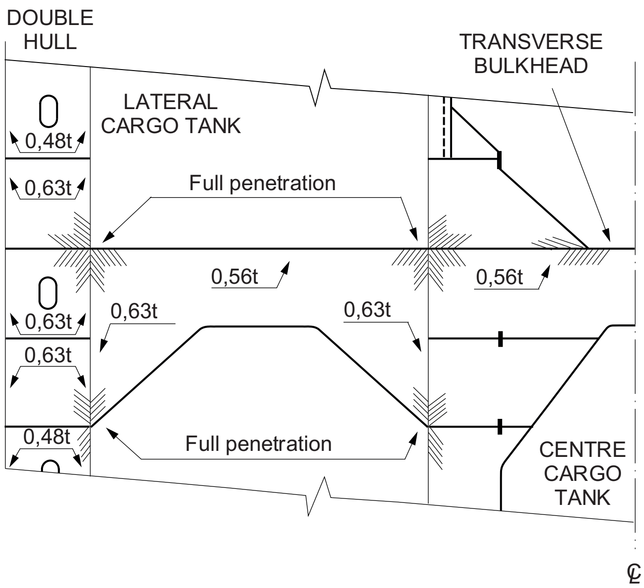


Figure 30 : Reinforcement of leg length for a stringer



Section 4 Hydrodynamic Analysis

1 General

1.1 Principle

1.1.1 Application

Hydrodynamic analysis is to be performed for both site conditions and towing/transit phases, taking into account the probability levels defined in [1.1.3].

The target of hydrodynamic analysis is to assess design values and distributions of parameters related to wave loading, defined in [1.1.2].

Direct calculations are to be carried out. Hydrodynamic calculations may be calibrated based on model tests.

1.1.2 Parameters related to wave loading

The hydrodynamic analysis is to result in the following parameters specified with their distribution over the length of the unit:

- wave induced vertical bending moment
- wave induced horizontal bending moment
- wave induced vertical shear force
- local accelerations in three directions for upright and inclined conditions
- relative wave elevation in upright condition.

The hydrodynamic analysis is also to result in the motions and global accelerations at the floating unit centre of gravity:

- surge acceleration
- sway acceleration
- heave acceleration
- yaw acceleration
- roll amplitude and acceleration
- pitch amplitude and acceleration.

1.1.3 Return period of considered environment

The parameters defined in [1.1.2] are to correspond to a probability level of:

- once in 100 years (typically referred to by a probability level of $10^{-8,7}$) for the unit on site
- once in 10 years (typically referred to by a probability level of $10^{-7,7}$) for the unit in transit conditions, except when otherwise specified by the party applying for Classification (see Ch 1, Sec 1, [1.10.3]).
- 10^{-5} when requested for deterministic fatigue analysis, see Ch 1, Sec 10, [4].

For the inspection cases the environmental data may be taken into account at a lower return period.

1.1.4 Documents to be submitted

List of documents to be submitted is given in Ch 1, Sec 1, [6.1.1], item b).

1.2 Hydrodynamic analysis

1.2.1 Software

Assessment by direct calculation is to be carried out using a recognized software, generally using three dimensional potential flow based on diffraction radiation theory. The software is to be documented.

2 Environmental data for hydrodynamic analysis

2.1 General

2.1.1 Requirements of the present Section are complementary to Part B, Chapter 2, which remain applicable, except where otherwise specified.

2.2 Nature of environmental data

2.2.1 General

Two types of environmental data may be available:

- long-term data: wave description over a long period of time
- short-term data: wave description of extreme sea states.

2.2.2 Long-term data

Two types of long-term environmental data may be accepted:

a) Scatter diagrams

The sea state statistic data are generally provided under the form of a “scatter diagram” (table including significant wave height, wave period and number of occurrences). The reference duration on which the scatter diagram is built is to be indicated.

In order to ensure a good accuracy of results, classes of wave height and wave periods are not to be too coarse. Typically, intervals of 1 meter in significant wave height and 1 second in wave zero-up crossing period are to be used.

b) Hindcast data

Hindcast data consist of a time history of sea states (wave spectrum parameters, wave height, wave period, wave direction...), and eventually wind and current.

2.2.3 Short-term data

Short-term data consist of information about extreme environmental conditions, given by metocean specialist. They can be presented under extreme wave height and most probable associated period or contours wave height/wave period. Information on sea state duration is to be provided.

2.2.4 Combination of wave components

In the case of more than one wave component in environmental data, information about the combinations of different wave components (joint probabilities) is to be provided. When no information is available from metocean specification, the combinations to be used are defined in NR493, Classification of Mooring Systems for Permanent and Mobile Offshore Units.

When relevant, and particularly in cyclonic areas, information is to encompass seasonal extremes.

2.3 Environmental data to be submitted

2.3.1 Description of on-site environment

For hydrodynamic analysis, the following environmental data are to be submitted to the Society:

- General description of environmental conditions.
- Description of wave spectral content: for each component, wave spectrum with the specification of its characteristic parameters, directional spreading if any, and prevailing directions.
- Long-term data as defined in [2.2.2]. A minimum of 10-year data is to be used to derive properly 100 years responses. Information of sea state duration is to be provided.
- Short-term data as defined in [2.2.3]. Extreme values are to be given at least for a return period of 100 years.
- Restrictions of relative headings between the different components, if any.
- Information regarding combination of wave components as required in [2.2.4], when available.

2.3.2 Description of transit environment

A description of routes used for transit is to be submitted to the Society. In addition, for each geographic sector on which wave description is defined, the following items are to be submitted:

- time spent in each sector
- description of wave spectral content: for each component, wave spectrum with the specification of its characteristic parameters, directional spreading if any, and prevailing directions
- restrictions of relative headings between the different components, if any
- short-term data as defined in [2.2.3]. Extreme values are to be given at least for a return period consistent with [1.1.3]
- when available, long-term data as defined in [2.2.2]. The amount of data is to be at the satisfaction of the Society.

3 Design conditions

3.1 Loading conditions

3.1.1 Loading conditions used for hydrodynamic analysis are to be selected from those specified in the loading manual.

If the party applying for Classification specifies additional loading conditions, these conditions are to be taken into account. All parameters required by the Rules for the definition of these conditions are to be specified and stated in the Design Criteria Statement.

3.1.2 As a minimum, the following loading conditions are to be considered:
- on-site condition at design maximum draught, as defined in Ch 1, Sec 1, [3.2.11]
- on-site condition at design minimum draught, as defined in Ch 1, Sec 1, [3.2.11]
- on-site condition in still water giving maximum shear force
- at least one condition in towing/transit.

The selection of draughts corresponding to each loading condition is to be at the satisfaction of the Society.

3.2 Advance speed

3.2.1 Hydrodynamic analysis for on-site conditions are to be performed using an advance speed equal to zero.

3.2.2 Hydrodynamic analysis for towing/transit is to take into account both of the following cases:
- advance speed equal to zero
- advance speed as specified by the party applying for classification.

4 Modelling principles

4.1 Hydrodynamic mesh

4.1.1 The wetted surface of the unit is to be modelled by elements having a size consistent with wave parameters (wave length and wave amplitude in particular). Mesh dimension of 2 meters is generally recommended.

The model is to take into account the effects of appendices if any, and unit trim.

4.2 Mass distribution

4.2.1 Information regarding mass distribution along all axes and in particular gyration radius along longitudinal axis is to be submitted for each loading condition.

Effects of free surface moment are to be taken into account and duly justified.

4.3 Connection with other structures

4.3.1 The society may request to take into account the connection of the floating unit with the seabed or other structures (risers, mooring...).

4.4 Water depth

4.4.1 Water depth is to be taken as indicated in the environmental data.

5 Floating unit responses

5.1 Results

5.1.1 The hydrodynamic analysis is to provide the following results for all loading conditions defined in [3.1]:
- floating unit natural periods, and
- for all parameters defined in [1.1.2]:
  - Response Amplitude Operators (RAOs) [3.1]
  - floating unit extreme values (single amplitude) at probability level defined in [1.1.3].

5.1.2 For all loading conditions, diagrams representing the variations of all parameters defined in [1.1.2] over the length of the floating unit and for various headings are to be submitted to the Society for review.

5.2 Response Amplitude Operators

5.2.1 General

RAOs (Response Amplitude Operators) of all parameters defined in [1.1.2] are to be calculated for each degree of freedom.

5.2.2 Wave headings

RAOs are to be calculated:
- for different headings including pure head, following and pure beam seas. RAOs are to be presented over all incidences
- with a step in headings not exceeding 15°, generally; the step is not to be less than 5° if directional spreading is used.

5.2.3 Wave frequencies

RAOs are to be calculated:

- for wave circular frequencies covering the anticipated sea states and spectra and typically from 0,1 rad/s to 2 rad/s
- with a step in wave circular frequencies not exceeding 0,05 rad/s. Refinements are to be performed around natural periods of the unit, in particular in roll.

5.2.4 Roll damping

Values and methodology taken into account for roll damping are to be duly justified.

5.3 Calculation of unit responses

5.3.1 Wave heading

Unit responses are to be calculated for all wave directions with a step not exceeding 15°. Pure head and following seas, and pure beam seas are to be considered.

The requirements of [5.3.2] and [5.3.3] are also to be considered.

5.3.2 Wave heading in transit/towing

In towing conditions, all wave headings (as defined in [5.3.1] are to be taken at the same probability (no prevailing direction) unless otherwise specified as stated in Ch 1, Sec 1, [1.10].

5.3.3 Wave heading for Single Point Moored units

For site conditions of Single Point Moored units (SPM), all wave headings (as defined in [5.3.1]) are to be considered unless:

- restrictions of headings for operating conditions are available
- a heading analysis performed at the satisfaction of the Society demonstrates that several wave headings cannot occur in 100 years environments (including waves, current and wind).

5.3.4 Directional spreading on site

Directional spreading may be considered in accordance with metocean specification for site conditions.

5.3.5 Directional spreading in towing/transit

Directional spreading for towing/transit conditions may be considered in accordance with towing/transit metocean specification. As an alternative, the formulation given in [5.3.6] may be used.

5.3.6 Alternative formulation for directional spreading in towing/transit

The wave energy density function can be written as:

$S(\omega,\theta) = D(\theta)\ s(\omega)$

where:

$D(\theta)$: Directional spreading function, characterizing the directional distribution of the wave energy around a main direction θ_m; by default, this function is to be taken as:

$D(\theta) = k \cos^2(\theta)$

with k satisfying:

$$\sum_{\theta m - 90°}^{\theta m + 90°} D(\theta) = 1$$

$s(\omega)$: Wave energy spectrum.

5.3.7 Sensitivity analysis

During hydrodynamic analysis, sensitivity analyses are to be performed on the following items, if deemed relevant:

- Wave parameters (wave spectrum parameter, direction...).
- Wave periods:
  - Based on wave height/wave period contours.
  - Performing a sensitivity study around the most probable wave period as defined by metocean specification. A range of at least ± 15% around the most probable peak period is to be considered.
- Other parameters (trim, loading of unit,...).

5.4 Design wave loads for structural analysis

5.4.1 The design values and distributions of the wave loads derived from extreme values obtained as per [5.1] are to be determined as defined in Ch 1, Sec 5, [3].

Section 5 Design Loads

Symbols

a_H : Heave acceleration, in m/s², defined in [3.4.4]
A_R : Roll acceleration, in rad/s², roll amplitude, in rad, defined in [3.4.5]
a_{SU} : Surge acceleration, in m/s², defined in [3.4.2]
a_{SW} : Sway acceleration, in m/s², defined in [3.4.3]
B : Moulded breadth, in m, taken equal to the greatest moulded breadth measured amidships at the maximum draught T
C : Wave parameter, to be taken equal to:

- for 65 m ≤ L < 90 m:

$$C = (118 - 0{,}36L)\frac{L}{1000}$$

- for 90 m ≤ L < 300 m:

$$C = 10{,}75 - \left(\frac{300 - L}{100}\right)^{1{,}5}$$

- for 300 m ≤ L ≤ 350 m:
  C = 10,75
- for 350 < L ≤ 500 m

$$C = 10{,}75 - \left(\frac{L - 350}{150}\right)^{1{,}5}$$

C_B : Total block coefficient, equal to:

$$C_B = \frac{\Delta}{1{,}025LBT}$$

C_B not to be taken greater than 1

d_0 : Distance, in m, to be taken equal to:

- $d_0 = 0{,}02\ L$ for 65 m ≤ L < 120 m
- $d_0 = 2{,}4$ for L ≥ 120 m

g : Gravity acceleration, in m/s², taken equal to 9,81
L : Length, in m, as defined in Ch 1, Sec 1, [3.2.6]
n : Navigation coefficient, defined in Tab 1
T : Maximum draught, in m, as defined in:

- for site condition: Ch 1, Sec 1, [3.2.11]
- for transit condition: Ch 1, Sec 1, [3.2.12]

T_1 : Draught associated to the loading condition considered
V_S : Maximum ahead speed in transit, in knots
z_{TOP} : Z co-ordinate, in m, of the highest point of the tank in the z direction
α_P : Pitch acceleration, in rad/s², defined in [3.4.6]
α_R : Roll acceleration, in rad/s², roll amplitude, in rad, defined in [3.4.5]
α_Y : Yaw acceleration, in rad/s², defined in [3.4.7]
Δ : Moulded displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m³)
ρ : Sea water density, in t/m³, to taken equal to 1,025
ρ_L : Density, in t/m³, of the liquid carried x, y, z
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 1, [3.3].

1 General

1.1 Principles

1.1.1 Application

The design loads are to be determined in accordance with the present Section, considering the relevant loading conditions and associated loads as listed in Ch 1, Sec 1, [1.5.4].

1.1.2 Site conditions

The design loads for site conditions are to be determined as stated in the present Section, taking into account the results of hydrodynamic analysis (see Ch 1, Sec 4, [5]). Two situations may be considered:

- when a navigation notation completes the site notation of the unit, the rule values of wave loads for this navigation notation are to be superimposed with the values obtained from hydrodynamic analysis, as defined in [3.2]
- when no navigation notation is granted to the unit for on-site conditions, the wave loads obtained from hydrodynamic analysis are to be superimposed with the rule values calculated for sheltered area, as defined in [3.2].

1.1.3 Transit conditions

The design loads for transit conditions are to be determined as stated in the present Section, taking into account the results of hydrodynamic analysis (see Ch 1, Sec 4, [5] and Ch 1, Sec 1, [1.10.3]). Two situations may be considered:

- when a navigation notation completes the transit notation of the unit, the rule values of wave loads for this navigation notation are to be superimposed with the values obtained from hydrodynamic analysis, as defined in [3.2]
- when no navigation notation is granted to the unit for transit conditions, the wave loads obtained from hydrodynamic analysis are to be used, as defined in [3.2].

1.2 Definitions

1.2.1 Still water loads

Still water loads are those acting on the ship at rest in calm water.

1.2.2 Wave loads

Wave loads are those due to wave pressures and ship motions.

1.2.3 Dynamic loads

Dynamic loads are those that have a duration much shorter than the period of the wave loads.

1.2.4 Local loads

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, hydrostatic internal liquid pressure and the static pressures and forces induced by the gravity
- wave local loads are constituted by the external sea pressures due to waves and the inertial pressures and forces induced by the ship accelerations
- dynamic local loads are constituted by the impact and sloshing pressures.

For structural watertight elements located below the deepest equilibrium waterline (excluding side shell structural elements) which constitute boundaries intended to stop vertical and horizontal flooding, the still water and wave pressures in flooding conditions are also to be considered.

1.2.5 Hull girder loads

Hull girder loads are internal forces and moments which result from the local loads acting on the unit.

1.2.6 Loading conditions

A loading condition is a distribution of weights carried onboard the unit.

1.2.7 Load case

A load case is a combination of hull girder and local loads.

1.3 Application criteria

1.3.1 Hull girder loads

The wave and dynamic hull girder loads are to be used for the determination of:

- the hull girder strength, according to the requirements of Ch 1, Sec 6; and
- the structural scantling of platings, ordinary stiffeners and primary supporting members contributing to the hull girder strength, in combination with the local loads given in Articles [5] and [6], according to the requirements in Ch 1, Sec 7; Ch 1, Sec 8 and Ch 1, Sec 9.

1.3.2 Load cases

The local loads defined in Articles [5] and [6] for the transit and site conditions are to be calculated in each of the mutually exclusive load cases described in Article [4].

1.3.3 Unit motions and global accelerations

The wave local loads are to be calculated on the basis of the reference values of unit motions and global accelerations specified in [3.4].

1.3.4 Calculation and application of local loads

The criteria for calculating:

- still water local loads
- wave local loads on the basis of the reference values of unit motions and global accelerations,

are specified in Articles [5] and [6].

1.3.5 Flooding conditions

The still water and wave pressures in flooding conditions are specified in [6.6].

1.3.6 Accidental loading cases

The design of the floating unit is to consider the possibility of accidental loads as may result from collisions, dropped objects, fire or explosions (see Ch 1, Sec 9, [3]).

Accidental loading cases may be required for the transit and site phases.

Accidental loading cases according to Pt B, Ch 2, Sec 3, [1.5] are also to be calculated.

In accidental conditions, environmental loads are to be evaluated taking into account the circumstances in which the considered situation may realistically occur, and the time needed for evacuation or other remedial action. The return period of such environmental loads is generally taken as 1 year.

1.3.7 Load definition criteria to be adopted in structural analyses of plates and secondary stiffeners

The present requirement applies for the definition of local loads to be used in the scantling checks of plating according to Ch 1, Sec 7 and ordinary stiffeners according to Ch 1, Sec 8.

Load model:

a) 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.

b) 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. This calculation is to be done considering the maximum draught
   - The still water and wave differential pressures (internal minus external sea pressure) considering the compartment adjacent to the outer shell as being loaded. This calculation is to be made considering the minimum draught.

Note 1: The external wave pressure in load case "b" as defined in Article [4] is to be taken equal to 0.

In the absence of more precise information, the unit minimum draught at site T_{mini}, in m, is to be obtained from the following formula:

$T_{mini} = 2 + 0{,}02\ L$

1.3.8 Load definition criteria to be adopted in structural analyses based on three dimensional structural models

The present requirement applies for the definition of local loads to be used in the scantling checks of primary supporting members. For primary supporting members a three dimensional structural model is required.

The most severe loading conditions and associated draught for the structural elements under investigation are specified in Ch 1, Sec 9.

2 Still water loads

2.1 Loading manual

2.1.1 General

A loading manual is to be submitted for approval.

The loading manual is to be approved by the Owner.

In addition the requirements given from [2.1.2] to [2.1.8] are to be satisfied.

2.1.2 Lightweight

The lightweight distribution is to be submitted.

The estimation and distribution of the lightweight is to include the topside loads:

- in dry conditions for transit
- in wet conditions at site (including loads from mooring system in case of pre-tension in lines).

The interface management quality plan for co-ordination between shipyard and topsides fabrication yard and the procedures for transfer of data for update of stability manual are to be addressed.

Lightweight of topsides and hull are to be identified independently.

2.1.3 Principle for loading conditions

For a floating unit with mainly ongoing loading/unloading process a special study is to be carried out to evaluate the sequence of filling with respect to draught, trim and heel restrictions, if any. Attention is to be paid to minimizing free surface areas (sloshing, stability).

The study is initially to provide the envelopes of still water bending moment and shear force, and the data for a certain number of load patterns, for which the strength of primary structure will be evaluated, as specified in the present Chapter.

2.1.4 Design loading conditions

The hull girder is to be designed to allow flexibility in cargo loading. Any combination of adjacent empty and full cargo tanks are to be permitted over the full operating draught range (transit draught to scantling draught), with the limitation of allowable bending moment, shear force and minimum draught or otherwise as approved by the Owner.

The design loading conditions are to be separated into four categories:

- maximum / minimum conditions at site
- intermediate conditions at site
- inspection conditions at site
- maximum / minimum conditions during transit.

2.1.5 Maximum / minimum loading conditions

The maximum condition is to consider the unit with maximum draught and with all compartments filled to their maximum capacity.

The minimum conditions are to be divided into installation condition at site and minimum operational draught.

2.1.6 Intermediate loading conditions

Several intermediate loading conditions must be evaluated in the loading booklet to reflect the constant loading/ unloading process and to estimate the maximum values of still water bending moment and shear force.

The intermediate loading conditions must be based on the operating requirements which need to be mentioned in the loading booklet.

The intermediate conditions must also reflect the difference in loading and unloading sequences.

The Society reserves its right to require further loading conditions to take into account change in loading pattern as a consequence of human failure and pump system abnormalities (redundancy of pumps).

2.1.7 Inspection and repair loading conditions

Inspection and repair conditions have usually to be combined with the same values for wave loads as given for the maximum, minimum and intermediate conditions.

However, for units anchored in areas with occasional severe weather conditions (such as tropical hurricanes), certain reductions of the wave loads may be considered for those conditions. In other words, an increase of the still water bending moment and still water shear force above the maximum values defined by maximum, minimum and intermediate conditions may be accepted provided the Owners written agreement.

2.1.8 Transit condition to intended site

The loading cases for the transit between shipyard and the intended site must be available in the loading manual. Values of trim and draught must be chosen to reduce the slamming and bow impact on the unit.

The criteria of the Rules for the transit conditions are based directly on the magnitude and distribution of the still water bending moment, shear force and draught. The loading case is therefore to be available early in the design phase.

2.2 Hull girder still water loads

2.2.1 Transit and site loads

The hull girder still water loads as per [2.2.2] and [2.2.3] have to be defined for both transit and on-site conditions. For this purpose, two distinct sets of still water bending moments and shear forces are to be specified.

2.2.2 Still water bending moment distribution

Design or allowable still water bending moment distribution is to be presented in a diagram or a table showing the values for bending moment at the position of centre of each compartment and at each transverse bulkhead.

2.2.3 Still water shear force distribution

Design or allowable still water shear force distribution is to be presented in a diagram or a table showing the values for shear force at the position of each transverse bulkhead.

2.3 Loading instrument

2.3.1 The loading instruments are to be in accordance with the requirements of Pt B, Ch 1, Sec 5, [3] of the Ship Rules. A floating unit with service notation as given in Ch 1, Sec 1, [1.2.1], is considered as belonging to “Category I ships”.

2.3.2 The loading instrument is also to perform stability calculations according to the procedures indicated in the Ship Rules as referenced above.

3 Wave loads

3.1 Transit and site conditions

3.1.1 Wave loads defined in the present Article are to be processed for both transit and on-site conditions. For this purpose, two distinct sets of design wave loads are to be considered.

3.2 Determination of the design wave loads

3.2.1 Definitions

The following terms are used to describe the wave loads:

- Wave load values:

  Wave load parameters constant along the length of the unit (absolute unit motions and accelerations at the centre of gravity of the unit).

- Wave load distributions:

  Wave load parameters varying along the length of the unit (e.g. hull girder wave loads, relative wave elevation).

3.2.2 Design values and distributions for ship areas

For ship areas, the design values and distributions of wave loads are the maximum between:

- Hydrodynamic values and distributions defined in [3.2.4]
- Minimum values and distributions (for site condition only) defined in [3.2.7]
- Rule values and distributions, if a navigation notation is granted, as defined in [3.2.5]

The design wave loads are to be entered in the Design Criteria Statement.

The following design values are to be provided:

- Absolute motions and global accelerations at the centre of gravity of the unit:
  - surge acceleration
  - sway acceleration
  - heave acceleration
  - yaw acceleration
  - roll amplitude and acceleration
  - pitch amplitude and acceleration

Note 1: Amplitude and acceleration in roll and pitch cannot be dissociate from each other. The rule values are to be adopted unless that hydrodynamic value of either the amplitude or the acceleration are found higher. In this case, both the amplitude and acceleration are to be adopted based on hydrodynamic values.

The following design distributions are to be provided:

- Hull girder loads defined in [3.3] and detailed below:
  - Vertical wave bending moment - Hogging
  - Vertical wave bending moment - Sagging
  - Horizontal wave bending moment
  - Vertical wave shear force - positive
  - Vertical wave shear force - negative.
- Relative wave elevation, defined in [3.5.1].
- Local accelerations in three directions for upright and inclined conditions, defined in [3.6].

3.2.3 Design values and distributions for offshore areas

For offshore areas, the design values and distributions are to be based on hydrodynamic analysis as defined in [3.2.4].

3.2.4 Hydrodynamic values and distributions

Hydrodynamic values and distributions of the wave loads are based on the results of the hydrodynamic analysis specified in Ch 1, Sec 4.

At preliminary stage, if the hydrodynamic analysis is not available, the Society may accept hydrodynamic values and distributions determined by the Designer, if duly justified.

3.2.5 Rule values and distributions

When a navigation notation as defined in Ch 1, Sec 1, [1.2.3] is granted to complete the site or the transit notation, rule values and distributions are to be calculated based on the formulas defined in the present Section and with the corresponding navigation coefficient n, given in Tab 1.

Note 1: It is reminded that the determination of fore and aft parts of the unit is established on a case-by-case basis, depending of the main wave heading (see Ch 1, Sec 1, [3.2.8]).

3.2.6 Selection of the navigation notation

When hydrodynamic values and distributions are significantly above rule values and distributions, the Society reserves the right to change the navigation notation with a more severe one.

3.2.7 Minimum values and distributions

Minimum values and distributions are rule values calculated for **sheltered area** according to Tab 1.

3.2.8 Factors of environment

The following factors of environment are to be defined with their distribution along the length of the unit:

f_{VBM} : Factor of environment for vertical wave bending moment:

$$f_{VBM} = \frac{M_{WV,\,hyd}}{M_{WV,\,S}}$$

f_{RWE} : Factor of environment for relative wave elevation in upright condition:

$$f_{RWE} = \frac{RWE}{h_1}$$

where:

h_1 : Rule distribution of the relative wave elevation defined in [3.5] and calculated for **unrestricted navigation** as per Tab 1

$M_{WV,hyd}$: Hydrodynamic distribution of the vertical wave bending moment obtained according to [3.2.4]

$M_{WV,S}$: Rule distribution of vertical wave bending moment in sagging defined in [3.3.1]and calculated for unrestricted navigation as per Tab 1

RWE : Hydrodynamic distribution of the relative wave elevation obtained according to [3.2.4].

Table 1 : Navigation coefficient n

Navigation notation	n
unrestricted navigation	1,00
summer zone	0,90
tropical zone	0,80
coastal area	0,80
sheltered area	0,65

3.3 Hull girder wave loads

3.3.1 Vertical wave bending moment

The rule vertical wave bending moments at any hull transverse section in upright ship condition are obtained, in kN.m, from the following formulae:

- hogging conditions:

  $M_{WV,H} = 190\ F_M\, n\, C\, L^2\, B\, C_B\, 10^{-3}$

- sagging conditions:

  $M_{WV,S} = -\,110\ F_M\, n\, C\, L^2\, B\, (C_B + 0{,}7)\, 10^{-3}$

where:

F_M : Distribution factor defined in Tab 2 and Fig 1.

3.3.2 Horizontal wave bending moment

The rule horizontal wave bending moment at any hull transverse section is obtained, in kN.m, from the following formula:

$M_{HW} = 0{,}42\ F_M\, n\, H\, L^2\, T\, C_B$

where:

F_M : Distribution factor defined in Tab 2 and Fig 1

H : Wave parameter to be taken as:

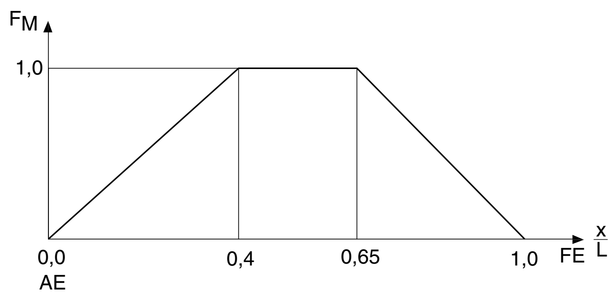
$$H = 8,13 - \left(\frac{250 - 0,7L}{125}\right)^3$$

without being taken greater than 8,13.

Table 2 : Distribution factor F_M

Hull transverse section location	Distribution factor F_M
$0 \le x < 0,4\ L$	$2,5\ \frac{x}{L}$
$0,4\ L \le x < 0,65\ L$	1
$0,65\ L \le x < L$	$2,86\left(1 - \frac{x}{L}\right)$

Figure 1 : Distribution factor F_M



3.3.3 Vertical wave shear force

The rule vertical wave shear force at any hull transverse section is obtained, in kN, from the following formula:

$Q_{WV} = 30\ F_Q\ n\ C\ L\ B\ (C_B + 0,7)\ 10^{-2}$

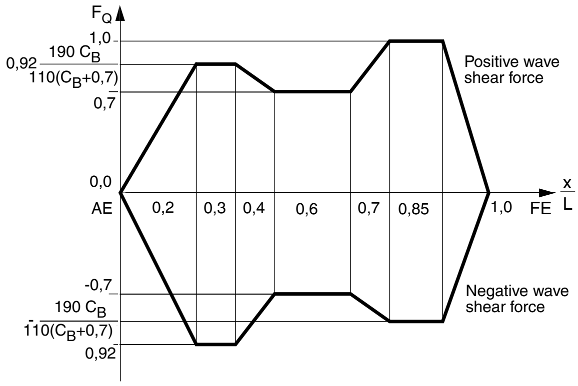
where:

F_Q : Distribution factor defined in Tab 3 (see also Fig 2).

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
$0,3\ L < x < 0,4\ L$	$(9,2A - 7)\left(0,4 - \frac{x}{L}\right) + 0,7$	$-2,2\left(0,4 - \frac{x}{L}\right) - 0,7$
$0,4\ L \le x \le 0,6\ L$	0,7	− 0,7
$0,6\ L < x < 0,7\ L$	$3\left(\frac{x}{L} - 0,6\right) + 0,7$	$-(10A - 7)\left(\frac{x}{L} - 0,6\right) - 0,7$
$0,7\ L \le x \le 0,85\ L$	1	− 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: $A = \frac{190C_B}{110(C_B + 0,7)}$		

Figure 2 : Distribution factor F_Q



3.4 Unit absolute motions and global accelerations

3.4.1 General

Rule values of the unit absolute motions and global accelerations are to be determined according to [3.4.2] to [3.4.7] with the parameter a_B obtained from the following formulae:

- for on-site conditions:

$$a_B = n\left(\frac{2,4}{\sqrt{L}} + 3\frac{h_w}{L}\right)$$

- for transit conditions:

$$a_B = n\left(\frac{0,2V_S}{\sqrt{L}} + 3\frac{h_w}{L}\right)$$

Unit motions and global accelerations are defined, with their signs, according to the reference co-ordinate system in Ch 1, Sec 1.

Unit motions and global accelerations are assumed to be periodic. The motion amplitudes, defined by the formulae in this Article, are half of the crest to through amplitudes.

3.4.2 Surge

The rule surge acceleration a_{SU}, in m/s², is to be taken equal to 0,8n.

3.4.3 Sway

The rule sway acceleration a_{SW}, in m/s² and rule sway period T_{SW}, in s, are obtained from the formulae in Tab 4.

Table 4 : Sway period and acceleration

Period T_{SW}, in s	Acceleration a_{SW}, in m/s²
$T_{SW} = \dfrac{0,8\sqrt{L}}{1,22F+1}$	$a_{SW} = 0,775\ a_B\ g$
Note 1: F, froude's number to be taken equal to: • for on-site conditions: $F = 1,968/L^{0,5}$ • for transit conditions: $F = 0,164\ V_S/L^{0,5}$	

3.4.4 Heave

T_{eh} rule heave acceleration a_H, in m/s², is obtained from the following formula:

$a_H = a_B\ g$

3.4.5 Roll

The rule roll amplitude A_R, in radian, roll period T_R, in s, and roll acceleration α_R, in rad/s² are obtained from the formulae:

$A_R = a_B\sqrt{E}$ without being taken greater than 0,35

$$T_R = 2,2\frac{\delta}{\sqrt{GM}}$$

$$\alpha_R = A_R\left(\frac{2\pi}{T_R}\right)^2$$

The meaning of symbols is as follows:

$$E = 1{,}39\frac{GM}{\delta^2}B \quad \text{to be taken not less than 1,0}$$

GM : Vertical distance, in m, from the unit centre of gravity to the transverse metacentre, for the loading considered, to be taken from the loading manual or Trim and Stability Booklet. When GM is not known, the values given in Tab 5 may be accepted by the Society on a case-by-case basis

δ : Roll radius of gyration, in m, for the loading considered, to be taken from the loading manual or Trim and Stability Booklet. When δ is not known, a value of 0,35 B may be accepted by the Society on a case-by-case basis.

Table 5 : Values of GM

Service notation	Full load	Ballast
oil storage	0,12 B	heavy ballast: 0,18 B light ballast: 0,24 B
Other service notation	0,07 B	0,18 B

3.4.6 Pitch

The rule pitch amplitude A_p , in radian, pitch period T_p , in s, and pitch acceleration α_p , in rad/s², are obtained from the formulae in Tab 6.

3.4.7 Yaw

The rule yaw acceleration α_Y , in rad/s², is obtained from the following formula:

$$\alpha_Y = 1{,}581\frac{a_B g}{L}$$

Table 6 : Pitch amplitude, period and acceleration

Amplitude A_P ,in rad	Period T_P , in s	Acceleration α_P , in rad/s²
$A_p = 0{,}328 a_B\left(1{,}32 - \frac{h_W}{L}\right)\left(\frac{0{,}6}{C_B}\right)^{0{,}75}$	$T_p = 0{,}575\sqrt{L}$	$\alpha_p = A_p\left(\frac{2\pi}{T_p}\right)^2$

Note 1:

h_W : Wave parameter, in m, equal to:

- for L < 350 m:

$$h_W = 11{,}44 - \left|\frac{L-250}{110}\right|^3$$

- for 350 m ≤ L ≤ 500 m:

$$h_W = \frac{200}{\sqrt{L}}$$

3.5 Relative wave elevation

3.5.1 Design relative wave elevation in upright condition

The design distribution of the relative wave elevation in upright condition, $h_{1,DES}$, in m, is the greatest of:

- rule distribution h_1
- hydrodynamic distribution RWE.

3.5.2 Rule relative wave elevation in upright ship condition

The rule distribution of the relative wave elevation in upright ship condition is obtained, at any hull transverse section, from the formulae in Tab 7.

Table 7 : Rule relative wave elevation in upright ship condition

Location	Reference value h_1 , in m, of relative wave elevation
$x = 0$	if $C_B < 0,875$ $h_1 = 0,7\left(\frac{4,35}{\sqrt{C_B}} - 3,25\right)h_{1,M}$ if $C_B \geq 0,875$ $h_1 = h_{1,M}$
$0 < x < 0,3\ L$	$h_{1,AE} - \frac{h_{1,AE} - h_{1,M}}{0,3}\frac{x}{L}$
$0,3\ L \leq x \leq 0,7\ L$	$0,67\ n\ C\ (C_B + 0,7)$
$0,7\ L < x < L$	$h_{1,M} + \frac{h_{1,FE} - h_{1,M}}{0,3}\left(\frac{x}{L} - 0,7\right)$
$x = L$	$\left(\frac{4,35}{\sqrt{C_B}} - 3,25\right)h_{1,M}$
Note 1: $h_{1,AE}$: 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 $x = L$	

3.5.3 Design relative wave elevation in inclined ship condition

The design distribution, in m, of the relative wave elevation in inclined ship condition, at any hull transverse section, is given by:

$$h_2 = 0,5h_{1,\,DES} + A_{R,\,DES}\frac{B_W}{2}$$

where:

$h_{1,DES}$: Design distribution of relative wave elevation in upright condition

$A_{R,DES}$: Design value of roll amplitude as defined in [3.2.2]

B_W : Moulded breadth, in m, measured at the waterline at draught T_1 at the hull transverse section considered.

Note 1: As an alternative the value of h_2 directly calculated by hydrodynamic analysis may be specially considered by the Society.

3.6 Local accelerations

3.6.1 The design values of reference longitudinal, transverse and vertical accelerations at any point are obtained from the formulae given in Tab 8 for upright and inclined conditions and based on the design unit absolute motions and global accelerations.

Note 1: As an alternative the local accelerations directly calculated by hydrodynamic analysis may be specially considered by the Society, for example: offshore appurtenances and associated loads distribution at foundation.

Note 2: load cases "a", "b", "c" and "d" are defined in Article [4].

Table 8 : Reference values of the accelerations a_X, a_Y and a_Z , in m/s²

Direction	Upright condition	Inclined condition
X axis - Longitudinal direction	$a_{X1} = \sqrt{a_{SU}^2 + [A_P g + \alpha_p(z - T_1)]^2}$	$a_{x2} = 0$
Y axis - Transverse direction	$a_{Y1} = 0$	$a_{Y2} = \sqrt{a_{SW}^2 + [A_R g + \alpha_R(z - T_1)]^2 + \alpha_Y^2 K_X L^2}$
Z axis - Vertical direction	$a_{Z1} = \sqrt{a_H^2 + \alpha_p^2 K_X L^2}$	$a_{Z2} = \sqrt{0,25 a_H^2 + \alpha_R^2 y^2}$
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		

4 Load cases

4.1 Transit and site conditions

4.1.1 Load cases defined in the present Article are to be processed for both transit and on-site conditions.

4.2 General

4.2.1 Load cases for structural analyses based on partial ship models

The load cases described in this Section are those to be used for structural element analyses which do not require complete unit modelling. They are:

- the analyses of plating (see Ch 1, Sec 7)
- the analyses of ordinary stiffeners (see Ch 1, Sec 8)
- the analyses of primary supporting members analysed through three dimensional structural models (see Ch 1, Sec 9)
- the fatigue analysis of the structural details of the above elements (see Ch 1, Sec 10).

These load cases are the mutually exclusive load cases "a", "b", "c" and "d" described in [4.3] and [4.4].

Load cases "a" and "b" refer to the ship in upright conditions, i.e. at rest or having surge, heave and pitch motions.

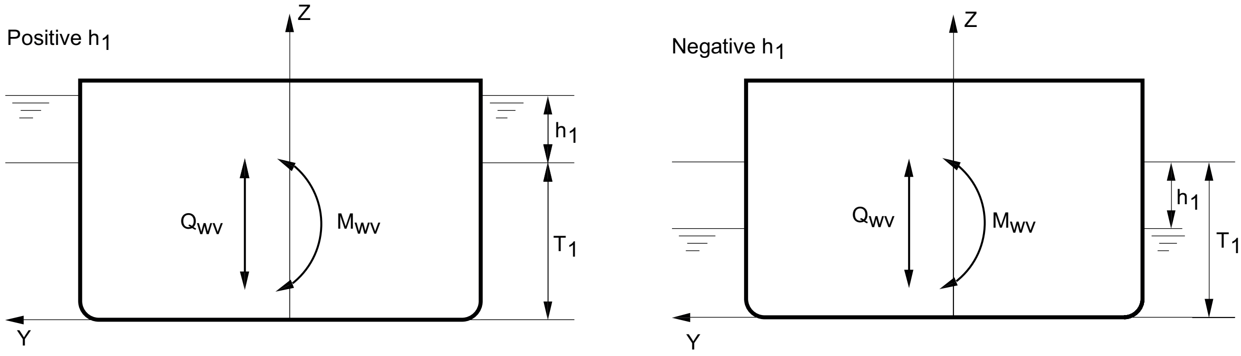
Load cases "c" and "d" refer to the ship in inclined conditions, i.e. having sway, roll and yaw motions.

4.3 Upright ship conditions (load cases "a" and "b")

4.3.1 Ship condition

The unit is considered to encounter a wave which produces (see Fig 3 "a" and Fig 4 for load case "b") a relative motion of the sea waterline (both positive and negative) symmetric on the unit 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.

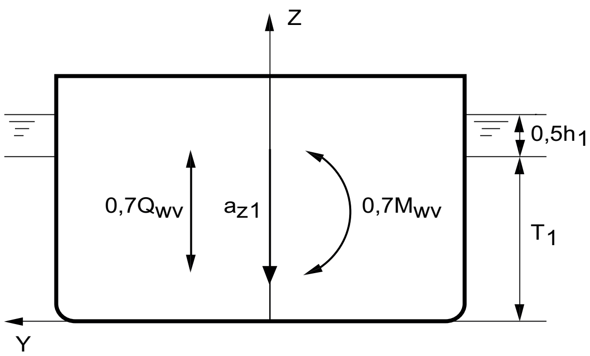
Figure 3 : Wave loads in load case a_1



Wave loads in load case a_1 crest

Wave loads in load case a_2 trough

Figure 4 : Wave loads in load case b



4.3.2 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.

4.3.3 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.

4.4 Inclined ship conditions (load cases "c" and "d")

4.4.1 Ship condition

The unit is considered to encounter a wave which produces (see Fig 5 for load case "c" and Fig 6 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.

4.4.2 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 5 : Wave loads in load case c +

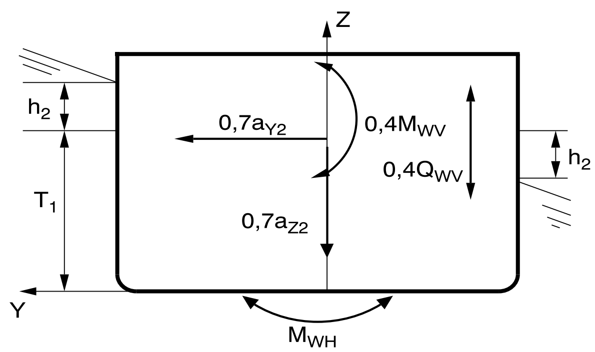


Figure 6 : Wave loads in load case d +

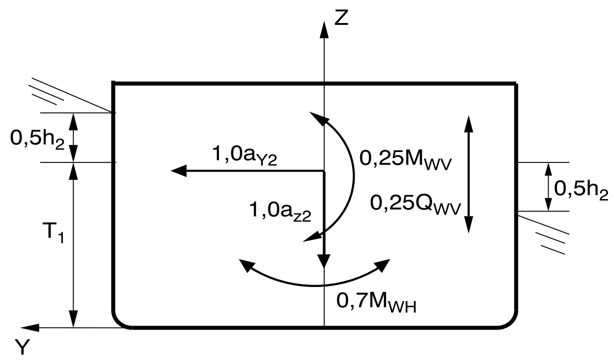


Table 9 : Wave local loads in each load case

Unit condition	Load case	Relative wave elevations		Reference accelerations a_X, a_Y, a_Z	
		Reference value	Combination factor	Reference value	Combination factor
Upright	a	$h_{1,DES}$	1,0	no acceleration taken into account for case “a”	
	b **(1) (2)**		0,5	a_{X1}; 0; a_{Z1}	1,0
Inclined	c + **(3)**	h_2	1,0	0; a_{Y2}; a_{Z2}	C_{FA} = 0,7
	c – **(4)**				
	d + **(3)**		0,5	0; a_{Y2}; a_{Z2}	C_{FA} = 1,0
	d – **(4)**				

(1) For a surface unit moving with a positive heave motion:
- $h_{1,DES}$ is positive
- the reference acceleration a_{X1} is towards the direction which maximise the
- the reference acceleration a_{Z1} is directed towards the negative part of the Z axis.

(2) For plating and ordinary stiffeners, refer to [1.3.7]

(3) For surface unit rolling with a negative roll angle (portside down):
- h_2 is positive for the points located in the positive part of the Y axis and is negative for the points located in the negative part of the Y axis
- the reference acceleration a_{Y2} is directed towards the positive part of the Y axis
- the reference 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 is directed towards the positive part of the Z axis for the points located in the negative part of the Y axis.

(4) For surface unit rolling with a positive roll angle (portside up)

Note 1: Reference accelerations a_{X1} and a_{Z1} are to be combined in each direction when assessing the foundations of equipment and appurtenances.

Note 2: Other combinations may be required by the Society on a case by case basis.

4.4.3 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.

4.5 Summary of load cases

4.5.1 The wave local and hull girder loads to be considered in each load case are summarized in Tab 10 and Tab 11, respectively.

These loads are obtained by multiplying, for each load case, the reference value of each wave load by the relevant combination factor.

Table 10 : Wave hull girder loads in each load case

Unit condition	Load case	Vertical bending moment		Vertical shear force		Horizontal bending moment	
		Reference value	Combination factor	Reference value	Combination factor	Reference value	Combination factor
Upright	a_1 crest	M_{WV}	1,0	Q_{WV}	1,0	M_{WH}	0,0
	a_2 trough						
	b		0,7		0,7		
Inclined	c	M_{WV}	0,4	Q_{WV}	0,4	M_{WH}	1,0
	d		0,25		0,25		0,7

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 Ch 1, Sec 7, Ch 1, Sec 8 and Ch 1, Sec 9

Note 2: The combination factors used for direct calculations are given in Ch 1, Sec 9.

5 Sea pressures

5.1 Transit and site conditions

5.1.1 Sea pressures defined in the present Article are to be processed for both transit and on-site conditions. For this purpose, two distinct sets of sea pressures are to be calculated.

5.2 General

5.2.1 The sea pressures to be taken into account are those given in the present Article [5].

However the Society may accept calculations based on pressures coming directly from hydrodynamic calculation, if duly justified.

5.3 Still water pressure

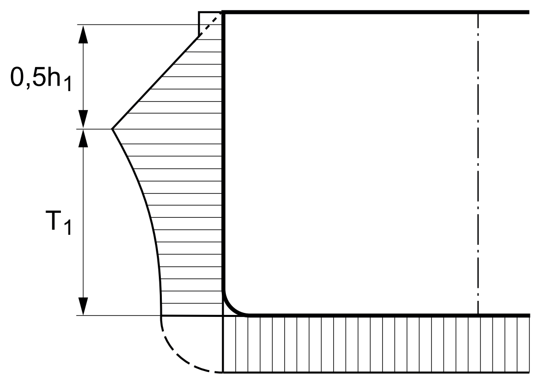
5.3.1 Pressure on side and bottom

The still water pressure at any point of the hull is obtained from the formulae in Tab 11 (see also Fig 7).

Table 11 : Still water pressure

Location		Still water pressure p_S, in kN/m²
Points at and below the waterline	$(z \le T_1)$	$\rho\ g\ (T_1 - z)$
Points above the waterline	$(z > T_1)$	0

Figure 7 : Still water pressure



5.3.2 Pressure on exposed deck

The still water pressure on exposed decks is to be taken equal to $10\varphi_1\ \varphi_1$, where φ_1 is defined in Tab 12 and φ_2 in Tab 13.

Table 12 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freebord 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

5.4 Wave pressure in upright ship conditions

5.4.1 Pressure on sides and bottom

The wave pressure in upright ship conditions at any point of the hull is obtained from the formulae given in Tab 13. See also Fig 8, Fig 9 and Fig 10.

Table 13 : 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 ($z \le T_1$)	$\frac{\rho g C_{F1} h_{1,DES}}{2}\left(\frac{z+T_1}{T_1}\right)$	$-\frac{\rho g C_{F1} h_{1,DES}}{2}\left(\frac{z+T_1}{T_1}\right)$ without being taken less than $\rho g (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g (T_1 + C_{F1} h_{1,DES} - z)$ without being taken, for case "a" only, less than $0{,}15\varphi_1\varphi_2 L$	0,0

Note 1:

C_{F1} : Combination factor, to be taken equal to:
- for load case "a": $C_{F1} = 1{,}0$
- for load case "b": $C_{F1} = 0{,}5$

φ_1 : Coefficients defined in Tab 12

φ_2 : Coefficients taken equal to:
- if $L \ge 120$ m: $\varphi_2 = 1$
- if $L < 120$ m: $\varphi_2 = L/120$

Figure 8 : Wave pressure in upright ship conditions (load case a_1 crest)

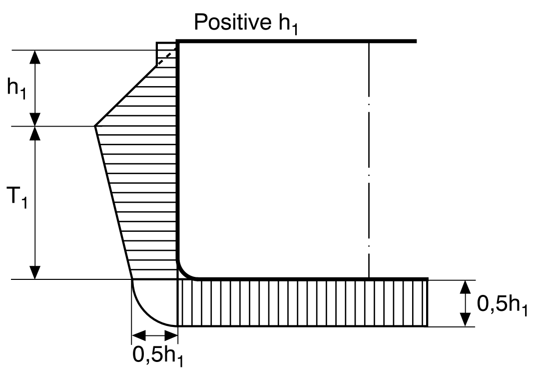


Figure 9 : Wave pressure in upright ship conditions (load case a_2 trough)

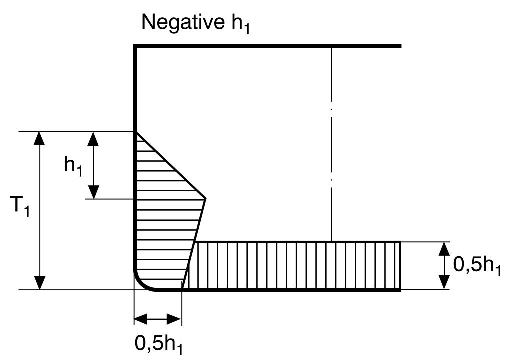
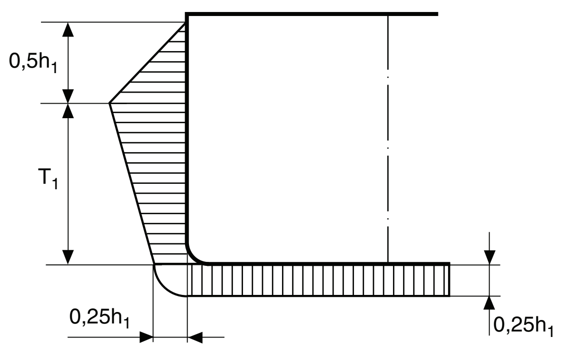


Figure 10 : Wave pressure in upright ship conditions (load case b)



5.4.2 Pressure on exposed decks

The wave pressure on exposed decks is to be considered for load cases "a crest" and "b crest" only. The distribution is obtained from the formulae given in Tab 14.

Table 14 : Wave pressure on exposed decks in upright ship conditions (load cases "a" and "b")

Location	Wave pressure p_W, in kN/m²	
	Crest	Trough
$0 \le x \le 0,5\ L$	$28 f_{RWE} \varphi_1 \varphi_2$	0
$0,5\ L < x < 0,75\ L$	$\left\{28 + \left[\frac{31,3\sqrt{H_F} - 28}{0,25}\right]\left(\frac{x}{L} - 0,5\right)\right\} f_{RWE} \varphi_1 \varphi_2$	0
$0,75\ L \le x \le L$	$31,3 f_{RWE} \varphi_1 \varphi_2 \sqrt{H}$	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

C_{F1} : Combination factor, to be taken equal to:
- for load case "a": $C_{F1} = 1,0$
- for load case "b": $C_{F1} = 0,5$

f_{RWE} : Factor of environment for relative wave elevation in upright condition, as defined in [3.2.8]

H_F : Value of H calculated at x = 0,75 L

V : To be taken as:
- for on-site conditions, V = 13
- for transit conditions, V is to be taken equal to V_s, but not less than 13 knots

φ_1 : Coefficient defined in Tab 12

φ_2 : Coefficient defined in Tab 13

5.5 Wave pressure in inclined ship conditions

5.5.1 Pressure on side and bottom

The wave pressure in inclined ship conditions at any point of the hull is obtained from the formulae in Tab 15. See also Fig 11 and Fig 12.

5.5.2 Pressure on exposed decks

The wave pressure on exposed decks is to be considered for load cases "a crest" and "b crest" only (see [5.4.2]).

Table 15 : Wave pressure in inclined ship conditions (load cases "c" and "d")

Location	Wave pressure p_W, in kN/m² (negative roll angle)	
	$y \ge 0$	$y < 0$
Bottom and sides below the waterline ($z \le T_1$)	$\rho g C_{F2} h_2 \frac{y}{B_W}\left[\frac{z + T_1}{T_1}\right]$	$\rho g C_{F2} h_2 \frac{y}{B_W}\left[\frac{z + T_1}{T_1}\right]$ without being taken less than $\rho\ g\ (z - T_1)$
Sides above the waterline ($z > T_1$)	$\rho g\left[T_1 + 2\frac{y}{B_W} C_{F2} h_2 - z\right]$ without being taken, for case "c" only, less than $0,15\ \varphi_1 \varphi_2 L$	0

Note 1:

B_W : Moulded breadth, in m, measured at the waterline at draught T_1, at the hull transverse section considered

C_{F2} : Combination factor, to be taken equal to:
- for load case "c": $C_{F2} = 1,0$
- for load case "d": $C_{F2} = 0,5$

h_2 : Relative wave elevation in inclined unit condition, in m, as defined in [3.5.3].

Figure 11 : Wave pressure in inclined ship conditions (load case c+)

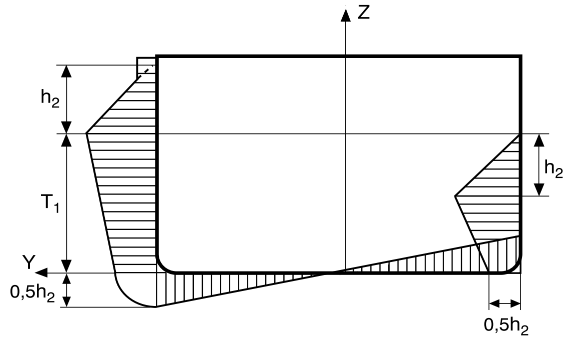
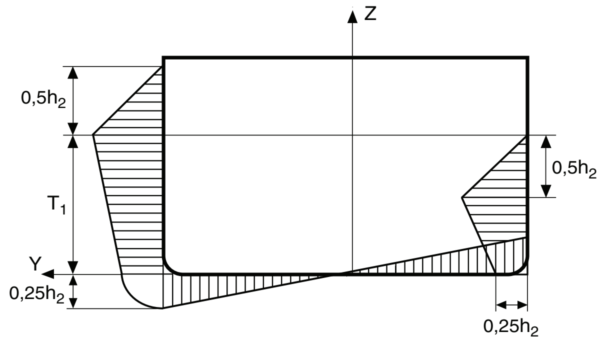


Figure 12 : Wave pressure in inclined ship conditions (load case d+)



6 Internal pressures

6.1 Transit and site conditions

6.1.1 Internal pressures defined in the present Article are to be processed for both transit and on-site conditions. For this purpose, two distinct sets of internal pressures are to be calculated.

6.2 Definitions

6.2.1 Cargo

The cargo mass density to be considered is the one indicated on the midship section drawing or in the loading manual.

In the absence of more precise values, a cargo mass density of 0,9 t/m^3 is to be considered for calculating the internal pressures.

In case of filling the oil capacities by sea water for transit between yard and site, the density is to be 1,025 t/m^3.

6.2.2 Sea water

A sea water mass density of 1,025 t/m^3 is to be considered.

6.2.3 Total acceleration vector

The total acceleration vector A_T is the vector whose absolute values of X, Y and Z components are the longitudinal, transverse and vertical accelerations defined in Tab 16.

In inclined ship conditions:

$$\vec{A_T} = a_{TY2}\vec{Y} + a_{TZ2}\vec{Z}$$

where:

Y, Z : Normed vectors as defined in Fig 13

a_{TY2} , a_{TZ2} : Total accelerations for inclined ship conditions defined in Tab 16.

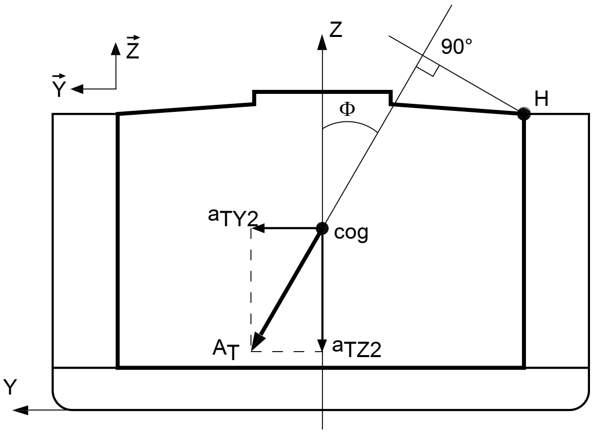
6.2.4 Highest point H of the tank in the direction of the total acceleration vector A_T

The highest point H of the tank in the direction of the total acceleration vector A_T, defined in [6.2.3], 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 conditions, as indicated in Fig 13, where cog is the tank's centre of gravity.

Table 16 : Total accelerations a_{TX}, a_{TY} and a_{TZ}

Direction	Upright condition	Inclined condition
X axis - Longitudinal direction	$a_{TX1} = a_{X1}$	$a_{TX2} = a_{X2}$
Y axis - Transverse	$a_{TY1} = a_{Y1}$	$a_{TY2} = 0{,}7C_{FA}a_{Y2}$
Z axis - Vertical	$a_{TZ1} = -a_{Z1} - g$	$a_{TZ2} = -0{,}7C_{FA}a_{Z2} - g$
Note 1: C_{FA} : Combination factor given in Tab 9.		

Figure 13 : Inclined ship conditions - Point H



6.3 Internal pressures and forces

6.3.1 Internal still water pressure

The still water pressure p_S , in kN/m² to be used in combination with the inertial pressure in [6.3.2] is the greater of the values obtained, from the following formulae: Φϕφ

$p_S = \rho_L\ g\ (z_L - z)$

$p_S = \rho_L\ g\ (z_{TOP} - z) + 100\ p_{PV}$

In no case is it to be taken, in kN/m², less than:

$$p_S = \rho_L g\left(\frac{0,8L_1}{420 - L_1}\right)$$

where:

L_1 : L, but to be taken not greater than 200 m

p_{PV} : Setting pressure, in bar, of safety valves

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 top of the air pipes, to be taken not less than z_{TOP}.

Note 1: Specific overflow systems leading to higher internal pressure are to be considered on case-by-case basis.

6.3.2 Internal inertial pressure

The inertial pressure is obtained from the formulae in Tab 17.

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 18, obtained by applying to those tanks the general formula in Tab 18.

In addition, the inertial pressure p_W is to be taken such that:

$p_S + p_W \geq 0$

where p_S is defined in [6.3.1].

6.3.3 Pressure for swash bulkheads

The still water and inertial pressures transmitted to the swash bulkhead structures are obtained, in kN/m², as specified in Tab 20.

Table 17 : Watertight bulkheads of liquid compartments - Inertial pressure

Ship condition	Load case	Inertial pressure p_W, in kN/m²
Upright	"a"	No inertial pressure
	"b"	$\rho_L[0,5 a_{X1} \ell_B + a_{Z1}(z - z_{TOP}) + g(z - z_{TOP})]$
Inclined	"c"	$\rho_L[a_{TY2}(y - y_H) + a_{TZ2}(z - z_H) + g(z - z_{TOP})]$
	"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 14)
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 [6.2.3] for load case "c" and load case "d".

Figure 14 : Upright ship conditions - Distance ℓ_B

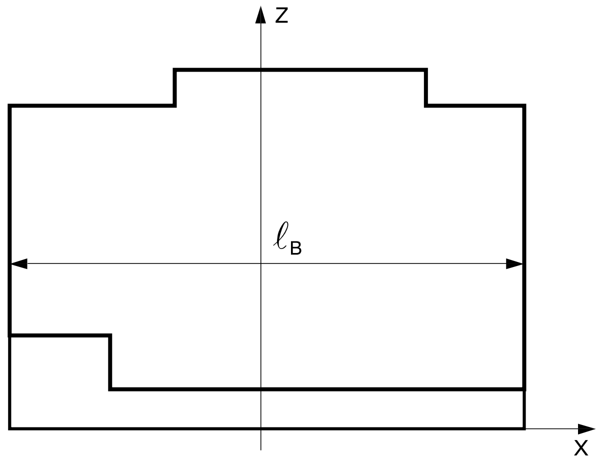


Table 18 : Liquid cargo and ballast - Inertial pressure for typical tank arrangements

Ship condition	Load case	Inertial pressure p_w, in kN/m²
Inclined (negative roll angle)	"c"	$p_w = 0,7\ C_{FA} \rho_L (a_{Y2} b_L + a_{Z2} d_H)$
	"d"	

Note 1:
C_{FA} : Combination factor taken equal to:
- C_{FA} = 0,7 for load case "c"
- C_{FA} = 1,0 for load case "d"

ρ_L : Density of the liquid cargo, in t/m³
a_{Y2}, a_{Z2} : Reference value of the acceleration in the inclined ship, defined in [3.6.1], calculated in way of the centre of gravity of the tank
b_L, d_H : Tranverse and vertical distances, in m, to be taken as indicated in Tab 20 for various type of tanks.

6.4 Partly filled tanks

6.4.1 General

All capacities are to be checked for several relevant partial filling levels.

6.4.2 Risk of resonance

The risk of resonance is to be evaluated according to Pt B, Ch 11, Sec 4, [1.5] of the Ship Rules.

The values of the pitch period and of the roll period may be taken from the hydrodynamic calculation.

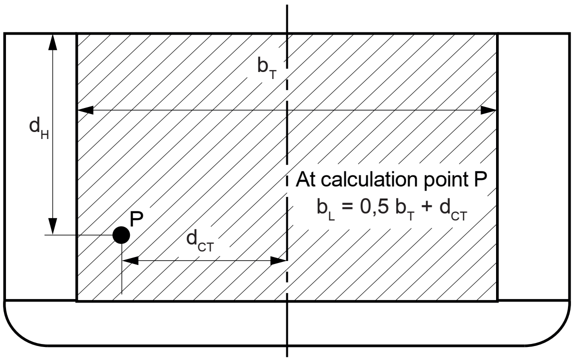
6.4.3 Impact pressure

If there is a risk of resonance, the scantlings are to be verified taking into account pressure given in Pt B, Ch 5, Sec 6, [2] of the Ship Rules.

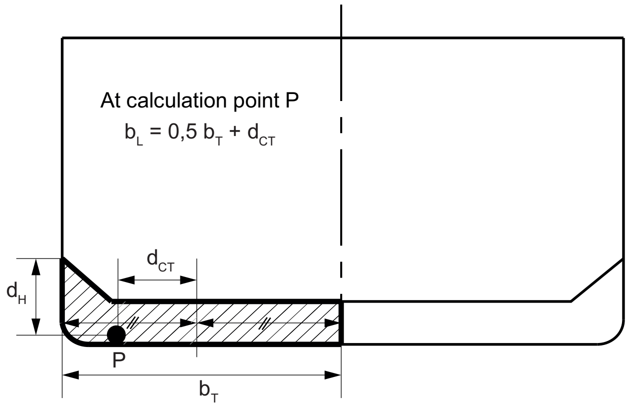
When hydrodynamic values of unit motions and accelerations are greater than rule values for unrestricted navigation, the impact pressure verification is to be specially considered.

Table 19 : Transverse et vertical distances b_L and D_H for various type of tanks

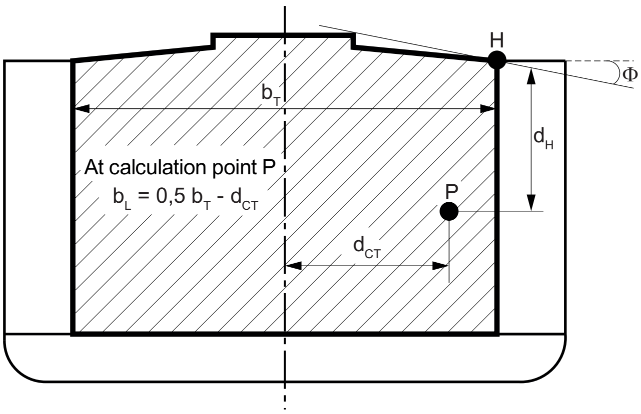
Type 1



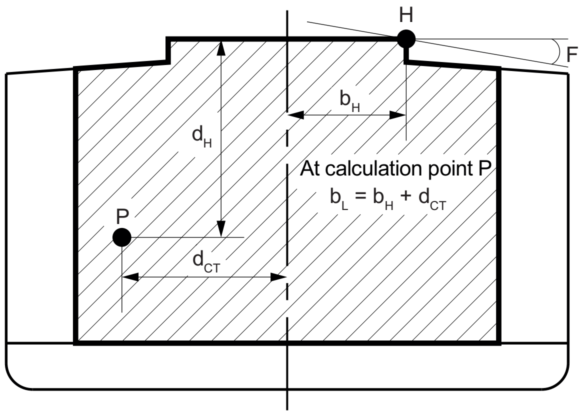
Type 2



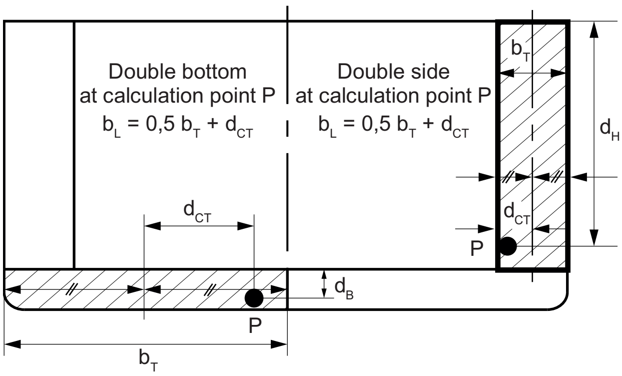
Type 3



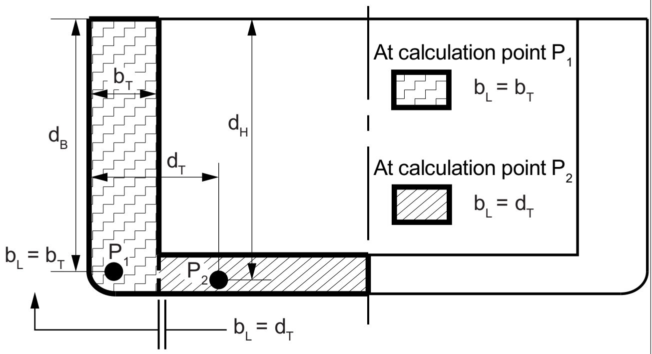
Type 4



Type 5



Type 6



Note 1: For type 1, type 2 type 3 and type 4, where the central cargo is divided into two or more tanks by longitudinal bulkhead, b_L and d_H for calculation points inside each tank are to be taken as indicated in type 5 for the double side.

Note 2: The angle Φ as defined in Fig 13

Table 20 : Swash bulkheads in liquid compartment - Still water and inertial pressure

	Still water pressure p_S in kN/m²	Inertial pressure p_W, in kN/m²
Swash transverse bulkhead	$p_S = 2{,}2\ \rho_L \ell_C (1-\alpha) A_P$ without being less than 0,4 g d_0	$p_W = 2{,}2\ \rho_L \ell_C (1-\alpha) A_P$ without being less than 0,4 g d_0
Swash longitudinal bulkhead	$p_S = 2{,}2\ \rho_L b_C (1-\alpha) \sin A_R$ without being less than 0,4 g d_0	$p_W = 2{,}2\ \rho_L b_C (1-\alpha) \sin A_R$ without being less than 0,4 g d_0

Note 1:

b_c : Transverse distance, in m, between longitudinal watertight bulkheads or longitudinal wash bulkheads, if any, or between a longitudinal watertight bulkhead and the adjacent longitudinal wash bulkhead

ℓ_c : Longitudinal distance, in m, between transverse watertight bulkheads or transverse wash bulkheads, if any, or between a transverse watertight bulkhead and the adjacent transverse wash bulkhead

d_0 : Distance, in m, to be taken equal to:
- for 65 m ≤ L < 120 m: $d_0 = 0{,}02L$
- for L ≥ 120 m: $d_0 = 2{,}4$

α : Ratio of the lightening hole area to the bulkhead area, not taken greater than 0,3

ρ_L : Density, in t/m³, of the liquid carried.

6.5 Accommodation

6.5.1 Design pressure

The scantlings of the accommodation decks are calculated using a conventional still water and inertial pressure as defined in [6.5.2].

6.5.2 Still water and inertial pressures

The inertial pressures transmitted to the deck structures are obtained, in kN/m², as specified in Tab 21.

The values of p_S depending on the type of the accommodation compartment are given in Tab 22.

Table 21 : Accommodation Still water and inertial pressures

Ship condition	Load case	Still water pressure p_S and inertial pressure p_W, in kN/m²
Upright (positive heave motion)	"a"	No inertial pressure
	"b"	$p_W = p_S \dfrac{a_{Z1} + g}{g}$
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 22 : Minimum still water deck pressure in accommodation compartments

Type of accommodation compartment	p_s, in kN/m_2
Large public spaces, such as: restaurants, halls, cinemas, lougnes	5,0
Large rooms, such as: • rooms with fixed furniture • games and hobbies rooms, hospitals	3,0
Cabins	3,0
Other compartments	2,5

6.6 Flooding

6.6.1 Still water and inertial pressures

Unless otherwise specified, the still water and inertial pressures to be considered as acting on platings (excluding bottom and side shell platings) which constitute boundaries of compartments not intended to carry liquids, but considered flooded for damaged stability verification, are obtained, in kN/m², from the formulae in Tab 23.

Table 23 : Flooding still water pressure and inertial pressures

Still water pressure p_{SF} , in kN/m²	Inertial pressure p_{WF} , in kN/m²
$p_{SF} = \rho g(z_F - z)$ without being taken less than 0,4 g d_0	$p_{WF} = 0,6\rho(a_{Z1} + g)(z_F - z)$ without being taken less than 0,4 g d_0
Note 1: z_F : Z co-ordinate, in m, of the freeboard deck at side in way of the transverse section considered. Where the results of damage stability calculations are available, the deepest equilibrium waterline may be considered in lieu of the freeboard deck; in this case, the Society may require transient conditions to be taken into account.	

6.7 Testing

6.7.1 Still water pressures

The still water pressure to be considered as acting on plates and stiffeners subject to tank testing is to be obtained from Tab 24.

6.7.2 Inertial pressures

No inertial pressure is to be considered as acting on plates and stiffeners subject to tank testing.

Table 24 : 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: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z)$
Double side tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z)$
Deep tanks other than those listed elsewhere in this Table	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4])$
Cargo oil tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4]$ $p_{ST} = 10\ [(z_{TOP} - z) + 10]$
Peak tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4])$
Chain locker	$p_{ST} = 10\ [(z_{CP} - z)$ where: z_{CP} : Z co-ordinate, in m, of the top of chain pipe
Ballast ducts	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ Ballast pump maximum pressure
Fuel oil tanks	The greater of the following: $p_{ST} = 10\ [(z_{TOP} - z) + d_{AP}]$ $p_{ST} = 10\ [(z_{TOP} - z) + 2,4])$ $p_{ST} = 10\ [(z_{TOP} - z) + 10\ p_{PV}]$ $p_{ST} = 10\ [(z_{BD} - z)$
Note 1: d_{AP} : Distance from the top of air pipe to the top of compartment, in m p_{pv} : As defined in [6.3.1] z_{BD} : Z co-ordinate, in m, of the bulkhead deck.	

Section 6 Hull Girder Strength

Symbols

E : Young's modulus, in N/mm², as defined in Ch 1, Sec 3

g : Gravity acceleration, in m/s², taken equal to 9,81

k : Material factor as defined in Pt B, Ch 4, Sec 1, [2.2] of the Ships Rules

I_Y : Moment of inertia, in m⁴, of the hull transverse section about its horizontal neutral axis, to be calculated according to [2.4]

I_Z : Moment of inertia, in m4, of the hull transverse section about its vertical neutral axis, to be calculated according to [2.4]

M_{SW} : Still water bending moment, in KN.m, as defined in Ch 1, Sec 5, [2.2.2]

M_{WV} : Vertical wave bending moment, in KN.m, as defined in Ch 1, Sec 5, [2.2.3]

Q_{SW} : Still water shear force, in KN.m, as defined in Ch 1, Sec 5, [2.3]

Q_{WV} : Vertical wave shear force, in kN.m, as defined in Ch 1, Sec 5, [3.3]:

- Q_{WV} is the positive wave shear force if $Q_{SW} \geq 0$
- Q_{WV} is the negative wave shear force if $Q_{SW} < 0$

S : First moment, in m³, of the hull transverse section, to be calculated according to [2.5].

1 General

1.1 Principle

1.1.1 The hull girder strength is to be evaluated independently for the transit phases covered by classification and on-site conditions.

1.1.2 The hull girder is to be designed to allow flexibility in cargo loading (see Ch 1, Sec 4).

1.2 Strength characteristics of the hull girder transverse sections

1.2.1 The requirements for calculating the hull girder strength characteristics to be used for the checks in Articles [3] and [4], in association with the hull girder loads specified in Ch 1, Sec 5, [2.2] and Ch 1, Sec 5, [3.3]are specified in Article [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 [2.1.6].

These members are to be considered as having:

- gross scantlings, when the hull girder strength characteristics to be calculated are used for the yielding checks in Article [3]
- net scantlings, when the hull girder strength characteristics to be calculated are used for the ultimate strength checks in Article [4] and for calculating the hull girder stresses for the strength checks of plating, ordinary stiffeners and primary supporting members in Ch 1, Sec 7; Ch 1, Sec 8 and Ch 1, Sec 9.

2.1.2 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 2,06 10⁵ 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:

$$A_{SE} = \frac{E}{2{,}06{,}10^5} A_M$$

where:

A_M : Sectional area, in m², of the member under consideration.

2.1.3 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.

2.1.4 Small openings

Smaller openings than those in [2.1.3] 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:

$\Sigma b_S \le 0,06 \, (B - \Sigma b)$

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 1

Σb : Total breadth of large openings, in m, at the transverse section considered, determined as indicated in Fig 1.

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.

Additionally, individual small openings which do not comply with the arrangement requirements given in Ch 1, Sec 3, [11.7.2], are to be deducted from the sectional areas included in the hull girder transverse sections.

2.1.5 Lightening holes, draining holes and single scallops

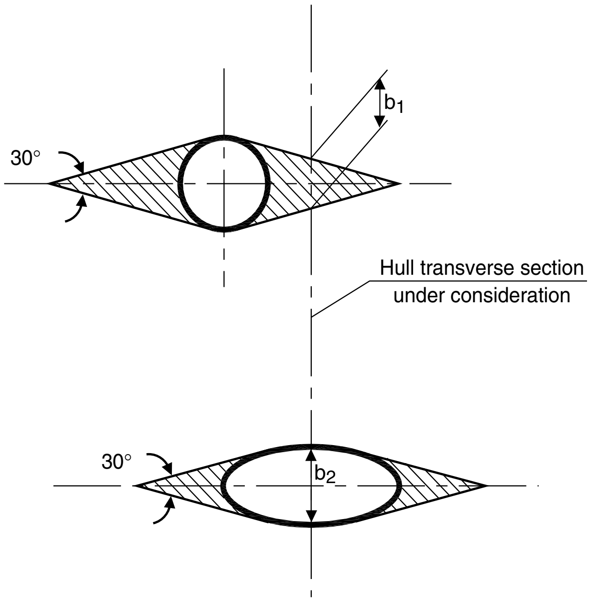
Lightening holes, draining holes and single scallops in longitudinals need not be deducted if their height is less than 0,25 h_W, without being greater than 75 mm, where h_W is the web height, in mm.

Otherwise, the excess is to be deducted from the sectional area or compensated.

2.1.6 Bilge keels

Bilge keels may not be included in the hull girder transverse sections, as they are considered not contributing to the hull girder sectional area.

Figure 1 : Calculation of Σb and Σb_S



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).

2.3 Section modulus

2.3.1 The section modulus at any point of a hull transverse section is obtained, in m³, from the following formula:

$$Z_A = \frac{I_Y}{|z - N|}$$

where:

I_Y : Moment of inertia, in m⁴, defined in [2.4]

z : Z co-ordinate, in m, of the calculation point with respect to the reference co-ordinate system defined in Ch 1, Sec 1, [3.3]

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 1, [3.3].

2.3.2 The section moduli at bottom and at deck are obtained, in m³, from the following formulae:

- at bottom:

$$Z_{AB} = \frac{I_Y}{N}$$

- at deck:

$$Z_{AB} = \frac{I_Y}{V_D}$$

where:

I_Y : Defined in [2.4]

N : Defined in [2.3.1]

V_D : Vertical distance, in m: $V_D = z_D - N$

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 1, [3.3].

2.4 Moments of inertia

2.4.1 The moments of inertia I_Y and I_Z, in m⁴, 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 m³, 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 shear stresses

2.6.1 The structural models that can be used for the calculation of shear stresses, induced by shear forces, are:

- three dimensional finite element models
- thin walled beam models

representing the members which constitute the hull girder transverse sections according to [2.1].

3 Yielding checks

3.1 Hull girder stresses

3.1.1 Normal stresses induced by vertical bending moments

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 deck:

$$\sigma_1 = \frac{M_{SW} + M_{WV}}{Z_{AD}} 10^3$$

where:

Z_A : Gross section modulus, in cm³, at any point of the hull transverse section, to be calculated according to [2.3.1]

Z_{AB} , Z_{AD} : Gross section moduli, in cm³, at bottom and deck, respectively, to be calculated according to [2.3.2].

3.1.2 The normal stresses in a member made in material other than steel with a Young's modulus E equal to 2,06 x 10^5 N/mm², included in the hull girder transverse sections as specified in [2.1.2], 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 [3.1.1] considering this member as having the steel equivalent sectional area A_{SE} defined in [2.1.2].

3.1.3 Shear stress

a) The shear stresses induced by shear forces and torque are obtained through direct calculation analyses based on a structural model in accordance with [2.6.1].

The shear force corrections ΔQ_C and ΔQ are to be taken into account, in accordance with [3.1.4] and [3.1.5], respectively.

b) The vertical shear forces to be considered in these analyses are the vertical shear forces Q_{SW} and Q_{WV}, taking into account the combination factors defined in Ch 1, Sec 5, Tab 10.

When deemed necessary by the Society on the basis of the ship's characteristics and intended service, the horizontal shear force is also to be calculated, using direct calculations, and taken into account in the calculation of shear stresses.

c) 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 [3.1.4] and [3.1.5].

3.1.4 Simplified calculation of shear stresses induced by vertical shear forces for 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:

$$\tau_1 = (Q_{SW} + Q_{WV} - \varepsilon\Delta Q_C)\frac{S}{I_Y t}\delta$$

where:

$\varepsilon = \mathrm{sgn}(Q_{SW})$

δ : Shear distribution coefficient defined in Tab 1

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 1

ΔQ_C : Shear force correction (see Fig 2), which takes into account, when applicable, the portion of loads transmitted by the double bottom girders to the transverse bulkheads:

- for ships with double bottom in alternate loading conditions:

$$\Delta Q_C = \alpha\left|\frac{P}{B_H \ell_C} - \rho T_1\right|$$

- for other ships:

$\Delta Q_C = 0$

with:

$$\alpha = g\frac{\ell_0 b_0}{2 + \varphi\frac{\ell_0}{b_0}}$$

$$\varphi = 1,38 + 1,55\frac{\ell_0}{b_0} \le 3,7$$

ℓ_0 , b_0 : Length and breadth, respectively, in m, of the flat portion of the double bottom in way of the hold considered; b_0 is to be measured on the hull transverse section at the middle of the hold

B_H : Unit's breadth, in m, measured on the hull transverse section at the middle of the hold considered

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads.

P : Total mass of cargo, in t, in the hold

T_1 : Draught, in m, measured vertically on the hull transverse section at the middle of the hold considered, from the moulded baseline to the waterline in the loading condition considered

ρ : Sea water density, in t/m³, taken equal to 1,025

Figure 2 : Shear force correction ΔQ_C

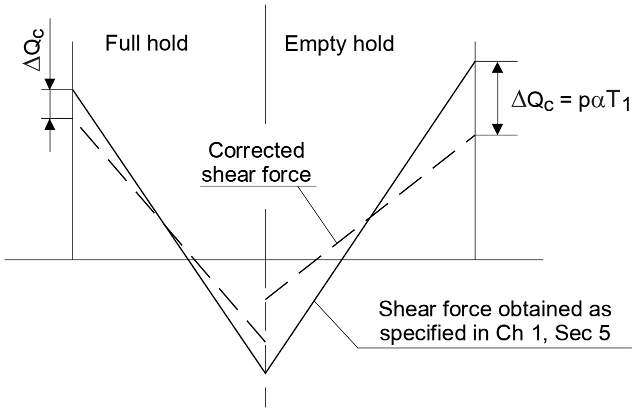
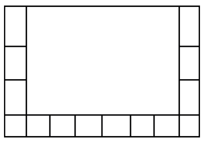
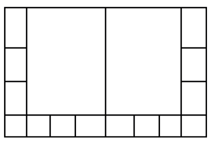


Table 1 : Shear stresses induced by vertical shear forces

Ship typology		Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Double side ships without effective longitudinal bulkheads		Sides	t_S	$(1 - \Phi) / 2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$
		Inner sides	t_{IS}	$\Phi / 2$	
Double side ships with one effective longitudinal bulkhead		Sides	t_S	$(1 - \Phi)\Psi / 2$	$\Phi = 0{,}275 + 0{,}25\,\alpha$ $\alpha = t_{ISM} / t_{SM}$
		Inner sides	t_{IS}	$\Phi\Psi / 2$	$\Psi = 1{,}9\beta\left[\gamma\left(2\delta + 1 + \frac{1}{\alpha_0}\right) - 0{,}17\right]$ $\chi = \frac{\Psi}{0{,}85 + 0{,}17\alpha}$
		Longitudinal bulkhead	t_B	$1 - \chi$	$\alpha_0 = \frac{0{,}5t_{BM}}{t_{SM} + t_{ISM}}$ $\beta = \frac{0{,}75}{3\delta + \alpha_0 + 1}$ $\gamma = \frac{2\delta + 1}{4\delta + 1 + \frac{1}{\alpha_0}}$ $\delta = \frac{B}{2D}$

Note 1:

t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively

t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner 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, inner side and longitudinal bulkhead.

3.1.5 Simplified calculation of shear stresses induced by vertical shear forces for 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/mm^2, from the following formula:

$$\tau_1 = [(Q_{SW} + Q_{WV})\delta + \varepsilon_Q \Delta Q]\frac{S}{I_Y t}$$

where:

δ : Shear distribution coefficient defined in Tab 2

$$\varepsilon_Q = \mathrm{sgn}\left(\frac{Q_F - Q_A}{\ell_C}\right)$$

Q_F, Q_A : Value of Q_{SW}, in kN, in way of the forward and aft transverse bulkhead, respectively, of the hold considered

ℓ_C : Length, in m, of the hold considered, measured between transverse bulkheads

t : Minimum thickness, in mm, of side, inner side and longitudinal bulkhead plating, as applicable according to Tab 2

ΔQ : Shear force correction, in kN, which takes into account the redistribution of shear force between sides and longitudinal bulkheads due to possible transverse non-uniform distribution of cargo:

- in sides:

$$\Delta Q = \frac{\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{n}{3(n+1)} - (1 - \Phi)\right]$$

- in longitudinal bulkheads:

$$\Delta Q = \frac{\varepsilon(p_C - p_W)\ell_C b_C}{4}\left[\frac{2n}{3(n+1)} - \Phi\right]$$

with:

$\varepsilon = sgn(Q_{SW})$

b_C : Breadth, in m, of the centre hold, measured between longitudinal bulkheads

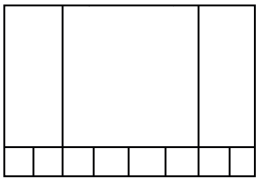
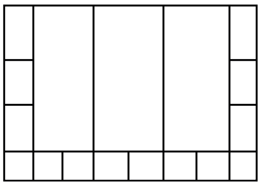
n : Number of floors in way of the centre hold

p_C : Pressure, in kN/m², acting on the inner bottom in way of the centre hold in the loading condition considered

p_W : Pressure, in kN/m², acting on the inner bottom in way of the wing hold in the loading condition considered, to be taken not greater than p_C

Φ : Coefficient defined in Tab 2

Table 2 : Shear stresses induced by vertical shear forces

Ship typology		Location	t, in mm	δ	Meaning of symbols used in the definition of δ
Single side ships with two effective longitudinal bulkheads		Sides	t_S	$(1 - \Phi) / 2$	$\Phi = 0,3 + 0,21\,\alpha$ $\alpha = t_{BM} / t_{SM}$
		Longitudinal bulkheads	t_B	$\Phi / 2$	
Double side ships with two effective longitudinal bulkheads		Sides	t_S	$(1 - \Phi) / 4$	$\Phi = 0,275 + 0,25\,\alpha$ $\alpha = \frac{t_{BM}}{t_{SM} + t_{ISM}}$
		Inner sides	t_{IS}	$(1 - \Phi) / 4$	
		Longitudinal bulkheads	t_B	$\Phi / 2$	

Note 1:

t_S, t_{IS}, t_B : Minimum thicknesses, in mm, of side, inner side and longitudinal bulkhead plating, respectively

t_{SM}, t_{ISM}, t_{BM} : Mean thicknesses, in mm, over all the strakes of side, inner 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, inner side and longitudinal bulkheads.

3.2 Checking criteria

3.2.1 Normal stresses induced by vertical bending moments

It is to be checked that the normal stresses σ_1 calculated according to [3.1.1] are in compliance with the following formula:

$\sigma_1 \le \sigma_{1,ALL}$

where:

$\sigma_{1,ALL}$: Allowable normal stress, in N/mm², obtained from the following formulae:

$$\sigma_{1,ALL} = \frac{125}{k} \quad \text{for} \quad \frac{x}{L} \le 0,1$$

$$\sigma_{1,ALL} = \frac{175}{k} - \frac{250}{k}\left(\frac{x}{L} - 0,1\right) \quad \text{for} \quad 0,1 < \frac{x}{L} < 0,3$$

$$\sigma_{1,ALL} = \frac{175}{k} \quad \text{for} \quad 0,3 \le \frac{x}{L} \le 0,7$$

$$\sigma_{1,ALL} = \frac{175}{k} - \frac{250}{k}\left(\frac{x}{L} - 0,7\right) \quad \text{for} \quad 0,7 < \frac{x}{L} < 0,9$$

$$\sigma_{1,ALL} = \frac{125}{k} \quad \text{for} \quad \frac{x}{L} \ge 0,9$$

3.2.2 Shear stresses

It is to be checked that the shear stresses τ_1 calculated according to [3.1.3], [3.1.4] and [3.1.5] are in compliance with the following formula:

$\tau_1 \le \tau_{1,ALL}$

where:

$\tau_{1,ALL}$: Allowable shear stress, in N/mm²: $\tau_{1,ALL} = 110 / k$

3.3 Section modulus and moment of inertia

3.3.1 General

The requirements in [3.3] provide the minimum hull girder section modulus, complying with the checking criteria indicated in [3.2], and the midship section moment of inertia required to ensure sufficient hull girder rigidity.

The k material factors are to be defined with respect to the materials used for the bottom and deck members contributing to the longitudinal strength according to [1.2]. When material factors for higher strength steels are used, the requirements in [3.3.5] apply.

3.3.2 Section modulus within 0,4 L amidships

The gross section moduli Z_{AB} and Z_{AD} within 0,4 L amidships are to be not less than the greater value of $Z_{R,\,Min}$ and Z_R , in m³, obtained from the following formulae:

$Z_{R,MIN} = n_1\, C\, L^2\, B\, (C_B + 0{,}7)\, k\, 10^{-6}$

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,\,ALL}} 10^{-3}$$

where:

C_B : Total block coefficient:

$$C_B = \frac{\Delta}{1{,}025 L B T}$$

n_1 : Coefficient defined as follows:

- when a navigation notation completes the transit or site notation of the unit, n_1 is to be taken as given in Tab 3
- when no navigation notation is granted to the unit for the transit or site condition, n_1 is to be taken equal to the value of factor of environment for vertical wave bending moment, f_{VBM}, as defined in Ch 1, Sec 5, [3.2], but not less than 0,80.

$Z_{R,MIN}$: Minimum section modulus taken as the maximum value between $Z_{R,MIN}$ calculated for transit condition and calculated for site condition. Parameters n_1 and C_B are to be taken accordingly

Where the total breadth Σb_S of small openings, as defined in [1.2], is deducted from the sectional areas included in the hull girder transverse sections, the values Z_R and $Z_{R,MIN}$ may be reduced by 3%.

Scantlings of members contributing to the longitudinal strength (see [1.2]) are to be maintained within 0,4 L amidships.

Table 3 : Navigation coefficient n_1 when a navigation notation is assigned

Navigation notation	Navigation coefficient n_1
unrestricted navigation	1,00
summer zone	0,95
tropical zone	0,90
coastal area	0,90
sheltered area	0,80

3.3.3 Section modulus outside 0,4 L amidships

The gross section moduli Z_{AB} and Z_{AD} outside 0,4 L amidships are to be not less than the value Z_R , in m³, obtained, in m³, from the following formula:

$$Z_R = \frac{M_{SW} + M_{WV}}{\sigma_{1,\,ALL}} 10^{-3}$$

Scantlings of members contributing to the hull girder longitudinal strength (see [1.2]) may be gradually reduced, outside 0,4 L amidships, to the minimum required for local strength purposes at fore and aft parts, as specified in Ch 1, Sec 11.

3.3.4 Midship section moment of inertia

The gross 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:

$I_{YR} = 3\ Z'_{R,MIN}\ L\ 10^{-2}$

where $Z'_{R,MIN}$ is the required midship section modulus $Z_{R,MIN}$, in m[3], calculated as specified in [3.3.2], but assuming k = 1.

3.3.5 Extent of higher strength steel

When a material factor for higher strength steel is used in calculating the required section modulus at bottom or deck according to [3.3.2] or [3.3.3], the relevant higher strength steel is to be adopted for the members contributing to the longitudinal strength (see [1.2]), at least up to a vertical distance, in m, obtained from the following formulae:

- above the baseline (for section modulus at bottom):

$$V_{HB} = \frac{\sigma_{1B} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} z_D$$

- below a horizontal line located at a distance V_D (see [1.2]) above the neutral axis of the hull transverse section (for section modulus at deck):

$$V_{HD} = \frac{\sigma_{1D} - k\sigma_{1,ALL}}{\sigma_{1B} + \sigma_{1D}} (N + V_D)$$

where:

N : Z co-ordinate, in m, of the centre of gravity of the hull transverse section defined in [1.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 1, [3.3]

V_D : Vertical distance, in m, defined in [1.2]

z_D : Z co-ordinate, in m, of the strength deck, defined in [1.2], with respect to the reference co-ordinate system defined in Ch 1, Sec 1, [3.3]

σ_{1B}, σ_{1D} : Normal stresses, in N/mm[2], at bottom and deck, respectively, calculated according to [3.1.1].

The higher strength steel is to extend in length at least throughout 0,4 L amidships where it is required for strength purposes.

4 Ultimate strength check

4.1 General

4.1.1 The ultimate strength of the hull girder is to be checked for transit and on site conditions.

The check is to be done on net scantlings, calculated according to Ch 1, Sec 3, [7].

The partial safety factors to be taken into account are those given in [4.2].

4.2 Partial safety factors

4.2.1 The safety factors to be taken into account in the ultimate strength check of the hull girder are those given in Tab 4.

Table 4 : Partial safety factors

Partial safety factor covering uncertainties on:	Symbol	On-site condition value	Transit condition value
Still water hull girder loads	γ_{S1}	1,00	1,00
Wave induced hull girder loads	γ_{W1}	1,25 **(1)**	1,10
Material	γ_m	1,02	1,02
Resistance	γ_R	1,10	1,03

(1) If the vertical wave bending moment M_{WV} considered is derived from hydrodynamic calculations with a 10 000 years return period, the partial safety factor γ_{W1} may be reduced to 1,00.
In this case, the product γ_{W1} x M_{WV} defined above with 10 000 years RP is not to be less than 1,25 M_{WV} derived with 100 years RP.

4.3 Hull girder loads

4.3.1 Bending moment

The bending moments in transit and on site conditions, in sagging and hogging, to be considered in the ultimate strength check of the hull girder, are to be obtained, in kN.m, from the following formula:

$M = \gamma_{S1}\ M_{SW} + \gamma_{W1}\ M_{WV}$

4.4 Hull girder ultimate bending moment capacities

4.4.1 The hull girder ultimate bending moment capacities are to be determined according to Pt B, Ch 6, Sec 2, [2.3] and Pt B, Ch 6, App 2 of the Ship Rules.

4.4.2 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 [1.2].

4.5 Checking criteria

4.5.1 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, as defined in Pt B, Ch 6, Sec 2, [2.1] of the Ship Rules

M : Bending moment in transit and on-site conditions, in kN.m, defined in [4.3.1].

Section 7 Scantlings of plating

Symbols

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:

$$C_r = 1 - \frac{0{,}5\, s}{r}$$

to be taken not less than 0,5

k : Material factor as defined in Pt B, Ch 4, Sec 1, [2.2] of the Ships Rules

ℓ : Length, in m, of the longer side of the plate panel

L : Rule length, in m, as defined in Ch 1, Sec 1, [3.2.6]

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

N : Z co-ordinate, in m, 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

p_S : Still water pressure, in kN/m^2, see [3.2.3]

r : Radius of curvature of the panel, in m

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

s : Length, in m, of the shorter side of the plate panel

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 1, [3.3]

σ_{X1} : In-plane hull girder normal stress, in N/mm^2, defined in:

- [3.2.6] for the strength check of plating subjected to lateral pressure
- [4.2.1] for the buckling check of plating

τ_1 : In-plane hull girder shear stress, in N/mm^2, defined in [3.2.7].

1 General

1.1 Principles

1.1.1 General

The plating thickness is to be calculated according to the present section.

1.1.2 The requirements of the present Section cover the assessment of plating for the transit and site conditions of the unit, except when otherwise specified.

The hull scantlings are to be evaluated independently for transit and site conditions.

1.2 Net thicknesses

1.2.1 As specified in Ch 1, Sec 3, [7], 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 1, Sec 3, [8].

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

Table 1 : Plating - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Strength check of plating subjected to lateral pressure				Buckling check
		General	Sloshing pressure	Watertight bulkhead plating **(1)**	Testing check	
Still water hull girder loads	γ_{S1}	1,00	0	1,00	N.A.	1,00
Wave hull girder loads	γ_{W1}	1,07	0	1,07	N.A.	1,07
Still water pressure	γ_{S2}	1,00	1,00	1,00	1,00	N.A.
Wave pressure	γ_{W2}	1,07	1,05	1,07	N.A.	N.A.
Material	γ_m	1,02	1,02	1,02	1,02	N.A.
Resistance	γ_R	1,02	1,10	1,02 **(2)**	1,05	N.A.

(1) Applies also to plating of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For plating of the collision bulkhead, γ_R =1,25
Note 1: N.A. = not applicable.

1.4 Elementary plate panel

1.4.1 The elementary plate panel is the smallest unstiffened part of plating.

1.5 Load point

1.5.1 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 elementary plate panel or at the lower strake welding joint, if any.

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] to [2.5] are to be applied to plating in addition of those in Article [3] to Article [4].

2.2 Minimum net thicknesses

2.2.1 The net thickness of plating is to be not less than the values given in Tab 2.

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 value obtained from [3.3.1].

2.3.2 The net thickness of the transversely framed bilge plating, in mm, is to be not less than:

$$t = 0,7\ [\ \gamma_R\ \gamma_m\ (\gamma_{S2}\ p_S + \gamma_{W2}\ p_W)\ s_b\ ]^{0,4}\ R^{0,6}\ k^{1/2}$$

where:

p_s : Still water sea pressure, defined in Ch 1, Sec 5, [5.3]

p_w : Wave pressure, defined in Ch 1, Sec 5, [5.4] and Ch 1, Sec 5, [5.5] for each load case “a”, “b”, “c” and “d”

R : Bilge radius, in m

s_b : Spacing of floors or transverse bilge brackets, in m.

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.

2.3.4 The net thickness of bilge plating is to be such as to satisfy the buckling check, as indicated in Article [4].

Table 2 : Minimum net thickness of plating (in mm)

Plating	Minimum net thickness
Keel	$3,8 + 0,040\ L\ k^{1/2} + 4,5\ s$
Bottom	
• longitudinal framing	$1,9 + 0,032\ L\ k^{1/2} + 4,5\ s$
• transverse framing	$2,8 + 0,032\ L\ k^{1/2} + 4,5\ s$
Inner bottom	
• outside the engine room	$1,9 + 0,024\ L\ k^{1/2} + 4,5\ s$
• engine room	$3,0 + 0,024\ L\ k^{1/2} + 4,5\ s$
Side	
• below freeboard deck	$2,1 + 0,031\ L\ k^{1/2} + 4,5\ s$
• between freeboard deck and strength deck	$2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Inner side	
• $L < 120$ m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$3,6 + 2,20\ k^{1/2} + s$
Weather strength deck and trunk deck, if any	
• area within 0,4 L amidships	
- longitudinal framing	$1,6 + 0,032\ L\ k^{1/2} + 4,5\ s$
- transverse framing	$1,6 + 0,040\ L\ k^{1/2} + 4,5\ s$
• area outside 0,4 L amidships	**(1)**
• at fore and aft part	$2,1 + 0,013\ L\ k^{1/2} + 4,5\ s$
Accommodation deck	
• $L < 120$ m	$1,3 + 0,004\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$2,1 + 2,20\ k^{1/2} + s$
Platform in engine room	
• $L < 120$ m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$3,6 + 2,20\ k^{1/2} + s$
Transv. watertight bulkhead	
• $L < 120$ m	$1,3 + 0,004\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$2,1 + 2,20\ k^{1/2} + s$
Longitud. watertight bulkhead	
• $L < 120$ m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$3,6 + 2,20\ k^{1/2} + s$
Tank and wash bulkheads	
• $L < 120$ m	$1,7 + 0,013\ L\ k^{1/2} + 4,5\ s$
• $L \geq 120$ m	$3,6 + 2,20\ k^{1/2} + s$

(1) The minimum net thickness is to be obtained by linearly interpolating between that required for the area within 0,4 L amidships and that at the fore and aft part.
Note 1: L need not be taken greater than 300 m.

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 unit'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.

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 0,6L amidships, over a length of about one sixth of the unit'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.

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 unit'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.

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 unit'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.

3 Strength check of plating subjected to lateral pressure

3.1 General

3.1.1 The requirements of this Article apply for the strength check of plating subjected to lateral pressure 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 1, Sec 5, [1.3.7].

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 1, Sec 5, [4].

3.2.2 Load definition criteria

a) Cargo and ballast distribution

   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 unit 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.

b) Draught associated with each cargo and ballast distribution

   Local loads are to be calculated on the basis of the ship's draught T_1 corresponding to the cargo or ballast distribution considered according to the criteria in item a). The unit 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 cargo 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
- light ballast condition, when one or more ballast tanks are considered as being loaded and the cargo 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:

  $T_B = 0,03\ L < 7,5$ m in general

3.2.3 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 1, Sec 5, [5.3]
- the still water internal pressure, defined in Ch 1, Sec 5, [6] for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 1, Sec 5, [5.4] and Ch 1, Sec 5, [5.5] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 1, Sec 5, [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 1, Sec 5, [6.4].

Sloshing and impact pressures are to be applied to plating of tank structures, when such tanks are partly filled and if a risk of resonance exists (see Ch 1, Sec 5, [6.4]).

3.2.4 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 1, Sec 5, [6.6].

3.2.5 Lateral pressure in testing conditions

The lateral pressure (p_T) in testing conditions is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Still water pressure defined in Ch 1, Sec 5, [6.7]

p_S : Still water sea pressure defined in Ch 1, Sec 5, [5.3] 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 [3.2.2].

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 not contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = 0$

- for plating contributing to the hull girder longitudinal strength:

  $$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}C_{FT}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH1})$$

where:

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 3

C_{FV}, C_{FH} : Combination factors defined in Tab 4

Table 3 : Hull girder normal stresses

Condition	σ_{S1}, in N/mm²	σ_{WV1}, in N/mm²	σ_{WH1}, in N/mm²
$\dfrac{\lvert\gamma_{S1}M_{SW,S} + \gamma_{W1}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H} + \gamma_{W1}M_{WV,H}} \geq 1$	$\left\lvert\dfrac{M_{SW,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{M_{WV,S}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$\dfrac{\lvert\gamma_{S1}M_{SW,S} + \gamma_{W1}C_{FV}M_{WV,S}\rvert}{\gamma_{S1}M_{SW,H} + \gamma_{W1}M_{WV,H}} < 1$	$\left\lvert\dfrac{M_{SW,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	$\left\lvert\dfrac{M_{WV,H}}{I_Y}(z-N)\right\rvert 10^{-3}$	

Table 4 : Combination factors C_{FV} and C_{FH}

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	0,7	0
"c"	0,4	1,0
"d"	0,25	0,7
Flooding	0,6	0

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, subjected to lateral loads, which contributes to the longitudinal strength are obtained, in N/mm², from the following formula:

$$\tau_1 = \gamma_{S1}\tau_{S1} + C_{FV}\gamma_{W1}\tau_{W1}$$

where:

C_{FV} : Combination factor defined in Tab 4

τ_{S1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum still water hull girder vertical shear force in the section considered

τ_{W1} : Absolute value of the hull girder shear stresses, in N/mm², induced by the maximum wave hull girder vertical shear force in the section considered.

When the shear forces distribution in plating according to the theory of bidimensional flow of shear stresses is not known, τ_{S1} and τ_{W1} may be taken equal to the values indicated in Tab 5.

Table 5 : Hull girder shear stresses

Structural element	τ_{S1}, τ_{W1} in N/mm²
Bottom, inner bottom and decks (excluding possible longitudinal sloping plates)	0
Bilge, side, inner side and longitudinal bulkheads (including possible longitudinal sloping plates):	
• $0 \le z \le 0{,}25\ D$	$\tau_0\left(0{,}5 + 2\dfrac{z}{D}\right)$
• $0{,}25\ D < z \le 0{,}75\ D$	τ_0
• $0{,}75\ D < z \le D$	$\tau_0\left(2{,}5 - 2\dfrac{z}{D}\right)$
Note 1: τ_0 , in N/mm², to be taken equal to: $\tau_0 = \dfrac{47}{k}\left\{1 - \dfrac{6,3}{\sqrt{L}}\right\}$ N/mm² with L to be taken not greater than 200 m.	

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:

$$\lambda_L = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0{,}95\left(\gamma_m \frac{\sigma_{x1}}{R_y}\right)^2 - 0{,}225\gamma_m \frac{\sigma_{x1}}{R_y}$$

3.3.2 Flooding conditions

The net thickness of plating subject to flooding 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 1, Sec 5, [6.7] 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:

$$t = 17{,}2 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda_T R_y}}$$

where:

$$\lambda_T = \sqrt{1 - 3\left(\gamma_m \frac{\tau_1}{R_y}\right)^2} - 0{,}89 \gamma_m \frac{\sigma_{x1}}{R_y}$$

3.4.2 Flooding conditions

The net thickness of plating subject to flooding 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 1, Sec 5, [6.7] 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:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.5 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 net thickness of plating subject to flooding 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 1, Sec 5, [6.7] 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:

$$t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_T}{R_y}}$$

3.6 Plating subject to impact loads

3.6.1 General

Unless otherwise specified, the net thickness of plate panels subject to impact generated by fluids is to be not less than the value obtained, in mm, from the following formula:

$$t = \frac{15,8\alpha s}{C_d}\sqrt{\frac{P_I}{R_{eH}}}$$

where:

α : Coefficient defined as follows:

$$\alpha = 1,2 - \frac{s}{2,1\ell}$$

without being taken greater than 1,0

C_d : Plate capacity correction coefficient:

- C_d = 1,0 for sloshing and flat bottom forward impact
- C_d = 1,2 for bow flare impact

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 1, Sec 11, [3.4]
- bow impact pressure, as defined in Ch 1, Sec 11, [4.3]
- dynamic impact pressure, as defined in Ch 1, Sec 5, [6.4.3]

R_{eH} : Minimum yield stress, in N/mm², of the plating material, defined in Ch 4, Sec 1, [2] of the Ship Rules.

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

4 Buckling check

4.1 General

4.1.1 The buckling check of plating is to be performed in accordance with NR615, Buckling Assessment of Plated Structures.

The compression and shear stresses to be taken into account for the checking criteria are to be calculated in accordance with [4.2.1] to [4.2.5].

4.2 Load model

4.2.1 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 in inclined unit conditions are obtained, in N/mm², from the following formula:

$$\sigma_{X1} = \gamma_{S1}\sigma_{S1} + \gamma_{W1}(C_{FV}\sigma_{WV1} + C_{FH}\sigma_{WH})$$

where:

C_{FV}, C_{FH} : Combination factors defined in Tab 4

σ_{S1}, σ_{WV1}, σ_{WH} : Hull girder normal stresses, in N/mm², defined in Tab 6.

σ_{X1} is to be taken as the maximum compression stress on the plate panel considered.

Table 6 : Hull girder normal compression stresses for buckling check of plates

Condition	σ_{S1} in N/mm²	σ_{WV1} in N/mm²	σ_{WH} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{M_{WV,H}}{I_Y}(z-N)10^{-3}$	

4.2.2 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.

4.2.3 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 Ch 1, Sec 5.

With respect to the reference co-ordinate system defined in Ch 1, Sec 1, [3.3], 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 [4.2.1]

$\sigma_{X2,S}$: Compression normal stress in x direction, 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 Ch 1, Sec 5

$\sigma_{X2,W}$: Compression normal stress in x direction, 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 Ch 1, Sec 5

$\sigma_{Y2,S}$: Compression normal stress in y direction, 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 Ch 1, Sec 5

$\sigma_{Y2,W}$: Compression normal stress in y direction, 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 Ch 1, Sec 5.

4.2.4 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 Ch 1, Sec 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 [3.2.7]

$\tau_{2,S}$: 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 Ch 1, Sec 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 Ch 1, Sec 5.

4.2.5 Hull girder stress for prescriptive buckling check

For prescriptive buckling check of plating according to NR615, Buckling Assessment of Plated Structures, the hull girder stresses (σ_{hg}, τ_{hg}) are considered as follow:

$$\sigma_{hg} = \sigma_{X1}$$

$$\tau_{hg} = \tau_1$$

4.3 Buckling check criteria

4.3.1 The buckling strength of plating is to satisfy the following criterion:

$\eta \le \eta_{ALL}$ with: $\eta_{ALL} = 1$

η : Utilisation factor as defined in NR615.

Section 8 Scantling of ordinary stiffeners

Symbols

A_{Sh} : Net shear sectional area, in cm², of the stiffener, to be calculated as specified in Ch 1, Sec 3, [5.4]

E : Young's modulus, in N/mm², to be taken as defined in Ch 1, Sec 3

h_w : Web height, in mm

k : Material factor as defined in Pt B, Ch 4, Sec 1, [2.2] of the Ships Rules

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 1, Sec 3, [5.2]

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

$M_{SW,H}$: Design still water bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{SW,S}$: Design still water bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5

N : Z co-ordinate, in m, 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

p_S : Still water pressure, in kN/m², see [3.3.2]

p_W : Wave pressure, in kN/m², (see [3.3.2])

R_{eH} : Specified minimum yield stress, in N/mm², of the material

R_m : Specified minimum tensile strength, in N/mm², of the material

R_y : Minimum yield stress, in N/mm², of the material, to be taken equal to 235/k N/mm², unless otherwise specified

s : Spacing, in m, of ordinary stiffeners

t_w : Net web thickness, in mm

w : Net section modulus, in cm³, of the stiffener, to be calculated as specified in Ch 1, Sec 3, [5.4]

b_p : Width, in m, of the plating attached to the stiffener, for the yielding check, defined in Ch 1, Sec 3, [5.3.1]

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 1, [3.3]

σ_{X1} : Hull girder normal stress, in N/mm², defined in:
- [3.3.5] for the yielding check of ordinary stiffeners
- [4.2.1] for the buckling check of ordinary stiffeners.

1 General

1.1 Principles

1.1.1 The scantling of ordinary stiffeners is to be calculated according to the present Section.

1.1.2 The requirements of the present Section cover the assessment of ordinary stiffeners for the transit and site conditions of the unit, except when otherwise specified.

The scantlings are to be evaluated independently for transit and site conditions.

1.2 Net thickness

1.2.1 As specified in Ch 1, Sec 3, [7], 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 1, Sec 3, [8].

1.3 Partial safety factors

1.3.1 The partial safety factors to be considered for the checking of the plating are specified in Tab 1.

Table 1 : Ordinary stiffeners - Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check				Buckling check	Ultimate strength check
		General	Sloshing pressure	Watertight bulkhead ordinary stiffeners **(1)**	Testing check		
Still water hull girder loads	γ_{S1}	1,00	0	1,00	N.A.	1,00	1,00
Wave hull girder loads	γ_{W1}	1,07	0	1,07	N.A.	1,07	1,30
Still water pressure	γ_{S2}	1,00	1,00	1,003	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,07	1,10	1,05	N.A.	1,15	1,40
Material	γ_m	1,02	1,02	1,02	1,02	N.A.	1,02
Resistance	γ_R	1,02	1,02	1,02 **(2)**	1,20	N.A.	1,02

(1) Applies also to ordinary stiffeners of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.
(2) For ordinary stiffeners of the collision bulkhead, γ_R =1,25.
Note 1: N.A. = Not applicable.

1.4 Slenderness requirement

1.4.1 Structural members are to comply with slenderness and proportion requirements of NR615, Buckling Assessment of Plated Structures.

1.5 Load point

1.5.1 Lateral pressure

Unless otherwise specified, lateral pressure is to be calculated at mid-span of the ordinary stiffener considered.

1.5.2 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 attached plating of the stiffener considered.

2 General requirements

2.1 General

2.1.1 The requirements in [2.2] and [2.3] are to be applied to ordinary stiffeners in addition of those in Article [3] to Article [5].

2.2 Minimum net thicknesses

2.2.1 The net thickness of the web of ordinary stiffeners is to be not less than the lesser of:

- the value obtained, in mm, from the following formulae:

  $t_{MIN} = 0,8 + 0,004\ L\ k^{1/2} + 4,5\ s$ for $L < 120$ m

  $t_{MIN} = 1,6 + 2,2\ k^{1/2} + s$ for $L \geq 120$ m
- the net as built thickness of the attached plating.

2.3 Struts connecting ordinary stiffeners

2.3.1 The sectional area A_{SR}, in cm², and the moment of inertia I_{SR} about the main axes, in cm⁴, of struts connecting ordinary stiffeners are to be not less than the values obtained from the following formulae:

$$A_{SR} = \frac{p_{SR} s \ell}{20}$$

$$I_{SR} = \frac{0{,}75 s \ell (p_{SR1} + p_{SR2}) A_{ASR} \ell_{SR}^2}{47{,}2 A_{ASR} - s \ell (p_{SR1} + p_{SR2})}$$

where:

A_{ASR} : Actual net sectional area, in cm², of the strut

ℓ_{SR} : Length, in m, of the strut

p_{SR} : Pressure to be taken equal to the greater of the values obtained, in kN/m², from the following formulae:

$p_{SR} = 0,5\ (p_{SR1} + p_{SR2})$

$p_{SR} = p_{SR3}$

p_{SR1} : External pressure in way of the strut, in kN/m², acting on one side, outside the compartment in which the strut is located, equal to:

$p_{SR1} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{SR2} : External pressure in way of the strut, in kN/m², acting on the opposite side, outside the compartment in which the strut is located, equal to:

$p_{SR2} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

p_{SR3} : Internal pressure at mid-span of the strut, in kN/m², in the compartment in which the strut is located, equal to:

$p_{SR3} = \gamma_{S2}\ p_S + \gamma_{W2}\ p_W$

2.4 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

2.4.1 The scantlings of deck ordinary stiffeners are to be determined by direct calculations.

2.4.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.4.3 The combined stress, in N/mm², is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$.

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 and, for ordinary stiffeners contributing to the hull girder longitudinal strength, to hull girder normal stresses.

3.1.2 When tanks are partly filled and if a risk of resonance exists, the yielding check of vertical ordinary stiffeners of tank structures subjected to sloshing and impact pressures is to be carried out by direct calculation.

3.1.3 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 [3.4.2], [3.4.3], [3.5] and [3.6] apply to stiffeners considered either:

- clamped at both ends with end connections complying with the requirements in
- 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.

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 end brackets, where the bracket length is not greater than 0,2 ℓ.

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 1, Sec 7, [3.2.2].

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 1, Sec 5, [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 1, Sec 5, [5.3]
- the still water internal pressure, defined in Ch 1, Sec 5, [6] for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure, defined in Ch 1, Sec 5, [5.4] and Ch 1, Sec 5, [5.5] for each load case "a", "b", "c" and "d"
- the inertial pressure, defined in Ch 1, Sec 5, [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 1, Sec 5, [6.4].

Sloshing and impact pressures are to be applied to ordinary stiffeners of tank structures, when such tanks are partly filled and if a risk of resonance exists (see Ch 1, Sec 5, [6.4]).

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 1, Sec 5, [6.6].

p_{SF}, p_{WF} : Still water and wave pressures, in kN/m², in flooding conditions, defined in Ch 1, Sec 5, [6.6]

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 1, Sec 5, [6.7]

p_S : Still water sea pressure defined in Ch 1, Sec 5, [5.3] 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 1, Sec 7, [3.2.2].

3.3.5 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:

  $\sigma_{X1} = \gamma_{S1}\,\sigma_{S1} + \gamma_{W1}\,C_{FT}\,(C_{FV}\,\sigma_{WV1} + C_{FH}\,\sigma_{WH1})$
- for longitudinal stiffeners not contributing to the hull girder longitudinal strength:

  $\sigma_{X1} = 0$
- for transverse stiffeners:

  $\sigma_{X1} = 0$

where:

C_{FV}, C_{FH} : Combination factors defined in Tab 3

σ_{S1}, σ_{WV1}, σ_{WH1} : Hull girder normal stresses, in N/mm², defined in Tab 2.

Table 2 : Hull girder normal stresses - Ordinary stiffeners subjected to lateral pressure

Condition	σ_{S1} , in N/mm²	σ_{WV1} , in N/mm²	σ_{WH} , in N/mm²
Lateral pressure applied on the side opposite to the ordinary stiffener, with respect to the plating:			$\left\lvert \frac{M_{WH}}{I_Z} y \right\rvert 10^{-3}$
• $z \geq N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	
• $z < N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
Lateral pressure applied on the same side as the ordinary stiffener:			
• $z \geq N$	$\left\lvert \frac{M_{SW,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{M_{WV,H}}{I_Y}(z-N) \right\rvert 10^{-3}$	
• $z < N$	$\left\lvert \frac{M_{SW,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	$\left\lvert \frac{M_{WV,S}}{I_Y}(z-N) \right\rvert 10^{-3}$	

Table 3 : Combination factor C_{FV} and C_{FH} for stiffeners

Load case	C_{FV}	C_{FH}
"a"	1,0	0
"b"	0,7	0
"c"	0,4	1,0
"d"	0,25	0,7
Flooding	0,6	0

3.4 Net section modulus and net shear sectional area of ordinary stiffeners in intact conditions

3.4.1 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus given in [3.4.2] to [3.4.4] 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.

3.4.2 Single span longitudinal and transverse ordinary stiffeners subjected to lateral pressure

The net section modulus w, in cm³, and the net shear sectional area A_{Sh}, in cm², of longitudinal or transverse ordinary stiffeners subjected to lateral pressure are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \alpha_S \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

α_S : Coefficient to be taken equal to 0,9

β_b, β_s : Coefficients defined in Tab 4.

Table 4 : 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}	$\left(1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}\right)^2$	$1 - \frac{\ell_{b1}}{2\ell} - \frac{\ell_{b2}}{2\ell}$
Note 1: The bracket length ℓ_b is defined in Ch 1, Sec 3. ℓ_{b1} and ℓ_{b2} are the lengths of the two brackets fitted at each end.			

3.4.3 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 4

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/m^2, at the lower end of the ordinary stiffener considered

p_{Su} : Still water pressure, in kN/m^2, at the upper end of the ordinary stiffener considered

p_{Wd} : Wave pressure, in kN/m^2, at the lower end of the ordinary stiffener considered

p_{Wu} : Wave pressure, in kN/m^2, 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 1, Sec 5
- 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.

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to comply with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.5 Net section modulus and net shear sectional area of ordinary stiffeners in flooding conditions

3.5.1 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus given in [3.5.2] to [3.5.4] 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.

3.5.2 Single span longitudinal and transverse ordinary stiffeners

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 are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{m(R_y - \gamma_R \gamma_m \alpha_S \sigma_{X1})}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

α_S : Coefficient to be taken equal to 0,9

β_b, β_s : Coefficients defined in Tab 4.

3.5.3 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:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{12 R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_{SF} + \gamma_{W2} p_{WF}}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in Tab 4

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 (see Ch 1, Sec 5, [6.6])

p_{SFu} : Still water pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered (see Ch 1, Sec 5, [6.6])

p_{WFd} : Wave pressure, in kN/m², in flooding conditions, at the lower end of the ordinary stiffener considered (see Ch 1, Sec 5, [6.6])

p_{WFu} : Wave pressure, in kN/m², in flooding conditions, at the upper end of the ordinary stiffener considered (see Ch 1, Sec 5, [6.6]).

3.5.4 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener in flooding conditions are to be determined by a direct calculation taking into account:

- the distribution of still water and wave pressure and forces in flooding conditions, to be determined on the basis of the criteria specified in Ch 1, Sec 5
- 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.

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to comply with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5\frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

3.6 Net section modulus and net shear sectional area of ordinary stiffeners in testing conditions

3.6.1 Groups of equal ordinary stiffeners

Where a group of equal ordinary stiffeners is fitted, it is acceptable that the minimum net section modulus in [3.6.2]] to [3.6.4] 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.

3.6.2 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:

$$w = \gamma_R \gamma_m \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.2].

3.6.3 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:

$$w = \gamma_R \gamma_m \gamma_b \beta_b \frac{\gamma_{S2} p_T}{m R_y}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \gamma_s \beta_s \frac{\gamma_{S2} p_T}{R_y}\left(1 - \frac{s}{2\ell}\right) s \ell$$

where:

β_b, β_s : Coefficients defined in [3.4.2]

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:

$$\lambda_b = 1 + 0,4\frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

$$\lambda_b = 1 - 0,4\frac{p_{Td} - p_{Tu}}{p_{Td} + p_{Tu}}$$

p_{Td} : Still water pressure, in kN/m², in testing conditions, at the lower end of the ordinary stiffener considered

p_{Tu} : Still water pressure, in kN/m², in testing conditions, at the upper end of the ordinary stiffener considered.

3.6.4 Multispan ordinary stiffeners

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener in testing conditions are to be determined by a direct calculation taking into account:

- the distribution of still water and forces in testing conditions, to be determined on the basis of the criteria specified in Ch 1, Sec 5
- 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.

The maximum normal stress σ and shear stress τ in a multispan ordinary stiffener are to comply 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 subject to impact loads

3.7.1 Single span longitudinal, transverse and vertical ordinary stiffeners

Unless otherwise specified, the net plastic section modulus Z_{pl}, in cm_3, as defined in Ch 1, Sec 3, [5.4.2] and the net web thickness t_w, in mm, of stiffeners subject to impact generated by fluids are to be not less than the values obtained from the following formulae:

$$Z_{pl} = \frac{P_I}{0,9(n+2)4R_{eH}} s\ell^2 10^3$$

$$t_w = \frac{\sqrt{3}}{2}\frac{P_I}{(h_w + t_p)R_{eH}} s\ell 10^3$$

where:

n : Number of fixed ends of stiffener:

- n = 2 for continuous members or members with brackets fitted at both ends
- n = 1 for one end equivalent to built-in and the other end simply supported
- n = 0 for both ends with low end fixity

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 1, Sec 11, [3.4]
- bow impact pressure, as defined in Ch 1, Sec 11, [4.3]
- dynamic impact pressure, as defined in Ch 1, Sec 5, [6.4.3]

t_p : Net thickness, in mm, of the attached plating.

If deemed necessary by the Society and depending on specific natures of loadings, different calculation methods may be applied, on a case-by-case basis.

4 Buckling check

4.1 General

4.1.1 The prescriptive buckling check of ordinary stiffeners is to be performed in accordance with NR615 Buckling Assessment of Plated Structures.

4.1.2 The load model for prescriptive buckling check is given in [4.2].

4.1.3 The prescriptive buckling check criterion is given in [4.3].

4.2 Load model

4.2.1 Hull girder compression normal stresses

The hull girder compression normal stresses σ_{X1} , in N/mm², to be considered for the prescriptive buckling check of ordinary stiffeners are obtained from the following formula:

$\sigma_{X1} = \gamma_{S1}\ \sigma_{S1} + \gamma_{W1}\ (C_{FV}\ \sigma_{WV1} + C_{FH}\ \sigma_{WH})$

where:

σ_{S1}, σ_{WV1}, σ_{WH} : Hull girder normal stresses, in N/mm², defined in Tab 5

C_{FV} , C_{FH} : Combination factors defined in Tab 3.

For longitudinal stiffeners, σ_{X1} is to be taken as the maximum compression stress on the stiffener considered.

The hull girder bending stress σ_{hg} , as defined in NR615, Sec 5, [2.3.4], is to be taken as follows:

- $\sigma_{hg} = \sigma_{X1}$ for intact and flooding conditions
- $\sigma_{hg} = 0$ for testing condition.

4.2.2 Lateral pressure

The lateral pressure P, as defined in NR615, Sec 5, [2.3.4], is to be taken according to [3.3] for the intact, flooding and testing conditions.

Table 5 : Hull girder normal compression stresses for buckling check

Condition	σ_{S1} in N/mm²	σ_{WV1} in N/mm²	σ_{WH} in N/mm²
$z \geq N$	$\frac{M_{SW,S}}{I_Y}(z-N)10^{-3}$	$\frac{M_{WV,S}}{I_Y}(z-N)10^{-3}$	$-\left\lvert\frac{M_{WH}}{I_Z}y\right\rvert 10^{-3}$
$z < N$	$\frac{M_{SW,H}}{I_Y}(z-N)10^{-3}$	$\frac{M_{WV,H}}{I_Y}(z-N)10^{-3}$	

4.3 Buckling check criteria

4.3.1 The buckling strength of ordinary stiffeners is to satisfy the following criterion for intact, flooding and testing conditions:

$\eta_{Stiffener} \leq \eta_{ALL}$ with: $\eta_{ALL} = 1$

where:

$\eta_{Stiffener}$: Utilisation factor as defined in NR615, Sec 3, [3.3].

Section 9 Scantling of Primary Supporting Members

Symbols

M_{SW} : Still water bending moment, in KN.m, as defined in Ch 1, Sec 5, [2.2]:
- in hogging condition: $M_{SW} = M_{SW,H}$
- in sagging condition: $M_{SW} = M_{SW,S}$

$M_{SW,H}$: Still water bending moment, in KN.m, in hogging condition

$M_{SW,S}$: Still water bending moment, in KN.m, in sagging condition

M_{WV} : Vertical wave bending moment, in KN.m as defined in Ch 1, Sec 5, [3.3]:
- in hogging condition: $M_{WV} = M_{WV,H}$
- in sagging condition: $M_{WV} = M_{WV,S}$

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5, [3.3]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5, [3.3]

Q_{SW} : Still water shear force, in KN.m, as defined in Ch 1, Sec 5, [2.3]

Q_{WV} : Vertical wave shear force, in kN.m, as defined in Ch 1, Sec 5, [3.3.3]

R_{eH} : Specified minimum yield stress, in N/mm^2, of the material

R_m : Specified minimum tensile strength, in N/mm^2, of the material.

1 Application

1.1 VeriSTAR- Hull

1.1.1 All units covered by the present Chapter are to be granted the additional service feature **VeriSTAR-Hull** (as stated in Ch 1, Sec 1, [1.2.4], and are to comply with the requirements of the present Ch 1, Sec 9.

1.2 VeriSTAR- Hull FLM

1.2.1 In addition, units intended to receive the additional notation **VeriSTAR-Hull FLM**, as defined in Ch 1, Sec 1, [1.2.5] are to comply with the requirements of NR551 “Structural Analysis of Offshore Surface Units through Full Length Finite Elements Models”.

2 General

2.1 Principles

2.1.1 The scantling of primary supporting members is to be calculated according to the present section.

2.1.2 The requirements of the present Section cover the assessment of primary supporting members for the transit and site conditions of the unit, except when otherwise specified.

The scantlings are to be evaluated independently for transit and site conditions.

2.2 Net thickness

2.2.1 The net thickness of plating which forms the webs and flanges of primary supporting members are to be checked in accordance with Ch 1, Sec 7.

2.2.2 Minimum net thickness

The net thickness of plating which forms the webs of primary supporting members is to be not less than the value obtained, in mm, from the following formulae:

$t_{MIN} = 3,7 + 0,015\ L\ k^{1/2}$ for $L < 120$ m

$t_{MIN} = 3,7 + 1,8\ k^{1/2}$ for $L \geq 120$ m

In addition, the net thickness is to be not less than the values given, respectively in:
- Tab 1 for plating which forms the webs of primary supporting members of the double bottom
- Tab 2 for plating which forms the webs of primary supporting members of the single bottom.

Table 1 : Minimum net thicknesses of webs of double bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$2,0\ L^{1/3}\ k^{1/6}$	$1,7\ L^{1/3}\ k^{1/6}$
Side girders	$1,4\ L^{1/3}\ k^{1/6}$	$1,4\ L^{1/3}\ k^{1/6}$
Floors	$1,5\ L^{1/3}\ k^{1/6}$	$1,5\ L^{1/3}\ k^{1/6}$
Girder bounding a duct keel **(1)**	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$	$1,5 + 0,8\ L^{1/2}\ k^{1/4}$
Margin plate	$L^{1/2}\ k^{1/4}$	$0,9\ L^{1/2}\ k^{1/4}$

(1) The minimum net thickness is to be taken not less than that required for the centre girder.

Table 2 : Minimum net thicknesses of webs and flanges of single bottom primary supporting members

Primary supporting member	Minimum net thickness, in mm	
	Area within 0,4L amidships	Area outside 0,4L amidships
Centre girder	$6,0 + 0,05\ L_2\ k^{1/2}$	$4,5 + 0,05\ L_2\ k^{1/2}$
Floors and side girders	$5,0 + 0,05\ L_2\ k^{1/2}$	$3,5 + 0,05\ L_2\ k^{1/2}$

2.3 Deck primary members in way of launching appliances used for survival craft or rescue boat

2.3.1 The scantlings of deck primary supporting members are to be determined by direct calculations.

2.3.2 The loads exerted by launching appliance are to correspond to the SWL of the launching appliance.

2.3.3 The combined stress, in N/mm^2, is not to exceed the smaller of $R_{eH}/2,2$ and $R_m/4,5$.

2.4 Finite element model

2.4.1 For the checking of the scantlings of primary supporting members, a three-dimensional finite element model is required.

The check is to be made in accordance with the present Section.

In addition, design mooring loads and appurtenances design loads defined in Ch 1, Sec 14, [1] and Ch 1, Sec 14, [2] are to be considered in the model for the verification of the Ship area.

2.4.2 Number of models

Each typical cargo tank is to be subject to finite element calculation.

At least three cargo tanks are to be assessed:

- the cargo oil tank at midship (midship model)
- the forward cargo tank (fore model)
- the afterward cargo tank (aft model).

2.5 Partial safety factors

2.5.1 The partial safety factors to be considered for the checking of the scantlings of the primary supporting members are specified in Tab 3 and Tab 4.

Table 3 : Resistance partial safety factor

Type of three dimensional model	Resistance partial safety factor γ_R	
	General	Watertight bulkhead, primary supporting members
Coarse mesh finite element model	1,15	1,02
Standard mesh finite element model	1,02	1,02
Fine mesh finite element model	1,02	1,02

Table 4 : Primary supporting members analysed through three dimensional models – Partial safety factors

Partial safety factors covering uncertainties regarding:	Symbol	Yielding check		Buckling check
		General	Watertight bulkhead primary supporting members **(1)**	Plate panels
Still water hull girder loads	γ_{S1}	1,00	1,00	1,00
Wave hull girder loads	γ_{W1}	1,02	1,02	1,02
Still water pressure	γ_{S2}	1,00	1,00	1,00
Wave pressure	γ_{W2}	1,07	1,07	1,07
Material	γ_m	1,02	1,02	N.A.
Resistance	γ_R	defined in Tab 3	defined in Tab 3	N.A.

(1) Applies also to primary supporting members of bulkheads or inner side which constitute boundary of compartments not intended to carry liquids.

Note 1: For primary supporting members of the collision bulkhead, γ_R = 1,25.

2.6 Slenderness requirement

2.6.1 Structural members are to comply with slenderness and proportion requirements of NR615 Buckling Assessment of Plated Structures.

3 Structural modelling

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 mesh size, as defined in [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 1, Sec 3, [7]. 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.

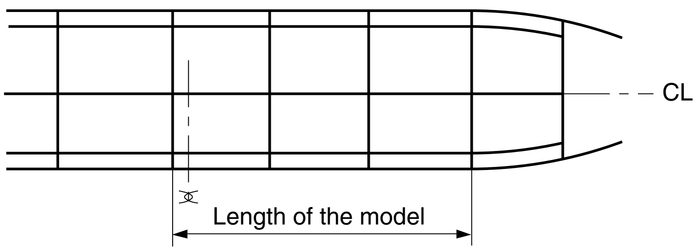
3.2.2 In general, the conditions in [3.2.1] are considered as being satisfied when the model is extended over at least three cargo tank lengths.

For the analysis of the midship area, this model is to be such that its aft end corresponds to the first transverse bulkhead aft of the midship, as shown in Fig 1. The structure of the fore and aft transverse bulkheads located within the model, including the bulkhead plating, is to be modelled.

Fore and aft models are to extend respectively to the collision bulkhead and the aft peak bulkhead.

3.2.3 In the case of structural symmetry with respect to the unit's centreline longitudinal plane, the hull structures may be modelled over half the unit's breadth.

Figure 1 : Model longitudinal extension



3.3 Boundary conditions

3.3.1 Structural model extended over at least three cargo tank lengths

The whole three-dimensional model is assumed to be fixed at one end, while shear forces and bending moments are applied at the other end to ensure equilibrium (see Article [4]).

At the free 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 unit's breadth (see [3.2.3]), in way of the unit's centreline longitudinal plane, symmetry or anti-symmetry boundary conditions as specified in Tab 5 are to be applied, depending on the loads applied to the model (symmetrical or anti-symmetrical, respectively).

Table 5 : Symmetry and anti-symmetry conditions in way of the unit's 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 1, [3.3].

3.4 Finite element modelling criteria

3.4.1 Modelling of primary supporting members

The analysis of primary supporting members based on standard mesh models, as defined in [3.5.3], 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 standard mesh
- an analysis of the whole three-dimensional model based on a coarse mesh, as defined in [3.5.2], 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.

3.4.2 Modelling of the most highly stressed areas

The areas which appear from the analyses based on standard mesh models to be highly stressed may be required to be further analysed, using the mesh accuracy specified in [3.5.4].

3.5 Finite element models

3.5.1 General

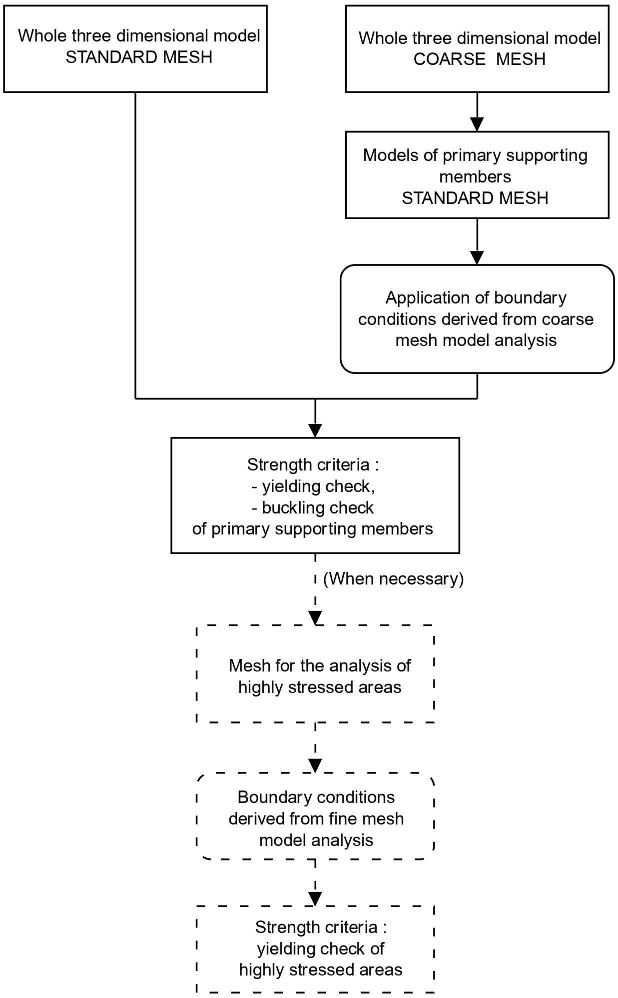
Finite element models are generally to be based on linear assumptions. The mesh is to be executed using membrane or shell elements, with or without mid-side nodes.

Meshing is to be carried out following uniformity criteria among the different elements.

Most of quadrilateral elements are to be such that the ratio between the longer side length and the shorter side length does not exceed 2. Some of them may have a ratio not exceeding 4. 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 [3.5.2] to [3.5.4].

Figure 2 : Finite element modelling criteria



3.5.2 Coarse mech

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 strip
- 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.

In case of an analysis based on coarse mesh model, the following standard mesh models are to be made:

- transverse rings
- primary supporting members supporting the transverse bulkheads
- bottom and deck girders.

3.5.3 Standard mesh

The unit's structure may be considered as standard 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 strips
- 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.

3.5.4 Fine mesh models

Evaluation of detailed stresses requires the use of fine mesh in way of areas of high stress (see [5.2] and [5.3]). The fine mesh analysis may be performed on separate finite element models, having boundary conditions obtained from the standard mesh model. As an alternative, fine mesh zones incorporated in the standard mesh model may be used.

The extent of fine mesh zone is not to be less than the relevant spacing of ordinary stiffeners in the considered structural region, in all directions from the area under investigation. When separate models are used, the extent is to be such that the calculated stresses within the investigated area are not significantly affected by the imposed boundary conditions and application of loads.

The elements inside the fine mesh zones are to be modelled based on net scantlings, as defined in Ch 1, Sec 3, [7].

All platings inside the fine mesh zone are to be represented by shell elements having dimensions not above 100 mm x 100 mm. Element aspect ratio is to be as close to 1 as possible, and not to exceed 3. Element's corner angles are to be greater than 60° and less than 120°. Triangular elements and elements having dimensions less than their thickness are to be avoided.

Face plates of primary supporting members or openings are to be modelled with shell elements within the fine mesh zone.

4 Load model

4.1 Loading conditions

4.1.1 The design on-site loading conditions specified in Fig 3 and Fig 4 as relevant, are to be considered in the analysis of primary supporting members in cargo and ballast tanks.

In addition, 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.

When some of the on-site loading conditions shown in Fig 3 and Fig 4 are not included in the loading manual, and in particular, the alternate and the non-symmetrical load cases, it must be indicated on the midship section drawing as well as in the loading manual, that these cases are not allowed. In addition, it should be demonstrated that these cases will never happen during the life of the unit, in particular in case of accidental conditions.

When the conditions shown in Fig 3 and Fig 4 are foreseen in the loading manual, the analysis is to be carried out, taking into account the associated draughts as specified in the table, and not the draughts as given in the loading manual.

The filling of ballast tanks as indicated in Fig 3 and Fig 4 is given as default value and may be changed if available loading information indicates otherwise.

The loads of the topside facilities are to be added, in static conditions, to represent the light weight of the unit, as well as the weight of the external structures (riser supports, etc.). For fore and aft models, the loading patterns are to be adjusted considering the capacity plan of the unit in the studied area. The loading conditions selected cases are to maximize internal pressure applied on watertight bulkheads, local shear stress at bulkheads location and torsion on the hull.

4.2 Local loads

4.2.1 The local loads to be taken into account are given in Ch 1, Sec 5.

The loads induced by the topside on deck are to be taken into account.

4.3 Hull girder loads

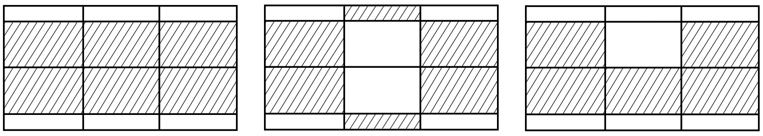
4.3.1 The hull girder loads to be taken into account are given in:

- Tab 6 and Tab 7 for the midship model
- Tab 8 and Tab 9 for the fore and aft models

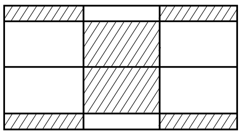
Note 1: For fore and aft peak analysis, see Ch 1, Sec 11, [2.1.2] and Ch 1, Sec 12, [2.1.2] respectively.

Figure 3 : Loading conditions for units fitted with one central longitudinal bulkhead for on-site condition

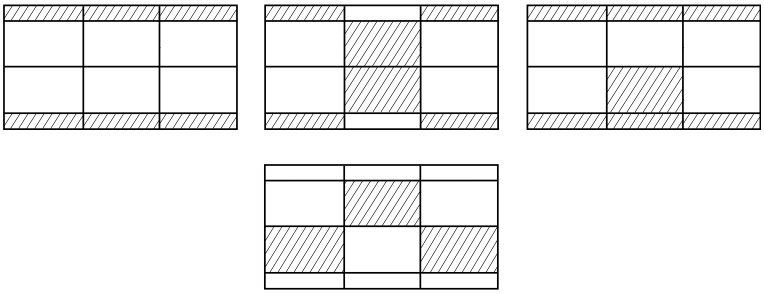
Loading conditions at maximum draught T



Loading condition at draught 0,9T



Loading conditions at minimum draught T_{mini}



Loading condition at draught 0,75T

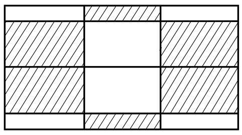
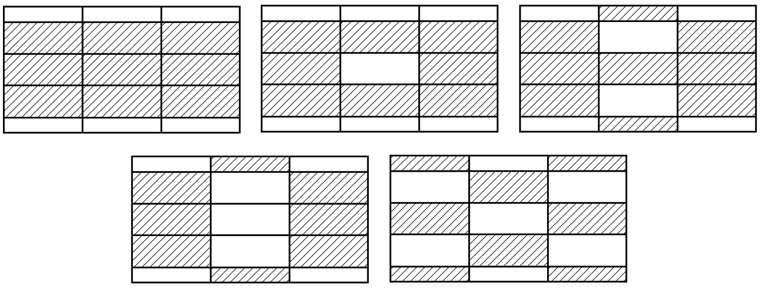
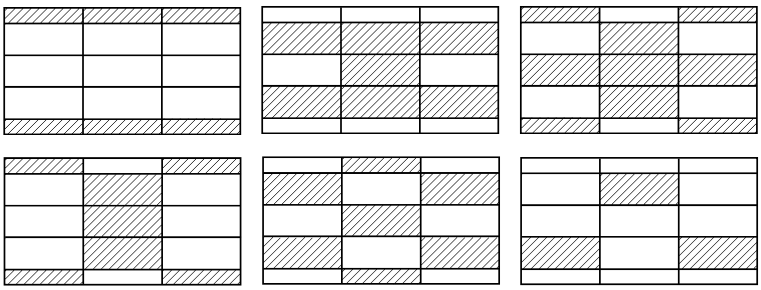


Figure 4 : Loading conditions for units fitted with two central longitudinal bulkhead for on-site condition

Loading conditions at maximum draught T



Loading conditions at minimum draught T_{mini}



Loading conditions at draught 0,75T

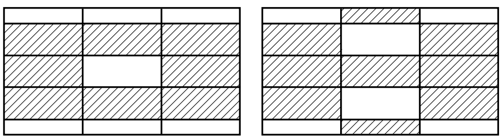


Table 6 : Midship model - Maximal bending moments at the middle of the central tank

Ship condition	Load case	Vertical bending moments at the middle of the central tank/hold		Horizontal wave bending moment at the middle of the central tank/hold	Vertical shear forces at the middle of the central tank/hold	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1}\ M_{SW}$	$\gamma_{W1}\ M_{WV,H}$	0	0	0
	"a" trough	$\gamma_{S1}\ M_{SW}$	$\gamma_{W1}\ M_{WV,S}$	0	0	0
	"b"	$\gamma_{S1}\ M_{SW}$	0,7 $\gamma_{W1}\ M_{WV,S}$	0	0	0
Inclined	"c"	$\gamma_{S1}\ M_{SW}$**(1)**	0,4 $\gamma_{W1}\ M_{WV}$**(2)**	$\gamma_{W1}\ M_{WH}$	0	0
	"d"	$\gamma_{S1}\ M_{SW}$**(1)**	0,25 $\gamma_{W1}\ M_{WV}$**(2)**	0,7 $\gamma_{W1}\ M_{WH}$	0	0

Note 1: Hull girder loads are to be calculated at the middle of the central tank/hold.
(1) M_{SW} is to be taken equal to $M_{SW,H}$ or to $M_{SW,S}$ depending on the loading condition.
(2) M_{WV} is to be taken equal to $M_{WV,H}$ or to $M_{WV,S}$ depending on the loading condition.

Table 7 : Midship model - Maximal shear forces in way of the aft bulkhead of the central tank

Ship condition	Load case	Vertical bending moments in way of the aft bulkhead of the central tank/hold		Vertical shear forces in way of the aft bulkhead of the central tank/hold	
		Still water	Wave	Still water	Wave
Upright	"a" crest	$\gamma_{S1}\ M_{SW}$**(1)**	0,4 $\gamma_{W1}\ M_{WV,H}$	$\gamma_{S1}\ Q_{SW}$	$\gamma_{W1}\ Q_{WV}$
	"a" trough	$\gamma_{S1}\ M_{SW}$**(1)**	0,4 $\gamma_{W1}\ M_{WV,S}$	$\gamma_{S1}\ Q_{SW}$	$\gamma_{W1}\ Q_{WV}$
	"b"	$\gamma_{S1}\ M_{SW}$**(1)**	0,4 $\gamma_{W1}\ M_{WV,S}$	$\gamma_{S1}\ Q_{SW}$	0,7 $\gamma_{W1}\ Q_{WV}$

Note 1: Hull girder loads are to be calculated in way of the aft bulkhead of the central tank.
(1) M_{SW} may be taken from the loading manual among the relevant loading conditions in order to maximize the shear forces.

Table 8 : Fore / aft model - Maximal bending moments

Ship condition	Load case	Vertical bending moments		Horizontal wave bending moment	Vertical shear forces	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1}\ M_{SW}$	$\gamma_{W1}\ M_{WV,H}$	0	$\gamma_{S1}\ Q_{SW}$**(3)**	$\gamma_{W1}\ Q_{WV}$
	"a" trough	$\gamma_{S1}\ M_{SW}$	$\gamma_{W1}\ M_{WV,S}$	0	$\gamma_{S1}\ Q_{SW}$**(3)**	$\gamma_{W1}\ Q_{WV}$
	"b"	$\gamma_{S1}\ M_{SW}$	0,7 $\gamma_{W1}\ M_{WV,S}$	0	$\gamma_{S1}\ Q_{SW}$**(3)**	0,7 $\gamma_{W1}\ Q_{WV}$
Inclined	"c"	$\gamma_{S1}\ M_{SW}$**(1)**	0,4 $\gamma_{W1}\ M_{WV}$**(2)**	$\gamma_{W1}\ M_{WH}$	$\gamma_{S1}\ Q_{SW}$**(3)**	0,4 $\gamma_{W1}\ Q_{WV}$
	"d"	$\gamma_{S1}\ M_{SW}$**(1)**	0,25 $\gamma_{W1}\ M_{WV}$**(2)**	0,7 $\gamma_{W1}\ M_{WH}$	$\gamma_{S1}\ Q_{SW}$**(3)**	0,25 $\gamma_{W1}\ Q_{WV}$

Note 1: Hull girder loads are to be calculated at the middle of studied region. Several studied region may be necessary in order to obtain the target hull girder loads over the length of the fore/aft model.
(1) M_{SW} is to be taken equal to $M_{SW,H}$ or to $M_{SW,S}$ depending on the loading condition.
(2) M_{WV} is to be taken equal to $M_{WV,H}$ or to $M_{WV,S}$ depending on the loading condition.
(3) Q_{SW} may be taken from the loading manual among the relevant loading conditions in order to maximize the bending moments.

Table 9 : Fore / aft model - Maximal shear forces

Ship condition	Load case	Vertical bending moments		Horizontal wave bending moment	Vertical shear forces	
		Still water	Wave		Still water	Wave
Upright	"a" crest	$\gamma_{S1}\ M_{SW}$**(3)**	$\gamma_{W1}\ M_{WV,H}$	0	$\gamma_{S1}\ Q_{SW}$	$\gamma_{W1}\ Q_{WV}$
	"a" trough	$\gamma_{S1}\ M_{SW}$**(3)**	$\gamma_{W1}\ M_{WV,S}$	0	$\gamma_{S1}\ Q_{SW}$	$\gamma_{W1}\ Q_{WV}$
	"b"	$\gamma_{S1}\ M_{SW}$**(3)**	0,7 $\gamma_{W1}\ M_{WV,S}$	0	$\gamma_{S1}\ Q_{SW}$	0,7 $\gamma_{W1}\ Q_{WV}$
Inclined	"c"	$\gamma_{S1}\ M_{SW}$**(1)(3)**	0,4 $\gamma_{W1}\ M_{WV}$**(2)**	$\gamma_{W1}\ M_{WH}$	$\gamma_{S1}\ Q_{SW}$	0,4 $\gamma_{W1}\ Q_{WV}$
	"d"	$\gamma_{S1}\ M_{SW}$**(1)(3)**	0,25 $\gamma_{W1}\ M_{WV}$**(2)**	0,7 $\gamma_{W1}\ M_{WH}$	$\gamma_{S1}\ Q_{SW}$	0,25 $\gamma_{W1}\ Q_{WV}$

Note 1: Hull girder loads are to be calculated at the middle of studied region. Several studied region may be necessary in order to obtain the target hull girder loads over the length of the fore/aft model.
(1) M_{SW} is to be taken equal to $M_{SW,H}$ or to $M_{SW,S}$ depending on the loading condition.
(2) M_{WV} is to be taken equal to $M_{WV,H}$ or to $M_{WV,S}$ depending on the loading condition.
(3) M_{SW} may be taken from the loading manual among the relevant loading conditions in order to maximize the shear forces.

4.4 Load cases

4.4.1 The loading conditions are to be combined with the load cases with the relevant wave loads and sea pressures as defined in Ch 1, Sec 5.

The sea state's return period for transit and site conditions are defined in Ch 1, Sec 4, [1.1].

5 Yielding strength criteria

5.1 Master allowable stress

5.1.1 The master allowable stress, σ_{MASTER}, in N/mm², is defined by the criteria:

$$\sigma_{MASTER} = \frac{R_y}{\gamma_R \gamma_m}$$

k : Material factor as defined in Pt B, Ch 4, Sec 1, [2.2] of the Ships Rules

R_y : Minimum yield stress, in N/mm², of the material, to be taken as follows, unless otherwise specified:

$$\frac{235}{k}$$

5.2 Yielding criteria for coarse and standard mesh analysis

5.2.1 For coarse mesh analysis and standard mesh analysis, and for elements located in ship areas (as defined in Ch 1, Sec 3, [1]), it is to be checked that the equivalent stress σ_{VM} , in N/mm², calculated according to Article [6] is in compliance with the following criteria:

$$\sigma_{VM} \leq \sigma_{MASTER}$$

Areas where the equivalent stress σ_{VM} obtained through standard mesh analysis is above $0,95\sigma_{MASTER}$, are to be investigated through fine mesh analysis based on the requirements of [3.5.4] and the criteria given in [5.4.1] are to be checked. The Society may require additional fine mesh analyses for areas where the assessment through standard mesh models is not judged as satisfactory.

5.3 Yielding criteria for face plates of primary supporting members and openings

5.3.1 For standard mesh analysis, face plates of primary supporting members and openings may be modelled by shell elements or by beam/bar elements.

When shell elements are used, the requirements of [5.2] are to be complied with.

When beam/bar elements are used, it is to be checked that the beam/bar element's axial stress σ_{ax}, in N/mm², is in compliance with the following criteria:

$$\sigma_{ax} \leq \sigma_{MASTER}$$

Areas where the beam/bar element's axial stress σ_{ax} is above 0,95 σ_{MASTER}, are to be investigated through fine mesh analysis (with shell elements) based on the requirements of [3.5.4] and the criteria given in [5.4.1] are to be checked.

Note 1: Values of beam/bar element's axial stress are generally calculated by finite element software. The direct use of nodal stresses is to be avoided. When different values of beam element's axial stress are calculated for each extremity of the element, both extremity values are to be checked.

5.4 Yielding criteria for fine mesh analysis

5.4.1 For fine mesh analysis required in [5.2]and/or [5.3] and complying with the requirements of [3.5.4], the following criteria are to be checked:

a) Average area:

The average Von Mises equivalent stress σ_{VM-av}, as defined in [5.5], is to comply with the following criteria:

$$\sigma_{VM-av} \leq \sigma_{MASTER}$$

b) Isolated mesh:

The equivalent stress σ_{VM} of each (100 mm x 100 mm) element in the fine mesh region excluding the area of structural discontinuity, in N/mm², calculated according to Article [6] is to comply with the following criteria:

$$\sigma_{VM} \leq \sigma_{MASTER}$$

c) Hot spot:

The equivalent stress σ_{VM} of each (100 mm x 100 mm) element in the fine mesh region at the vicinity of the structural discontinuity, in N/mm², calculated according to Article [6], is to comply with the following criteria:

- for elements not adjacent to the weld: $\sigma_{VM} \leq 1,42\sigma_{MASTER}$
- for elements adjacent to the weld: $\sigma_{VM} \leq 1,3\sigma_{MASTER}$

In case of mesh finer than (100 mm x 100 mm), the equivalent stress σ_{VM} is to be obtained by averaging over an equivalent area of (100 mm x 100 mm), based on the methodology given in [5.5].

5.5 Stress averaging on fine mesh

5.5.1 For the purpose of the criteria given in [5.4.1], item a), the average Von Mises equivalent stress σ_{VM-av} is to be calculated based on weighted average against element areas:

$$\sigma_{VM-av} = \frac{\sum_{1}^{n} \sigma_{VM-i} A_i}{\sum_{1}^{n} A_i}$$

where:

A_i : Area of the i-th element within the considered area, in mm²

n : Number of elements within the considered area

σ_{VM-av} : Average Von Mises equivalent stress, in N/mm²

σ_{VM-i} : Von Mises stress of the i-th element within the considered area, in N/mm²

Stress averaging is to be performed over an area defined as follows:

- the area considered for stress averaging is to have a size not above the relevant spacing of ordinary stiffeners (s x s)
- for fine mesh along rounded edges (openings, rounded brackets) the area considered for stress averaging is to be limited only to the first ring of border elements, over a length not above the relevant spacing of ordinary stiffeners (see Fig 5 and Fig 6).
- the area considered for stress averaging is to include an entire number of elements
- the area considered for stress averaging is not to be defined across structural discontinuities, web stiffeners or other abutting structure
- for regions where several different stress averaging areas may be defined, the worst is to be considered for the calculation of average Von Mises equivalent stress.

5.6 Particular requirements

5.6.1 Particular attention is to be paid to the stress flow along the studied structural member.

For fine mesh regions located on bracket webs in the vicinity of bracket toes, where an equivalent (s x s) area cannot be defined, the yielding check is to be based only on the criteria given in [5.4], item b).

Other structural details having shapes not allowing the stress averaging as required in [5.5] are to be specially considered by the Society, based on engineering judgment related to plastic redistribution ability.

Figure 5 : Example of stress averaging area at opening rounded edge

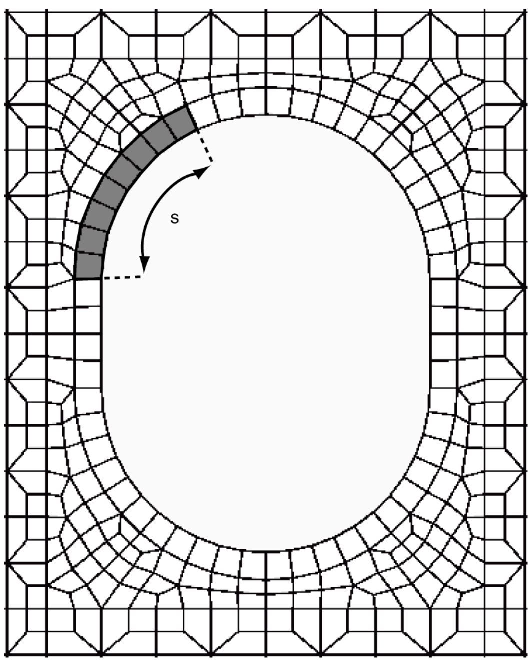
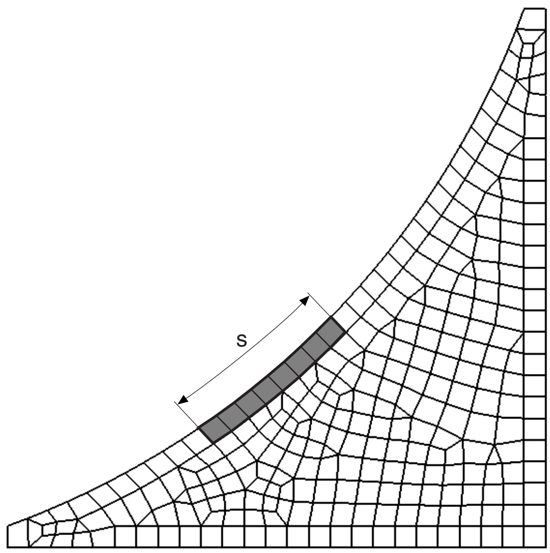


Figure 6 : Example of stress averaging area at rounded bracket edge



6 Stress calculation

6.1 Stresses induced by local and hull girder loads

6.1.1 Both local and hull girder loads are to be directly applied to the model, as specified in [4.3.1] and [4.4.1]. In this case, the stresses calculated by the finite element program include the contribution of both local and hull girder loads.

6.2 Stress components

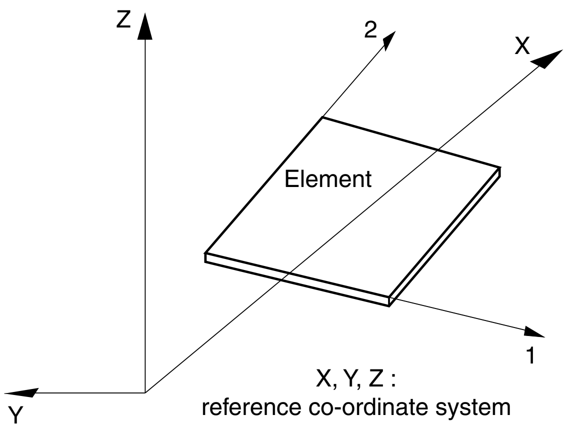
6.2.1 Stress components are generally identified with respect to the element co-ordinate system, as shown, by example, in Fig 7. The orientation of the element co-ordinate system may or may not coincide with that of the reference co-ordinate system in Ch 1, Sec 1, [3.3].

The following stress components are to be calculated at the centroid of the mid-plane layer 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 7 : Reference and element co-ordinate systems



6.3 Stress calculation points

6.3.1 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.

7 Buckling check

7.1 General

7.1.1 A local buckling check is to be carried out, according to Ch 1, Sec 7 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 the present Section.

7.2 Buckling criteria

7.2.1 The buckling criteria for plate panels is to satisfy the following criterion:

$\eta \le \eta_{ALL}$ with: $\eta_{ALL} = 1$

η : Utilisation factor as defined in NR615.

7.2.2 The compressive buckling strength of struts, pillars and cross ties is to satisfy the following criterion:

$\eta \le \eta_{ALL}$ with: $\eta_{ALL} = 0,75$

η : Utilisation factor as defined in NR615.

8 Primary members subject to impact loads

8.1 General

8.1.1 The net section modulus w, in cm^3, of primary supporting members and their net shear area A_{sh}, in cm^2, at any position along their span are not to be less than the values obtained from the following formulae:

$$w = \frac{f_{cb} P_I f_{pb} \ell^2 b_I}{m R_{eH}} 10^3$$

$$A_{sh} = 10 \frac{\sqrt{3} Q_I}{0,9 R_{eH}}$$

where:

b_I : Breadth of impact area supported by primary supporting member, in m, taken as:

$$b_I = \sqrt{A_I}$$

with b_1 not to be taken greater than s

$A_I = 1,1\ L\ B\ C_B\ 10^{-3}$

B : Moulded breadth, in m, taken equal to the greatest moulded breadth measured amidships at the maximum draught T

C_B : Total block coefficient as defined in Ch 1, Sec 5, Symbols

L : Unit rule length, in m, as defined in Ch 1, Sec 1, [3.2.7]

f_{cb} : Correction factor for the bending moment at the ends and considering the patch load, taken as:

$$f_{cb} = 3 f_{pb}^3 - 8 f_{pb}^2 + 6 f_{pb}$$

f_{pb} : Patch load modification factor for bending, taken as:

$$f_{pb} = \frac{\ell_I}{\ell}$$

ℓ : Span, in m, of primary supporting member, measured between the supporting elements

ℓ_I : Extent of impact load area, in m, along the span:

$$\ell_I = \sqrt{A_I}$$

not to be taken greater than:

- $0,5\ \ell$ for the calculation of Q_I
- ℓ for the calculation of f_{pb}

m : Boundary coefficient, to be taken equal to:

- m = 10 in general
- m = 12 for bottom and side primary supporting members

P_I : Any impact pressure defined in the Rules, including:

- bottom impact pressure, as defined in Ch 1, Sec 11, [3.4]
- bow impact pressure, as defined in Ch 1, Sec 11, [4.3]
- dynamic impact pressure, as defined in Ch 1, Sec 5, [6.4.3]

Q_I : Shear force, in kN, taken as:

$Q_I = f_{cs}\, f_{dist}\, P_I\, \ell_I\, b_I$

f_{cs} : Correction factor for the proportion of patch load acting on a single primary supporting member, taken as:

$$f_{cs} = 0,5(f_{ps}^3 - 2f_{ps}^2 + 2)$$

f_{dist} : Coefficient for shear force distribution along the span, as defined in Fig 8

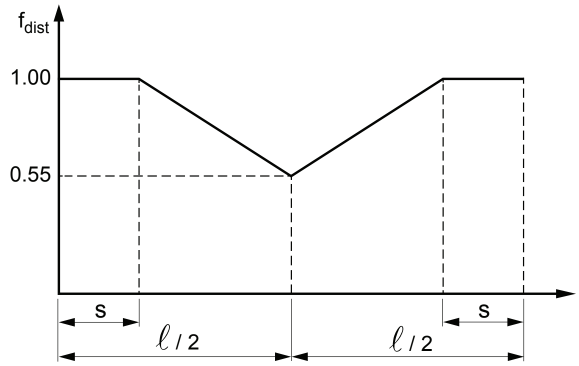
f_{ps} : Patch load modification factor for shear, taken as:

$$f_{ps} = 0,5\frac{b_I}{s}$$

For complex arrangements of primary supporting members, especially where grillage effect may not be ignored, or for primary supporting members having variable cross sections, direct calculation is to be performed.

It is to be checked that the maximum equivalent stress obtained by applying the load Q_I on a square area A_I to various locations on the model is not greater than 0,85 R_{eH} .

Figure 8 : Distribution of f_{dist} along the span of simple primary supporting members



Section 10 Fatigue Check of Structural Details

Symbols

h_1 : Rule distribution, in m, of the relative wave elevation in upright condition defined in Ch 1, Sec 5, [3.5]

h_2 : Rule distribution, in m, of the relative wave elevation in inclined ship condition defined in Ch 1, Sec 5, [3.5]

I_Y : Moment of inertia, in m^4, of the hull transverse section around its horizontal neutral axis

M_{SW} : Design still water bending moment, in kN.m, at the hull transverse section considered, defined in Ch 1, Sec 5, [2.2]

M_{WH} : Horizontal wave bending moment, in kN.m, at the hull transverse section considered, defined in Ch 1, Sec 5, [3.3]

$M_{WV,H}$: Vertical wave bending moment, in kN.m, in hogging condition, at the hull transverse section considered, defined in Ch 1, Sec 5, [3.3]

$M_{WV,S}$: Vertical wave bending moment, in kN.m, in sagging condition, at the hull transverse section considered, defined in Ch 1, Sec 5, [3.3]

N : Z co-ordinate, in m, with respect to the reference co-ordinate system defined in Ch 1, Sec 1, [3.3], 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

T : Maximum draught, in m, as defined in:

- Ch 1, Sec 1, [3.2.10] for site condition
- Ch 1, Sec 1, [3.2.11] for transit condition

T_1 : Draught, in m, corresponding to the loading condition considered

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 1, [3.3].

ρ : Sea water density, in t/m3: ρ = 1,025 t/m^3

ρ_L : Density of the liquid cargo, in t/m.

1 General

1.1 Application

1.1.1 The structural details to be checked are those defined in Article [2].

The Society may require other details to be checked, when deemed necessary on the basis of the detail geometry and stress level.

1.2 Fatigue life and sea conditions

1.2.1 The fatigue life and sea conditions of the unit are to be specified by the owner, and to be indicated on the midship section drawing.

By default, the fatigue life is to be greater than 20 years, on site conditions.

1.3 Fatigue calculation

1.3.1 Fatigue calculation is to be provided to the Society for design review.

1.4 Spectral fatigue

1.4.1 For units intended to be granted the additional notation **Spectral Fatigue**, as defined in Pt A, Ch 1, Sec 2, [8.4.4], this calculation is to be a spectral fatigue analysis performed according to Article [3] and NI611 Guidelines for Fatigue Assessment of Steel Ships and Offshore Units.

For all other units a deterministic fatigue calculation is to be carried out according to Article [4]. Deterministic fatigue calculation may be also carried out at pre-design stage, or for verification of the spectral fatigue calculation.

1.5 Corrosion protection

1.5.1 Corrosive environment is to be taken into account where there is no corrosion protection system. Information on the corrosion protection system, if any, is to be given by the Designer.

2 Structural details

2.1 Structural details to be checked

2.1.1 The structural details to be checked are those defined in Pt B, Ch 13, Sec 5 of the Ship Rules for the service notation **oil tanker ESP**.

2.1.2 In addition, the following structural details are also to be checked:

a) In each typical cargo tank within the cargo tank area:
   - Side shell, bottom and deck longitudinals with:
     - transverse oiltight and swash bulkheads
     - transverse web frame
   - Ends or bracket ends of:
     - longitudinal girders
     - bottom transverse
     - horizontal stringers
     - vertical buttress supporting the horizontal stringer
   - Flanges of transverse web frames in way of tripping brackets

b) Topside connection with the main deck

c) Crane pedestal

d) Mooring integration structure with hull (turret, buoy or spread mooring)

e) Flare tower connection with hull

f) Turret: The long-term distribution of forces is to be submitted by the turret designer.

3 Spectral fatigue analysis

3.1 Steps for analysis

3.1.1 The spectral fatigue analysis includes the following three steps:

- Hydrodynamic analysis:
  This analysis determines the external loads induced by the waves on the unit, and the resulting motions
- Structural analysis:
  Loads are applied on a structural model of the unit. The structural analysis provides the RAOs of stresses at location of interest, within the model
- Fatigue damage calculation based on statistics of stress ranges.

3.2 Load model

3.2.1 The spectral fatigue analysis is to take into account at least, except duly justified:

- 3 internal loading conditions, including minimum and maximum draughts
- 25 headings
- 25 frequencies.

3.2.2 Intermittent wetting effect, near free surface, is to be taken into account by means of an additional (differential) pressure loading on the side shell. Loading is defined for a representative finite wave height. The result is used to correct stiffener bending stress in intermittent wetting area, other contributions of this loading being negligible.

3.2.3 The overall (solid) mass is distributed on plate and beam elements by means of adjusted density. Weight of topsides modules are introduced according to the lightship weight distribution, by means of beam elements with no rigidity. The inertia loadings are generated from the above mass model and the accelerations of the vessel. Cargo and ballast tanks are loaded by internal fluid pressure calculated from acceleration at the centre of gravity of the tank (quasistatic approximation).

3.3 Distribution of hot spot stress ranges

3.3.1 The short-term distribution of hot spot stress ranges for a given sea-state is obtained by spectral analysis of the transfer function of hot spot stress ranges, and by Rayleigh statistics. The long-term distribution, over a given period in time, is obtained by summation of the short term distributions, over the scatter diagram at site where the unit will operate.

3.4 Fatigue damage

3.4.1 The fatigue damage is evaluated from the distribution of stress ranges, by the Miner Sum.

3.5 Checking criteria

3.5.1 For the spectral fatigue analysis, the fatigue damage ratio is to be not greater than those given in Tab 1.

Table 1 : Damage ratio for spectral fatigue analysis

Consequence of failure	Degree of accessibility for inspection, maintenance and repair		
	Not accessible **(2)**	Underwater inspection **(3)**	Dry inspection
Critical **(1)**	0,1	0,25	0,5
Non-critical	0,2	0,5	1,0

(1) Critical damage includes loss of life, uncontrolled pollution, collision, sinking, other major damage to the installations and major production losses. All the structural elements are to be considered as critical, unless duly justified by an analysis of the consequences of failure.
(2) Includes areas that can be inspected in dry or underwater conditions but require heavy works such as dry-docking for repair.
(3) Includes areas that can be inspected in dry conditions but with extensive preparation and heavy impact on operation.

4 Deterministic fatigue analysis

4.1 General

4.1.1 Deterministic fatigue analysis is to be conducted with loads defined in [4.2], partial safety factors defined in [4.1.2] and checking criteria defined in [4.7].

4.1.2 Partial safety factors

The partial safety factors to be taken into account are those given in Tab 2.

Table 2 : 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}	1,03	1,11
Still water pressure	γ_{S2}	1,00	1,00
Wave pressure	γ_{W2}	1,07	1,15
Resistance	γ_R	1,02	1,02

4.2 Load model

4.2.1 Loads

The loads to consider for deterministic fatigue analysis are the design wave loads defined in Ch 1, Sec 5 and taken to a probability level of 10^{-5}.

The loads to be determined are the following ones:

- vertical wave bending moment
- accelerations
- relative wave elevation.

4.2.2 Loading conditions

The calculations are generally to be carried out for 4 loading conditions with their associated draughts T_i, as defined in Tab 3, that are representative of the loading / unloading sequence of the unit.

However, more than 4 loading conditions can be considered on a case-by-case basis.

Table 3 : Loading conditions

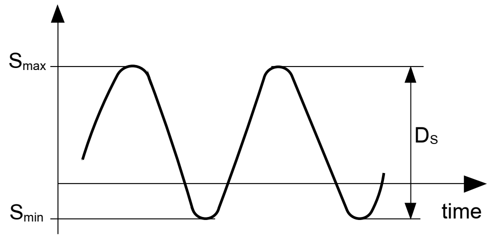
Draught T_i	Loading condition "i"
Maximum T_{maxi}	Full load
Intermediate 1 By default: 2/3 T_{maxi} + 1/3 T_{mini}	Case by case By default: full load
Intermediate 2 By default: 1/3 T_{maxi} + 2/3 T_{mini}	Case by case By default: ballast
Minimum T_{mini}	Ballast

4.2.3 Load cases

The fatigue check is based on the stress range induced at the hot spot by the time variation of the local pressures and hull girder loads in each load case "a", "b", "c" and "d" defined in [4.2.4] to [4.2.7] for the loading conditions defined in [4.2.2] (see Fig 1).

For the purpose of fatigue check, each load case "a", "b", "c" and "d" is divided in two cases "-max" and "-min" for which the local pressures defined in [4.2.4] to [4.2.7] and corresponding hull girder loads defined in [4.2.8].

Figure 1 : Stress range



4.2.4 Load cases "a-max" and "a-min", in upright ship condition

The still water sea pressure (p_S) is defined in Ch 1, Sec 5, [5.3].

The wave pressure (p_W) is defined in Tab 4.

No internal inertial pressures are considered.

Table 4 : Wave pressure in load case a

Location	Wave pressure p_W, in kN/m²	
	a-max	a-min
Bottom and sides below the waterline ($z \le T_1$)	$\alpha^{1/4}\dfrac{\rho g h_1}{2}\left[\dfrac{T_1 + z}{T_1}\right]$	$-\alpha^{1/4}\dfrac{\rho g h_1}{2}\left[\dfrac{T_1 + z}{T_1}\right]$ without being taken less than $\dfrac{\gamma_S}{\gamma_W}\rho g(z - T_1)$
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		

4.2.5 Load cases "b-max" and "b-min", in upright ship condition

Still water pressure (p_S) includes:

- the still water sea pressure defined in Ch 1, Sec 5, [5.3]
- the still water internal pressure, defined in Ch 1, Sec 5, [6.3.1]

for the various types of cargoes and for ballast.

Dynamic pressure (p_W) is constituted by internal inertial pressures defined in Tab 6.

No sea wave dynamic pressures are considered.

4.2.6 Load cases "c-max" and "c-min", in inclined ship condition

Still water pressure (p_S) includes:

- the still water sea pressure defined in Ch 1, Sec 5, [5.3]
- the still water internal pressure, defined in Ch 1, Sec 5, [6.3.1]

for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure obtained from Tab 5
- the inertial pressure obtained from Tab 6

for the various types of cargoes and ballast.

4.2.7 Load cases “d-max” and “d-min”, in inclined ship condition

Still water pressure (p_S) includes:

- the still water sea pressure defined in Ch 1, Sec 5, [5.3]
- the still water internal pressure, defined in Ch 1, Sec 5, [6.3.1]

for the various types of cargoes and for ballast.

Wave pressure (p_W) includes:

- the wave pressure obtained from Tab 5
- the inertial pressure obtained from Tab 6

for the various types of cargoes and ballast.

Table 5 : 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 1, Sec 5, [3.5.3] and not to be taken greater than the minimum of T_1 and (D – 0,9 T_1).

Table 6 : Inertial pressures

Cargo	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	$p_W = \rho_L[-0,7C_{FA}a_{Y2}(y-y_H) + (0,7C_{FA}a_{Z2}-g)(z-z_H) + g(z-z_{TOP})]$

(1) The symbols used in the formulae of inertial pressures are defined in Ch 1, Sec 5, [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”

4.2.8 Nominal hull girder normal stresses

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:

C_{FV}, C_{FH} : Combination factors defined in Tab 8

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 7.

Table 7 : 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 8 : Combination factors C_{FV}, 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

4.3 Damage ratio

4.3.1 Elementary 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:

N_t : Number of cycles, to be taken equal to:

$$N_t = \frac{31,55\alpha_0 T_{FL}}{T_A}10^6$$

α_0 : Sailing factor, taken equal to 1

T_A : Average period, in seconds, to be taken equal to: $T_A = 4 \log L$

T_{FL} : Design fatigue life, in years

$\Delta\sigma_{N,ij}$: Elementary notch stress range, in N/mm², defined in [4.6]

$$\mu_{ij} = 1 - \frac{\Gamma_N\left[\frac{3}{\xi}+1, \nu_{ij}\right] - \Gamma_N\left[\frac{5}{\xi}+1, \nu_{ij}\right]\nu_{ij}^{-2/\xi}}{\Gamma_C\left[\frac{3}{\xi}+1\right]}$$

$$\xi = \xi_0\left(1,04 - 0,14\frac{|z - T_1|}{D - T_1}\right)$$ without being less than 0,9 ξ_0

$$\xi_0 = \frac{73 - 0,07L}{60}$$ without being less than 0,85

T_1 : Draught, in m, corresponding to the loading condition "Full load" or "Ballast"

$$\nu_{ij} = -\left(\frac{S_q}{\Delta\sigma_{N,ij}}\right)^{\xi} \ln p_R$$

$$S_q = (K_p 10^{-7})^{1/3}$$

$$K_p = 5,802\left(\frac{22}{t}\right)^{0,9} 10^{12}$$

t : Net thickness, in mm, of the element under consideration not being taken less than 22 mm

$p_R = 10^{-5}$

$\Gamma_N[X+1,\nu_{ij}]$: 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 9. 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 10. For intermediate values of X, Γ_C may be obtained by linear interpolation.

4.3.2 Cumulative damage ratio

The cumulative damage ratio is to be obtained from the following formula:

$$D = \frac{1}{\beta_{IF}}\left(K_{cor}\sum_{i=1}^{4}\alpha_i D_i\right)$$

where:

D_i : Cumulative damage ratio for unit in loading condition "i"

$$D_i = \beta_{ab}\frac{D_{ai} + D_{bi}}{2} + \beta_c D_{ci} + \beta_d D_{di}$$

β_{ab}, β_c, β_d: Distribution coefficients for load cases "a", "b", "c", "d", as defined in Tab 11.

Other values may be considered on a case by case basis

D_{ai}, D_{bi}, D_{ci}, D_{di} : Elementary damage ratios for load cases "a", "b", "c" and "d", respectively, in loading condition "i", as defined in [4.3.1]

K_{cor} : Corrosion factor, equal to:

- $K_{cor} = 1,5$ for cargo tanks
- $K_{cor} = 1,1$ for ballast tanks having an effective coating protection.

α_i : Part of the unit's life in loading condition "i" taken equal to 0,25 in case of 4 loading conditions.

The Society reserves its right to modify the values of the α_i coefficients:

$$\sum_i \alpha_i = 1$$

β_{IF} : Fatigue life improvement factor for improvement technique, if any, as defined in:

- [4.3.3] in case of grinding
- [4.3.4] for improvement techniques other than grinding

$\beta_{IF} = 1,0$ if no improvement technique is used

Table 9 : Function Γ_N [X+1, ν_{ij}]

X	Value of ν_{ij}													
	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0
2,5	0,38	0,73	1,13	1,53	1,90	2,22	2,48	2,70	2,86	2,99	3,08	3,15	3,20	3,24
2,6	0,38	0,75	1,19	1,63	2,04	2,41	2,71	2,96	3,16	3,31	3,42	3,51	3,57	3,61
2,7	0,39	0,78	1,25	1,73	2,20	2,62	2,97	3,26	3,49	3,67	3,81	3,91	3,99	4,04
2,8	0,39	0,80	1,31	1,85	2,38	2,85	3,26	3,60	3,87	4,09	4,25	4,37	4,46	4,53
2,9	0,39	0,83	1,38	1,98	2,57	3,11	3,58	3,98	4,30	4,56	4,75	4,90	5,01	5,10
3,0	0,39	0,86	1,45	2,12	2,78	3,40	3,95	4,41	4,79	5,09	5,33	5,51	5,65	5,75
3,1	0,40	0,89	1,54	2,27	3,01	3,72	4,35	4,89	5,34	5,70	5,99	6,21	6,37	6,49
3,2	0,40	0,92	1,62	2,43	3,27	4,08	4,81	5,44	5,97	6,40	6,74	7,01	7,21	7,36
3,3	0,41	0,95	1,72	2,61	3,56	4,48	5,32	6,06	6,68	7,20	7,61	7,93	8,17	8,36
3,4	0,41	0,99	1,82	2,81	3,87	4,92	5,90	6,76	7,50	8,11	8,60	8,99	9,29	9,51
3,5	0,42	1,03	1,93	3,03	4,22	5,42	6,55	7,55	8,42	9,15	9,74	10,21	10,57	10,85
3,6	0,42	1,07	2,04	3,26	4,60	5,97	7,27	8,45	9,48	10,34	11,05	11,62	12,06	12,41
3,7	0,43	1,12	2,17	3,52	5,03	6,59	8,09	9,47	10,68	11,71	12,56	13,25	13,79	14,21
3,8	0,43	1,16	2,31	3,80	5,50	7,28	9,02	10,63	12,06	13,28	14,30	15,13	15,80	16,31
3,9	0,44	1,21	2,45	4,10	6,02	8,05	10,06	11,94	13,63	15,09	16,31	17,32	18,12	18,76
4,0	0,45	1,26	2,61	4,43	6,59	8,91	11,23	13,43	15,42	17,16	18,63	19,85	20,83	21,61
4,1	0,45	1,32	2,78	4,80	7,22	9,87	12,55	15,12	17,47	19,54	21,31	22,78	22,98	24,94
4,2	0,46	1,38	2,96	5,20	7,93	10,95	14,05	17,05	19,82	22,29	24,41	26,19	27,65	28,83
4,3	0,47	1,44	3,16	5,63	8,70	12,15	15,73	19,24	22,51	25,45	28,00	30,16	31,93	33,38
4,4	0,48	1,51	3,37	6,11	9,56	13,50	17,64	21,74	25,60	29,10	32,16	34,77	36,94	38,71
4,5	0,49	1,57	3,60	6,63	10,52	15,01	19,79	24,58	29,14	33,31	36,99	40,15	42,79	44,96
4,6	0,49	1,65	3,85	7,20	11,57	16,70	22,23	27,82	33,20	38,17	42,59	46,41	49,63	52,29
4,7	0,50	1,73	4,12	7,82	12,75	18,59	24,98	31,53	37,88	43,79	49,10	53,72	57,65	60,91
4,8	0,52	1,81	4,40	8,50	14,04	20,72	28,11	35,75	43,25	50,29	56,66	62,26	67,05	71,05
4,9	0,52	1,90	4,71	9,25	15,49	23,11	31,64	40,57	49,42	57,81	65,47	72,24	78,08	82,98
5,0	0,53	1,99	5,04	10,07	17,09	25,78	35,65	46,08	56,53	66,52	75,72	83,92	91,03	97,05
5,1	0,55	2,09	5,40	10,97	18,86	28,79	40,19	52,39	64,71	76,61	87,66	97,58	106,3	113,6
5,2	0,56	2,19	5,79	11,95	20,84	32,17	45,34	59,60	74,15	88,32	101,6	113,6	124,2	133,2
5,3	0,57	2,30	6,21	13,03	23,03	35,96	51,19	67,85	85,02	101,9	117,8	132,4	145,3	156,4
5,4	0,58	2,41	6,66	14,21	25,46	40,23	57,83	77,29	97,56	117,7	136,8	154,4	170,1	183,8
5,5	0,59	2,54	7,14	15,50	28,17	45,03	65,37	88,11	112,0	136,0	159,0	180,3	199,4	216,2
5,6	0,61	2,67	7,67	16,92	31,18	50,42	73,93	100,5	128,8	157,3	184,9	210,7	234,0	254,6
5,7	0,62	2,80	8,23	18,48	34,53	56,49	83,66	114,7	148,1	182,0	215,2	246,4	274,8	300,1
5,8	0,64	2,95	8,84	20,19	38,25	63,33	94,73	131,0	170,4	210,9	250,7	288,4	323,1	354,1
5,9	0,65	3,10	9,50	22,07	42,39	71,02	107,3	149,8	196,2	244,4	292,2	337,9	380,2	418,2
6,0	0,67	3,26	10,21	24,13	47,00	79,69	121,6	171,2	226,1	283,5	340,9	396,2	447,7	494,4
6,1	0,68	3,44	10,98	26,39	52,14	89,45	138,0	195,9	260,6	329,0	398,0	464,9	527,7	585,0
6,2	0,70	3,62	11,82	28,87	57,86	100,5	156,5	224,2	300,6	382,1	464,9	546,0	622,5	692,8
6,3	0,72	3,81	12,71	31,60	64,24	112,9	177,7	256,8	347,0	444,0	543,5	641,6	734,9	821,1
6,4	0,73	4,02	13,68	34,60	71,34	126,9	201,7	294,3	400,7	516,3	635,8	754,5	868,3	974,0
6,5	0,75	4,23	14,73	37,90	79,25	142,6	229,2	337,3	463,0	600,6	744,2	887,9	1026,6	1156,3
6,6	0,77	4,46	15,87	41,52	88,07	160,4	260,5	386,9	535,2	699,2	871,6	1045,5	1214,6	1373,8

Table 10 : Function Γ_C [X+1]

X	Γ_C [X+1]	X	Γ_C [X+1]
2,5	3,323	3,3	8,855
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

Table 11 : Distribution coefficients

	$T_i \geq \dfrac{T_{mini} + T_{maxi}}{2}$	$T_i < \dfrac{T_{mini} + T_{maxi}}{2}$
β_{ab}	1/3	2/3
β_c	1/3	1/3
β_d	1/3	0

4.3.3 Grinding of welds

Grinding technique for improving fatigue life is applicable to full penetration welds.

Grinding of welds is to be regarded as an exceptional measure considered case by case, and only when the design fatigue life cannot be achieved by the design (such as improvements of shape of cut-outs, softening of bracket toes and local increase in thickness) and geometry of the structural detail.

In such a case:

- the information “grinding of welds”, with indication of the toe to be ground, is to be specified by the designer on drawings
- the relevant grinding procedure, according to Ch 1, Sec 15, [2.2], is to be submitted to the Society by the designer for review
- the fatigue life improvement factor β_{IF}, as defined in [4.3.2], may be taken equal to 2,2, provided that a permanent protective coating is applied on the ground weld. Otherwise, the value of β_{IF} is considered by the Society on a case-by-case basis.

4.3.4 Improvement techniques other than grinding of welds

Improving fatigue life by using improvement techniques other than grinding is to be regarded as an exceptional measure. Such improvement techniques may be considered by the Society on a case-by-case basis. In such a case, the fatigue life improvement factor β_{IF}, as defined in [4.3.2], is to be duly justified by the designer.

4.4 Stress range

4.4.1 Unless otherwise specified, stresses are to be determined at the hot spots indicated, for each detail, in the relevant tables listed in Ship Rules Pt B, Ch 13, Sec 5, Tab 2 and Ship Rules Pt B, Ch 13, Sec 5, Tab 3.

4.4.2 Stress components

For the details in [2.1], the stresses to be used in the fatigue check are the normal stresses in the direction perpendicular to the weld joint.

Where the fatigue check is required for details other than those in [2.1], the stresses to be used are the principal stresses at the hot spots which form the smallest angle with the crack rising surface.

4.4.3 The hot spot stress range and the notch stress range are to be obtained according to [4.5] and [4.6], respectively.

4.5 Hot spot stress range

4.5.1 Elementary hot spot stress range

The elementary hot spot stress range $\Delta\sigma_{G,ij}$ is to be obtained, in N/mm², in accordance with:

- [4.5.2] for details where the stresses are to be calculated through a three dimensional structural models
- [4.5.3] for details located at ends of ordinary stiffeners.

4.5.2 Hot spot stresses directly obtained through finite element analyses based on a very fine mesh

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 item a) to item d).

a) 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.

b) 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 once to twice 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 2.

c) Calculation of hot spot stresses

When the detail is located at a structural discontinuity where a large stress gradient is expected the hot spot stresses are normally obtained by linear extrapolation. The stress components is to be evaluated at a distance of 0,5 and 1,5 times the thickness of the plating from the weld toe and linearly extrapolated to the weld toe. The two evaluation points are to be located in two different finite elements.

In other cases or when extrapolation can not be used the hot spot stresses are to be calculated at the centroid of the first element adjacent to the hot spot. The size of this element has to be determined according to the requirements in item b).

The stress components to be considered are those specified in [4.4.2]. 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), the hot spot stresses have to be calculated at the free edge. The stresses can be obtained by linear extrapolation or using fictitious truss elements with minimal stiffness fitted along the edge.

d) 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 [4.2.3] to [4.2.8]

i : Denotes the load case

j : Denotes the loading condition.

4.5.3 Hot spot stresses in structural details located at ends of ordinary stiffeners

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 specified in a) and b):

a) 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:

$$\sigma_{\ell} = \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{12 w}\left(1 - \frac{s}{2\ell}\right) s \ell^2 10^3$$

where:

ℓ : Span, in m, of ordinary stiffeners, measured between the supporting members, see Ch 1, Sec 3, [5.2]

s : Spacing, in m, of ordinary stiffeners

w : Net section modulus, in cm³, of the stiffener

b) 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:

$$\sigma_{G(i\text{-max})} = (\sigma_h + K_\ell K_S \sigma_\ell)_{(i\text{-max})}$$

$$\sigma_{G(i\text{-min})} = (\sigma_h + K_\ell K_S \sigma_\ell)_{(i\text{-min})}$$

$\Delta\sigma_{DEF,\,ij}$: Nominal stress range due to the local deflection of the ordinary stiffener to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{DEF,ij} = \frac{4(\Delta\delta)EI}{w\ell^2}10^{-5}$$

where:

$\Delta\delta$: Local range of deflection, in mm, of the ordinary stiffener

I : Net moment of inertia, in cm⁴, of the ordinary stiffener.

σ_h : Nominal hull girder stress, in N/mm², for the load case "i-max" or "i-min" considered, to be determined as in indicated in [4.2.8]

σ_ℓ : Nominal local stress for the load case "i-max" or "i-min" considered, to be determined as indicated in item a)

K_h, K_ℓ : Stress concentration factors, defined in Ch 1, App 1 for the special structural details there specified

K_S : Coefficient taking account of the stiffener section geometry, equal to:

$$K_S = 1 + \left[\frac{t_f(a^2 - b^2)}{2w_B}\right]\left[1 - \frac{b}{a+b}\left(1 + \frac{w_B}{w_A}\right)\right]10^{-3}$$

without being taken less than 1,0

where:

a, b : Eccentricities of the stiffener, in mm, defined in Fig 2:

Bulb sections are to be taken as equivalent to an angle profile, as defined in Ch 1, Sec 3, [5.1.2] with:

$a = 0,75\ b_f$

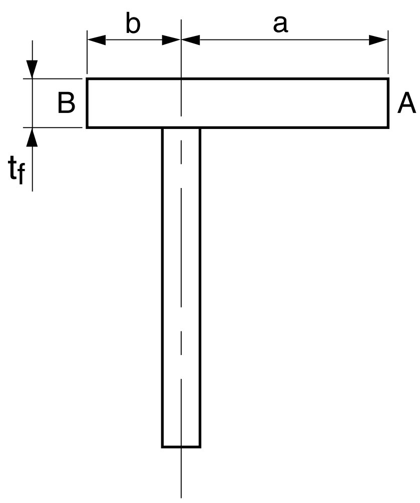
$b = 0,25\ b_f$

b_f : Face plate width, in mm

t_f : Face plate net thickness, in mm

w_A, w_B : Net section moduli of the stiffener without attached plating, in cm³, respectively in A and B (see Fig 2), about its neutral axis parallel to the stiffener web.

Figure 2 : Geometry of a stiffener section



4.6 Notch stress range

4.6.1 Elementary notch stress range

The elementary notch stress range is to be obtained, in N/mm², from the following formula:

$$\Delta\sigma_{N,ij} = K_{C,ij}\,\Delta\sigma_{N0,ij}$$

with:

$$\Delta\sigma_{N0,ij} = 0{,}7\,K_F\,K_m\,\Delta\sigma_{G,ij}$$

where:

$$K_{C,ij} = \frac{0{,}4\,R_{eH}}{\Delta\sigma_{N0,ij}} + 0{,}6 \quad \text{with} \quad 0{,}8 \le K_{C,ij} \le 1$$

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 the values defined in Tab 12, depending on the cutting quality, post treatment and control quality.

where:

λ : Coefficient depending on the weld configuration, and given in Tab 13

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 14, and to be taken not less than 1,0

$\Delta\sigma_{G,ij}$: Elementary hot spot stress range, defined in [4.5].

Table 12 : K_F values

Flame-cut edge description	K_F
Machine gas cut edges, with subsequent machining, dressing or grinding	1,4
Machine thermally cut edges, corners removed, no crack by inspection	1,6
Manually thermally cut edges, free from cracks and severe notches	2,0
Manually thermally cut edges, uncontrolled, no notch deeper than 0,5 mm	2,5

4.7 Checking criteria

4.7.1 The cumulative damage ratio D defined in [4.3.2] is to comply with the following criteria:

$$SF \cdot D \le \frac{1}{\gamma_R}$$

where:

SF = 2

γ_R : Partial safety factor defined in [4.1.2].

Note 1: In case that all hydrodynamic values and distributions are lower than minimum or rule values and distribution with significant margin (as a rule hydrodynamic loads lower than 25% of the rule loads), a Safety Factor SF lower than 2 may be considered by the Society.

4.8 Loading / unloading

4.8.1 The fatigue due to loading/unloading may have to be assessed.

By default, one loading/unloading per week is taken into account.

In this case the calculation should take into account the wave at a probability level not less than 10^{-4}.

Table 13 : Weld coefficient λ

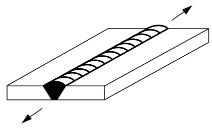
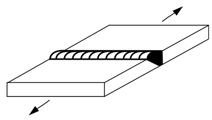
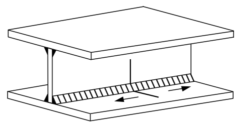
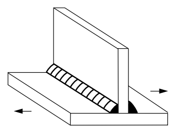
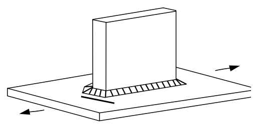
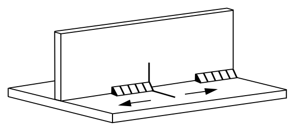
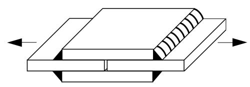
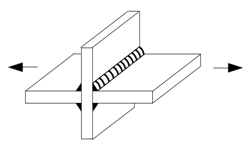
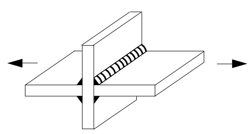
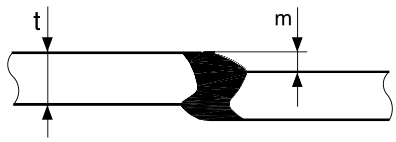
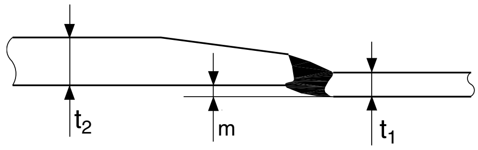
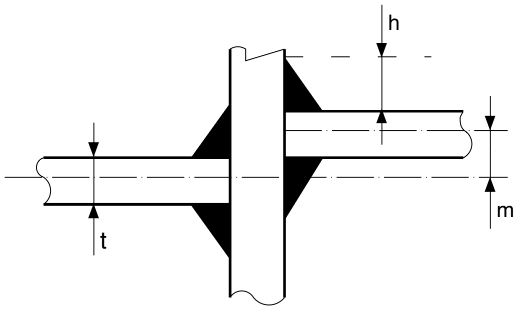
Weld configuration				Coefficient λ	Grinding applicable
Type	Description	Stress direction	Figure		
Butt weld		Parallel to the weld		2,10	yes
		Perpendicular to the weld		2,40	yes
Fillet weld	Continuous	Parallel to the weld		1,80	yes
		Perpendicular to the weld **(1)**		2,15	yes
	Well contoured end	Perpendicular to the weld		2,15	yes
	Not continuous	Parallel to the weld		2,90	yes
	Lap weld (root cracking)	Axial loading out of plane and perpendicular to the weld		4,50	no
Cruciform joint	Full penetration	Perpendicular to the weld		2,10	yes
	Partial penetration	Perpendicular to the weld		Toe cracking: 2,10	yes
				Root cracking: 4,50	no
(1) This case includes the hot spots indicated in the sheets of special structural details in Pt B, Ch 3, App 2 of the Ship Rules, relevant to the connections of longitudinal ordinary stiffeners with transverse primary supporting members.					

Table 14 : 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 Pt B, Ch 13, Sec 2 of the Ship Rules

Section 11 Fore Part

Symbols

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 1, Sec 5, [3.6]

B : Moulded breadth, in m, taken equal to the greatest moulded breadth measured amidships at the maximum draught T

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_B : Total block coefficient, equal to:

$$C_B = \frac{\Delta}{1{,}025\,LBT}$$

C_B not to be taken greater than 1

c_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \le 65$ m

$c_E = 3 - L / 32{,}5$ for $65\text{ m} < L < 90$ m

$c_E = 0$ for $L \ge 90$ m

c_F : Coefficient to be taken equal to:

$c_F = 0{,}9$ for forecastle sides

$c_F = 1{,}0$ in other cases

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 of the panel, in m

g : Gravity acceleration, in m/s², taken equal to 9,81

h_1 : Reference value of the ship relative motion defined in Ch 1, Sec 5, [3.5]

m : Boundary coefficient, to be taken equal to:

- in general, for stiffeners considered as clamped: m = 12
- for stiffeners considered as simply supported: m = 8

other values of m may be considered, on a case by case basis, for other boundary conditions

ℓ : Span, in m, of ordinary stiffeners

L : Rule length, in m, as defined in Ch 1, Sec 1, [3.2.6]

L_2 : L, but to be taken not greater than 120 m

p_{BI} : Bottom impact pressure, defined in [3.4]

p_{FI} : Bow impact pressure, defined in [4.3]

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

s : Spacing, in m, of ordinary stiffeners

T : Maximum draught, in m, as defined in:

- for site condition: Ch 1, Sec 1, [3.2.11]
- for transit condition: Ch 1, Sec 1, [3.2.12]

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 1, [3.3]

β_b , β_s : Coefficients defined in Ch 1, Sec 8, [3.4.2]

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m³)

ρ : Sea water density, in t/m³, to taken equal to 1,025

ρ_L : Density, in t/m³, of the liquid cargo.

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
- stems.

In addition, it includes:

- reinforcements of the flat bottom forward area
- reinforcements of the bow flare area.

1.1.2 The fore part of the unit is defined in Ch 1, Sec 1, [3.2.8].

The fore part may differ in site and transit conditions.

1.1.3 Fore peak structures which form vertical watertight boundary between two compartments 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 Ch 1, Sec 7 to Ch 1, Sec 9.

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 1, Sec 3, [11.3.2] for primary supporting members of transversally framed single side
- Ch 1, Sec 3, [11.5.3] for primary supporting members of transversally framed double side

as applicable.

1.3 Net scantlings

1.3.1 As specified in Ch 1, Sec 3, [7.1] all scantlings referred to in this Section, with the exception of those indicated in [5], are net, i.e. they do not include any margin for corrosion.

Gross scantlings are obtained as specified in Ch 1, Sec 3, [7.2].

2 Fore peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking fore peak structures are specified in:

- Ch 1, Sec 7, Tab 1 for plating
- Ch 1, Sec 8, Tab 1 for stiffeners
- Ch 1, Sec 9, Tab 4 for primary supporting members.

2.1.2 Finite element analysis

When a finite element analysis, as defined in Ch 1, Sec 9, [3.5], is performed in order to verify the scantlings of the fore peak structure, the hull girder loads do not need to be considered.

Note 1: For units provided with an external turret, the hull girder loads are to be considered on a case-by-case basis.

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 1
- the still water internal pressure due to liquids or ballast, defined in Tab 3
- the still water internal pressure due to dry uniform cargoes on deck, defined in Tab 4.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 1
- the inertial internal pressure due to liquids or ballast, defined in Tab 3
- the inertial internal pressure due to dry uniform cargoes on deck, defined in Tab 4.

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 : 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 φ_1 φ_2 L
Exposed deck	Pressure due to the load carried **(1)**	$19{,}6 n \varphi_1 \varphi_2 \sqrt{H}$

(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 and 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 2

φ_2 : Coefficient taken equal to:

- φ_2 = 1 if L ≥ 120 m
- φ_2 = L/120 if L < 120 m

$$H = \left[2{,}66\left(\frac{x}{L} - 0{,}7\right)^2 + 0{,}14\right]\sqrt{\frac{VL}{C_B}} - (z - T)$$

without being taken less than 0,8

V : Maximum ahead service speed, in knots, to be taken not less than 13 knots.

Table 2 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freeboard deck	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 : 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 4 : Still water and inertial internal pressures due to dry uniform cargoes

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.	$p_S \dfrac{a_{Z1}}{g}$

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.

2.3.4 Lateral pressure in testing conditions

The lateral pressure in testing conditions, p_T, in kN/m², is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Still water pressure defined in Ch 1, Sec 5, [6.7]

p_S : Still water sea pressure defined in Ch 1, Sec 5 and calculated 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 1, Sec 7, [3.2.2].

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 5 and the minimum values in the same table.

Table 5 : Scantling of bottom plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum 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: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$	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 net thickness of the attached plating.
	Net shear sectional area, in cm²: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell$	

(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 1, Sec 8, [3.3.5], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:

- for longitudinally framed bottom: $\lambda = \lambda_L$, defined in Ch 1, Sec 7, [3.3.1]
- for transversely framed bottom: $\lambda = \lambda_T$, defined in Ch 1, Sec 7, [3.4.1].

2.4.2 Floors

Floors are to be fitted at every four frame spacing 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 6.

In no case may the above scantlings be lower than those of the corresponding side transverses, as defined in [2.6.2].

Table 6 : Longitudinally framed bottom floor dimensions and scantlings

Dimension or scantling	Specified value
Web height h_M , 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 A_p , in cm^2	A_P = 3,15 D
Floor face plate net thickness t_p , in mm	t_P = 0,4 D + 5 t_p may be assumed not greater than 14 mm.

2.4.3 Centre girder

Where no centreline bulkhead is 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 5 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 7.

2.5.3 Centre girder

Where no centreline bulkhead is fitted (see [2.10]), a centre bottom girder is to be fitted according to [2.4.3].

Table 7 : Transversely framed bottom - Floor dimensions and scantlings

Dimension or scantling	Specified value
Web height h_M, 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 A_p, in cm^2	A_P = 1,67 D

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 8 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:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

λ_b , λ_s : Coefficients defined in Ch 1, Sec 8, [3.4.3]

Table 8 : Scantling of side plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum thickness, in mm **(1)**: $t = c_F (0{,}03\ L + 5{,}5)\ k^{1/2} - c_E$
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 net minimum 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: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} \left(1 - \frac{s}{2\ell}\right) s \ell$	

(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 1, Sec 8, [3.3.5], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:
- for longitudinally framed side: $\lambda = \lambda_L$, defined in Ch 1, Sec 7, [3.3.1]
- for transversely framed side: $\lambda = \lambda_T$, defined in Ch 1, Sec 7, [3.4.1].

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 8 and the minimum values in the table.

The value of the side frame section modulus is generally to be maintained for the full extension of the side frame.

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 frames 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 frames 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 cm^2, and the net inertia J_B, in cm^4, 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 9 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 1, Sec 9.

Table 9 : Scantling of deck plating and ordinary stiffeners

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = 14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	Net minimum thickness, in mm**(1)**: $t = 2{,}1 + 0{,}013\ L\ k^{1/2} + 4{,}5\ s$
Ordinary stiffeners	Net section modulus, in cm^3: $w = \gamma_R \gamma_m \beta_b \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{m(R_y - \gamma_R \gamma_m \sigma_{X1})}\left(1 - \dfrac{s}{2\ell}\right) s \ell^2 10^3$ Net shear sectional area, in cm^2: $A_{Sh} = 10 \gamma_R \gamma_m \beta_s \dfrac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y}\left(1 - \dfrac{s}{2\ell}\right) s \ell$	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 net thickness of the attached plating.

(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 1, Sec 8, [3.3.5], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength

λ : Coefficient taken equal to:
- for longitudinally framed deck: $\lambda = \lambda_L$, defined in Ch 1, Sec 7, [3.3.1]
- for transversely framed deck: $\lambda = \lambda_T$, defined in Ch 1, Sec 7, [3.4.1]
- for deck not contributing to the hull girder longitudinal strength: $\lambda = 1$

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:

$$A = 10\gamma_R\gamma_m\frac{\gamma_{S2}p_S+\gamma_{W2}p_W}{C_PR_y}d_Sh_S$$

where:

p_S, p_W : Still water pressure and wave pressure, defined in Ch 1, Sec 5, 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:

$$C_P = 1 \quad \text{for} \quad \frac{d_P}{r_P} \le 70$$

$$C_P = 1{,}7 - 0{,}01\frac{d_P}{r_P} \quad \text{for} \quad 70 < \frac{d_P}{r_P} \le 140$$

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.

2.10 Central longitudinal bulkhead

2.10.1 General

Except for dry peaks, a centreline longitudinal wash bulkhead may be required in liquid compartments for which there is a risk of resonance in the transverse direction.

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:

$t = 6{,}5 + 0{,}013\ L$

qith L to be taken not greater than 200 m.

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 transverse or side girder.

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 total area of the bulkhead, and, in the zone above, to not less than 10% of the total area of the bulkhead. 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.

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 Horizontal diaphragms

At the fore end of the bulb, the structure is generally to be supported by means of horizontal diaphragms, spaced not more than 1 m apart, and a centreline vertical diaphragm.

2.11.5 Longitudinal stiffeners

Bottom and side longitudinals are to extend inside the bulb, forward of the fore end by at least 30% of the bulb length measured from the perpendicular to the fore end of the bulb.

The fore end of longitudinals is to be located in way of a reinforced transverse ring; forward of such ring, longitudinals are to be replaced by ordinary transverse rings.

2.11.6 Floors

Solid floors are to be part of reinforced transverse rings generally arranged not more than 3 frame spaces apart.

2.11.7 Breasthooks

Breasthooks, to be placed in line with longitudinals, are to be extended on sides aft of the stem, so as to form longitudinal side girders.

2.11.8 Longitudinal centreline wash bulkhead

For a bulb of considerable width, a longitudinal centreline wash bulkhead may be required by the Society in certain cases.

2.11.9 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.

3 Reinforcements of the flat bottom forward area

3.1 General

3.1.1 The flat bottom forward area is to be assessed for both transit and site conditions.

Alternative method may be accepted on a case-by-case basis.

3.2 Area to be reinforced

3.2.1 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 extends:

- longitudinally, over the bottom located between ξ L and 0,05 L 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, in mm, from the base line, not less than 2 L. In any case, it is not necessary that such height be greater than 300 mm.

3.3 Conditions of impact

3.3.1 The bottom dynamic impact pressure is to be considered if:

$T_F < \min(0,04\ L;\ 8,6)$

where:

T_F : Minimum forward draught, in m, among those foreseen in operation

The value of T_F adopted for the calculations is to be specified in the loading manual.

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's length.

3.4 Bottom impact pressure

3.4.1 The bottom impact pressure p_{BI} is to be obtained, in kN/m², from the following formula:

$p_{BI} = 62\ C_1\ C_{SL}\ L^{0,6}$ if $L \le 135$

$p_{BI} = (1510 - 2,5\ L)\ C_1\ C_{SL}$ if $L > 135$

where:

$$C_1 = \frac{119 - 2300\frac{T_F}{L}}{78 + 1800\frac{T_F}{L}}$$ without being taken greater than 1,0

T_F : Draught defined in [3.3.1]

C_{SL} : Longitudinal distribution factor, taken equal to:

$C_{SL} = 0$ for $x \le x_1$

$C_{SL} = \dfrac{x - x_1}{x_2 - x_1}$ for $x_1 < x < x_2$

$C_{SL} = 1$ for $x \ge x_2$

with:

$$x_1 = \left(0,55 + \frac{L}{2000}\right)L$$

$$x_2 = \left(0,35 + 0,5C_B + \frac{L}{3000}\right)L \quad \text{with } 0,60 \le C_B \le 0,85$$

Note 1: When f_{RWE}, as defined in Ch 1, Sec 5, is greater than 1, bow impact pressure should be considered on a case-by-case basis.

3.5 Scantlings

3.5.1 In addition to the requirements in [2.4.1] and [2.5.1], the net scantlings of plating and net plastic section modulus of the ordinary stiffeners of the flat bottom forward area, defined in [3.2] and [3.3], are to be not less than the values obtained from the formulae in Tab 10 taking into account the minimum values given in the same table.

3.5.2 Tapering

Outside the flat bottom forward area, scantlings are to be gradually tapered so as to reach the values required for the areas considered.

3.5.3 Primary supporting members

The scantlings of the primary supporting members are to be checked according to Ch 1, Sec 9, taking into account a pressure of 0,3 p_{BI} over the ship breadth and, in the longitudinal direction, over one floor spacing.

Table 10 : Reinforcements of plating and ordinary stiffeners of the flat bottom forward area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = \frac{15,8\alpha_p s}{C_d}\sqrt{\frac{p_{BI}}{R_{eG}}}$	Net minimum thickness, in mm: $t = (0,03\ L + 5,5)\ k^{1/2}$ where k is the material factor defined in Pt B, Ch 4, Sec 1, [2.2] of the Ship Rules
Ordinary stiffeners	Net plastic section modulus, in cm^3: $Z_{pl} = \frac{p_{BI}}{0,9 x 4(n_s+2)R_{eG}} s\ell^2 10^3$	Net minimum web thickness, in mm, to be not less than the lesser of: • $t = 1,5\ L_2^{1/3}\ k^{1/6}$ where k is the material factor defined in Pt B, Ch 4, Sec 1, [2.2] of the Ship Rules • the net thickness of the attached plating
	Net web thickness sectional area, in mm: $t_w = \frac{\sqrt{3}}{2}\frac{p_{BI}}{(h_w+t_p)R_{eG}} s\ell 10^3$	

3.6 Arrangement of primary supporting members and ordinary stiffeners: longitudinally framed bottom

3.6.1 The requirements in [3.6.2] to [3.6.4] apply to the structures of the flat bottom forward area, defined in [3.2], in addition to the requirements of [2.4].

3.6.2 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.

3.6.3

The spacing of solid floors in a single or double bottom is to be not greater than either:

- that required for the midship section in Ch 1, Sec 3, [10] 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.

3.6.4 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.

3.7 Arrangement of primary supporting members and ordinary stiffeners: transversely framed double bottom

3.7.1 The requirements in [3.7.2] to [3.7.3] apply to the structures of the flat bottom forward area, defined in [3.2], in addition to the requirements of [2.5].

3.7.2 Solid floors are to be fitted:

- at every second frame between 0,75L and 0,8L from the aft end
- at every frame space forward of 0,8L from the aft end.

3.7.3 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.

4 Reinforcements of the bow area

4.1 General

4.1.1 The bow area is to be assessed for both transit and site conditions.

Alternative method may be accepted on a case-by-case basis.

4.2 Area to be reinforced

4.2.1 In addition to the requirements in Article [2], the structures of the bow area are to be able to sustain the dynamic pressures due to the bow impact pressure.

The bow area to be reinforced is the area extending forward of 0,9 L from the aft end and, vertically, above the minimum draught, as defined in Ch 1, Sec 1, [3.2.11].

4.3 Bow impact pressure

4.3.1 The bow impact pressure p_{FI} is to be obtained, in kN/m², from the following formula:

$$p_{FI} = C_S C_L C_Z (0{,}22 + 0{,}15 \tan\alpha)(k_c \sin\beta + 0{,}6\sqrt{L})^2$$

where:

C : Wave parameter, defined in Ch 1, Sec 5

C_L : Coefficient depending on the ship's length:

- $C_L = 0{,}0125\ L$ for $L < 80$ m
- $C_L = 1{,}0$ for $L \geq 80$ m

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_Z : Coefficient depending on the distance between the summer 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 $z < 2\ C + T - 11$

k_c : Parameter to be taken equal to:

- for on-site conditions: $k_c = 4{,}8$
- for transit conditions: $k_c = 0{,}4\ V_S$

V_S : Maximum ahead speed in transit, in knots

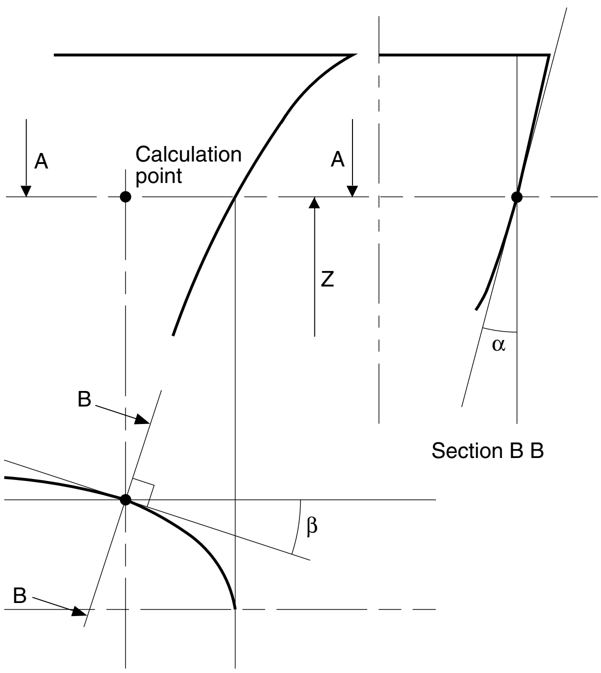
The Society may accept a reduced value for k on a case-by-case basis

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).

Note 1: When f_{RWE}, as defined in Ch 1, Sec 5, is greater than 1, bow impact pressure should be considered on a case-by-case basis.

Figure 1 : Definition of angles α and β



4.4 Scantlings

4.4.1 In addition to the requirements in [2.6.1] and [2.7.1], the net scantlings of plating and ordinary stiffeners of the bow area, defined in [4.2], are to be not less than the values obtained from the formulae in Tab 11 and the minimum values given in the same table.

Table 11 : Reinforcements of plating and ordinary stiffeners of the bow area

Element	Formula	Minimum value
Plating	Net thickness, in mm: $t = \frac{15,8\alpha_p s}{C_d}\sqrt{\frac{p_{FI}}{R_{eG}}}$	Net minimum thickness, in mm: $t = (0,03\ L + 5,5)\ k^{1/2}$ where k is the material factor defined in Pt B, Ch 4, Sec 1, [2.2] of the Ship Rules
Ordinary stiffeners	Net plastic section modulus, in cm³: $Z_{pl} = \frac{p_{FI}}{0,9 x 4(n_s+2)R_{eG}} s\ell^2 10^3$	Net minimum web thickness, in mm, to be not less than the lesser of: • $t = 1,5\ L_2^{1/3}\ k^{1/6}$ where k is the material factor defined in Pt B, Ch 4, Sec 1, [2.2] of the Ship Rules • the net thickness of the attached plating
	Net web thickness sectional area, in mm: $t_w = \frac{\sqrt{3}}{2}\frac{p_{FI}}{(h_w+t_p)R_{eG}} s\ell 10^3$	

4.4.2 Tapering

Outside the bow 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

Primary supporting members are generally to be verified through direct calculations carried out according to Ch 1, Sec 9 considering the bow impact pressures defined in [4.3].

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 1, Sec 3, [7.1] 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's 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 expanded width of the stem is not to be less than the rule breadth of the plate keel, defined in Ch 1, Sec 3, [10.1.3].

5.2.3 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.

5.2.4 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 not less than 0,05 or 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 Pt B, Ch 13, Sec 3, [5.6] of the Ship Rules.

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 that 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 12 Aft Part

Symbols

a_{Z1} : Reference value of the vertical acceleration, defined in Ch 1, Sec 5, [3.6]

B : Moulded breadth, in m, taken equal to the greatest moulded breadth measured amidships at the maximum draught T

g : Gravity acceleration, in m/s^2, taken equal to 9,81

h_1 : Reference value of the ship relative motion defined in Ch 1, Sec 5, [3.5]

k : Material factor as defined in Pt B, Ch 4, Sec 1, [2.2] of the Ships Rules

ℓ : Span, in m, of ordinary stiffeners

L : Rule length, in m, as defined in Ch 1, Sec 1, [3.2.6]

L_2 : L, but to be taken not greater than 120 m

p_S, p_W : Still water pressure and wave pressure defined in [2.3]

R_y : Minimum yield stress, in N/mm^2, of the material, to be taken equal to:

$R_y = 235/k$, unless otherwise specified

s : Spacing, in m, of ordinary stiffeners

T : Maximum draught, in m, as defined in:

- Ch 1, Sec 1, [3.2.11] for site condition
- Ch 1, Sec 1, [3.2.12] for transit condition

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 1, [3.3]

β_b, β_s : Coefficients defined in Ch 1, Sec 8, [3.4.2]

Δ : Moulded displacement, in tonnes, at draught T, in sea water (density ρ = 1,025 t/m^3)

ρ : Sea water density, in t/m^3, to taken equal to 1,025

ρ_L : Density, in t/m^3, of the liquid cargo.

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, if any.

1.1.2 The aft part of the unit is defined in Ch 1, Sec 1, [3.2.8].

The aft part may differ in site and transit conditions.

1.1.3 Aft peak structures which form vertical watertight boundary between two compartments 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 Ch 1, Sec 7 to Ch 1, Sec 9.

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 1, Sec 3, [7.1], 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 1, Sec 3, [7.2].

2 Aft peak

2.1 Partial safety factors

2.1.1 The partial safety factors to be considered for checking aft peak structures are specified in:

- Ch 1, Sec 7, Tab 1 for plating
- Ch 1, Sec 8, Tab 1 for stiffeners
- Ch 1, Sec 9, Tab 4 for primary supporting members.

2.1.2 Finite element analysis

When a finite element analysis, as defined in Ch 1, Sec 9, [3.5], is performed in order to verify the scantlings of the aft peak structure, the hull girder loads do not need to be considered.

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 1
- the still water internal pressure due to liquids or ballast, defined in Tab 3
- the still water internal pressure due to dry uniform cargoes on deck, defined in Tab 4.

Wave pressure (p_W) includes:

- the wave pressure, defined in Tab 1
- the inertial internal pressure due to liquids or ballast, defined in Tab 3
- the still water internal pressure due to dry uniform cargoes on deck, defined in Tab 4.

Table 1 : 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)**	$17{,}5\, n\, \varphi_1\, \varphi_2$

(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. 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 2

φ_2 : Coefficient taken equal to:

- if $L \ge 120$ m: $\varphi_2 = 1$
- if $L < 120$ m: $\varphi_2 = L/120$

Table 2 : Coefficient for pressure on exposed decks

Exposed deck location	φ_1
Freeboard deck	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 : 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 4 : Still water and inertial internal pressures due to dry uniform cargoes

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.	$p_S \frac{a_{Z1}}{g}$

2.3.2 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.

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.

2.3.4 Lateral pressure in testing conditions

The lateral pressure in testing conditions, p_T , in kN/m², is taken equal to:

- $p_T = p_{ST} - p_S$ for bottom shell plating and side shell plating
- $p_T = p_{ST}$ otherwise

where:

p_{ST} : Still water pressure defined in Ch 1, Sec 5, [6.7]

p_S : Still water sea pressure defined in Ch 1, Sec 5 and calculated 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 1, Sec 7, [3.2.2].

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, if any, 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 5 for plating
- Tab 6 for ordinary stiffeners

and not less than the minimum values in the same tables.

Table 5 : Net thickness of plating

Plating location	Net thickness, in mm	Net minimum thickness, in mm**(1)**
Bottom and side	$14{,}9 c_a c_r s \sqrt{\gamma_R \gamma_m \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{\lambda R_y}}$	$c_F (0{,}03\ L + 5{,}5)\ k^{1/2} - c_E$
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.

Note 1:

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_E : Coefficient to be taken equal to:

$c_E = 1$ for $L \leq 65$ m

$c_E = 3 - L/30$ for $65\ m < L < 90$ m

$c_E = 0$ for $L \geq 90$ m

c_F : Coefficient:

$c_F = 0{,}8$ for poop sides

$c_F = 1{,}0$ in other cases

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 of the panel, in m

λ : Coefficient taken equal to:

- for longitudinally framed plating: $\lambda = \lambda_L$, defined in Ch 1, Sec 7, [3.3.1]
- for transversely framed plating: $\lambda = \lambda_T$, defined in Ch 1, Sec 7, [3.4.1]
- for plating not contributing to the hull girder longitudinal strength: $\lambda = 1$

Table 6 : 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 net minimum 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:

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

z_M : Z co-ordinate, in m, of the stiffener mid-span

z_{TOP} : Z co-ordinate, in m, of the highest point of the peak tank

σ_{X1} : Hull girder normal stress, taken equal to:
- the value defined in Ch 1, Sec 8, [3.3.5], for stiffeners contributing to the hull girder longitudinal strength
- $\sigma_{X1} = 0$, for stiffeners not contributing to the hull girder longitudinal strength.

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 cm³, and the net shear sectional area A_{SH}, in cm², of side transverses are to be not less than the values obtained from the following formulae:

$$w = \gamma_R \gamma_m \lambda_b \beta_b \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{8 R_y} s \ell^2 10^3$$

$$A_{Sh} = 10 \gamma_R \gamma_m \lambda_s \beta_s \frac{\gamma_{S2} p_S + \gamma_{W2} p_W}{R_y} s \ell$$

λ_b, λ_s : Coefficients defined in Ch 1, Sec 8, [3.4.3].

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 1, Sec 9, considering the loads in [2.3].

4 Reinforcements of the bottom and aft areas

4.1 Spread mooring

4.1.1 In case of spread mooring, the Society may request reinforcements according to Ch 1, Sec 11, [3] and Ch 1, Sec 11, [4] for the aft part.

4.2 Turret mooring

4.2.1 In case of turret mooring system, the aft part does not need to be assessed according to Ch 1, Sec 11, [3] and Ch 1, Sec 11, [4].

4.3 Connection of after peak structures with the rudder horn

4.3.1 The connection of after peak structures with the rudder horn, if any, is to be in accordance with Pt B, Ch 11, Sec 3, [3] of the Ship Rules.

4.4 Sternframes

4.4.1 The arrangement, scantlings and connection to the hull structure of the sternframes is to be in accordance with Pt B, Ch 11, Sec 3, [4] of the Ship Rules.

Section 13 Superstructures and Deckhouses

Symbols

B : Moulded breadth, in m, taken equal to the greatest moulded breadth measured amidships at the maximum draught T

C_B : Total block coefficient, equal to:

$$C_B = \frac{\Delta}{1{,}025\,LBT}$$

C_B not to be taken greater than 1

k : Material factor, defined in:

- Pt B, Ch 4, Sec 1, [2.2] of the Ship Rules, for steel
- Pt B, Ch 4, Sec 1, [4.4] of the Ship Rules, for aluminium alloys

L : Rule length, in m, as defined in Ch 1, Sec 1, [3.2.6]

t_C : Corrosion addition, in mm, defined in Ch 1, Sec 3, [8]

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 1, [3.3]

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.

1.1.2 The requirements of this Section comply with the applicable regulations of the 1966 International Convention on Load Lines, as amended, with regard to the strength of enclosed superstructures.

1.2 Net scantlings

1.2.1 As specified in Ch 1, Sec 3, [7], 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 1, Sec 3, [8].

1.3 Definitions

1.3.1 Superstructures

A superstructure is a decked structure on the freeboard deck 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.

1.3.2 Deckhouses

A deckhouse is a decked structure on the freeboard or superstructure deck which does not comply with the definition of a superstructure.

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 a 3-frame spacing.

1.4.5 When the superstructures are not directly located on the freeboard deck but supported by pillars, a global strength calculation of the structure supporting the superstructures is to be submitted according to methods, standards or codes recognised by the Society.

The lateral pressures on the superstructures are to be calculated as defined in Article [2], considering that:

- when the height of the supporting pillars is equivalent to a standard superstructure height, the lowest tier of the superstructure is to be considered as a second tier of superstructure
- when the height of the supporting pillars is equivalent to two standard superstructure heights, the lowest tier of the superstructure is to be considered as a third tier of superstructure, and so on.

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 1, Sec 6, [2].

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.

Unless otherwise permitted by the Society, doors open outwards to provide additional security against the impact of the sea.

1.5.5 Strengthening of deckhouses in way of lifeboats and rescue boats

Sides of deckhouses are to be strengthened in way of lifeboats and rescue boats and the top plating is to be reinforced in way of their lifting appliances.

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 Side bulkheads of superstructures

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 Ch 1, Sec 5, [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 1, Sec 5, [6.3], is also to be considered.

2.2 Side and end bulkheads of deckhouses and end bulkheads of superstructures

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 front, side and aft bulkheads of deckhouses and of front and aft bulkheads of superstructures is to be obtained, in kN/m², from the following formula:

$p = 10\ n\ a\ c\ [b\ f - (z - T)]$

without being less than p_{min}

where:

a : Coefficient defined in Tab 1

b : Coefficient defined in Tab 2

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 the superstructure or deckhouse, in m, at the position considered, to be taken not less than 0,25 B_1

B_1 : Actual maximum breadth of unit on the exposed weather deck, in m, at the position considered

f : Coefficient defined in Tab 3

n : Navigation coefficient, defined in Ch 1, Sec 5, [3.2.5]

p_{min} : Minimum lateral pressure defined in Tab 4.

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
	Four 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
	Four 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 **(1)**	Lowest, second and third tiers	$0,5 + \frac{L}{150}$	2,5
	Four 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 ≤ 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	$0,5 + \frac{L}{1000} - 0,4\frac{x}{L}$	$0,8 - 0,4\frac{x}{L}$
(1) Applicable only to side bulkheads of deckhouses			

Table 2 : Lateral pressure for superstructures and deckhouses - Coefficient b

Location of bluckhead **(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 subdivided into parts of approximatively equal length, not exceeding 0,15L each, and x is to be taken as the co-ordinate of the center 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 pressure for superstructures and deckhouses

Location and type of bulkhead			P_{min}, in kN/m^2
Lowest tier of unprotected fronts			$30 \le 25,0 + 0,10\,L \le 50$
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 1, Sec 5, [3.4.5] or taken equal to 0,35 for unit less than 65 m in length

h_w : Wave parameter, in m, defined in Ch 1, Sec 5

2.3 Decks

2.3.1 The lateral pressure for the determination of deck scantlings is constituted by the still water internal pressure (p_S) and the inertial pressure (p_W), defined in Ch 1, Sec 5, [6.5].

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 1, Sec 5, [6.3], is also to be considered.

3 Plating

3.1 Front, side and aft bulkheads

3.1.1 Plating of side bulkheads of superstructures

The net thickness of plating of side bulkheads of superstructures is to be determined in accordance with the applicable requirements of Ch 1, Sec 7, considering the lateral pressure defined in [2.1.2].

3.1.2 Plating of side and end bulkheads of deckhouses and of end bulkheads of superstructures

The net thickness of plating of side and end bulkheads of deckhouses and of end bulkheads of superstructures is to be not less than the value obtained, in mm, from the following formula:

$$t = 0,95\,s\sqrt{kp} - t_c$$

where:

p : Lateral pressure, in kN/m^2, defined in [2.2.2].

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.

This net thickness is to be not less than:

- the values given in Tab 5 for steel superstructures,
- the following values for aluminium superstructures:
  - 4 mm for rolled products
  - 2,5 mm for extruded products.

Table 5 : Minimum thicknesses of superstructures and deckhouses

Location	Minimum thickness, in mm
Lowest tier **(1)**	$(5 + 0{,}01\ L)\ k^{1/2} - t_c$
Second tier and above **(2)**	$(4 + 0{,}01\ L)\ k^{1/2} - t_c$
(1) L is to be taken not greater than 300 m **(2)** L is to be taken not less than 100 m and not greater than 300 m.	

3.2 Decks

3.2.1 The net thickness of deck plating is to be determined in accordance with the applicable requirements of Ch 1, Sec 7.

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 General

The net scantlings of ordinary stiffeners are to be determined according to:

- [4.1.2] for single span vertical ordinary stiffeners of deckhouses side and end bulkheads and of superstructures end bulkheads
- Ch 1, Sec 8 for all the other cases.

4.1.2 Ordinary stiffeners of side and end bulkheads of deckhouses and of end bulkheads of superstructures

The net section modulus of ordinary stiffeners of side and end bulkheads of deckhouses and of end bulkheads of superstructures is to be not less than the value obtained, in cm3, 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]

s : Spacing, in m, of ordinary stiffeners

α , β : Parameters defined in Tab 6

φ : Coefficient depending on the stiffener end connections, and taken equal to:

- 1 for lower tier stiffeners
- value defined in Tab 7 for stiffeners of upper tiers.

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.

Table 6 : Coefficient α and β

Type of ordinary stiffeners	α	β
Flat bars	0,035	2,8
Flanged profiles	0,060	14,0
Bulb profiles: $w_G \leq 200\ cm^3$ $w_G > 200\ cm^3$	 0,070 0,035	 0,4 7,4

Table 7 : Coefficient φ for end connections of stiffeners of supertructures et deckhouses

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

4.2 Decks

4.2.1 The net scantlings of deck ordinary stiffeners are to be determined in accordance with the applicable requirements of Ch 1, Sec 8.

5 Primary supporting members

5.1 Front, side and aft bulkheads

5.1.1 Primary supporting members of side bulkheads of superstructures

The net scantlings of primary supporting members of side bulkheads of superstructures are to be determined in accordance with the applicable requirements of Ch 1, Sec 9.

5.1.2 Primary supporting members of side and end bulkheads of deckhouses and of end bulkheads of supertructures

The net scantlings of primary supporting members of side and end bulkheads of deckhouses and of end bulkheads of superstructures are to be determined in accordance with the applicable requirements of Ch 1, Sec 9, using the lateral pressure defined in [2.2].

5.2 Decks

5.2.1 The net scantlings of deck primary supporting members are to be determined in accordance with the applicable requirements of Ch 1, Sec 9.

Section 14 Other Structures

1 Station keeping

1.1 General

1.1.1 Scope of Classification

The process of the Classification takes place in a procedure defining the interface between the work carried out by the mooring contractor and the one carried out by the shipyard.

The tasks to be carried out by the mooring contractor are detailed in Rule Note NR493 Classification of Mooring Systems for Permanent Offshore Units.

The present Article [1] covers only the part concerning the hull.

1.1.2 Documents to be submitted

The following documents are to be submitted by the mooring designer:

a) specification of Design Limit Operational Conditions (DLOC) (for reference)
b) report of model test
c) mooring calculation
d) design load report (mooring loads
e) design load report (loads on hull)
f) specification of explosion pressure
g) report of hydrodynamic analysis. This report includes loads induced by mooring, including dynamic effect on the buoy in the most severe conditions, and load distribution for fatigue assessment.

Note 1: For items b) to f), information is to be reviewed for the purpose of verification of the mooring interface load only.

1.2 Turret mooring system

1.2.1 General

The supporting structure of the turret is included in the scope of Classification and is part of the hull structure.

The structure supporting the turret mooring system is to be able to withstand the forces generated by the mooring.

1.2.2 Location of the turret mooring system

The turret mooring system may be:

- External

  In this case, the turret may be located aft of the stern or forward of the bow.
- Internal

  In this case, the turret may be located all along the hull, inside the cargo tank area or not.

1.2.3 Longitudinal strength

The longitudinal strength of the hull girder at the location of the turret is to be checked according to Ch 1, Sec 6.

1.2.4 Calculation of the structure supporting the turret

A calculation using finite element method is to be carried out in order to verify the strength of the structure. If the turret is located:

- forward of the bow, externally of the structure:

  A local model is to be made.
- within the forward structure, forward of the cargo tank area:

  As a rule, the structure is to be modelled from the bow to the aft end of the cargo tank No.1. The model may be clamped in way of the transverse bulkhead located at the aft end of the cargo tank No.1.

Note 1: For this calculation, there is no need of model balancing, but the masses are to be modelled as accurately as possible.

- within the cargo tank area:

  As a rule, the model should include the adjacent cargo tanks, forward and aft of the turret area. The model may be clamped at the end of one adjacent cargo tank. The model should be balanced by an adequate procedure (see Ch 1, Sec 9).

1.2.5 Mooring loads

The extreme loads on the structure are to be taken into account for different headings.

As a rule, a heading analysis is mandatory as defined in Ch 1, Sec 4, [5.3.3]. Depending on the heading analysis results, load case d) may be disregarded for yield and buckling checks subject to the Society approval.

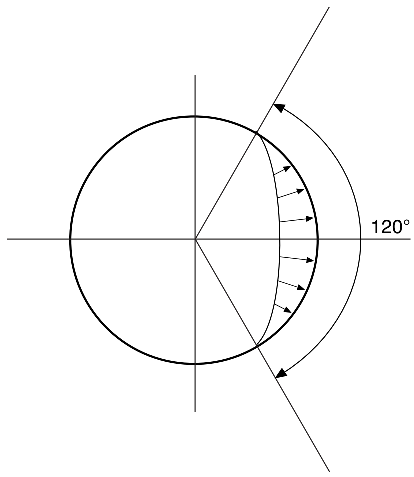
At least three headings are to be taken into account: 0°, 45°, 90° (or maximum heading from hydrodynamic analysis, not less than 60°, with associated mooring forces).

Other headings may be requested by the Society, based on the design of the structure supporting the turret.

The turret is supported in the unit by a system of bearings.

The reaction forces in way of the bearings are to be distributed according to the design load report procedure. If this distribution is not specified, the reaction force is to be distributed according to Fig 1, i.e. over an 120° angle, with a cosine distribution.

Figure 1 : Heading for turret



1.3 Spread mooring system

1.3.1 General

The structure supporting the equipment of the mooring system (as defined in NR493, Classification of Mooring Systems for Permanent Offshore Units) are included in the scope of Classification and are considered as part of the hull structure.

The structure supporting the equipment of the mooring system is to be able to withstand the extreme mooring loads and fatigue forces.

1.3.2 Calculation of the supporting structure

A calculation using the finite element method is to be carried out in order to verify the strength of the structure for the forces submitted by the mooring designer. The extension and balancing of the model is to be agreed by the Society.

1.4 Calculations

1.4.1 Corrosion additions

The structure should be modelled in net scantlings.

The corrosion addition t_c, in mm, for each exposed side of plates is not to be less than 1 mm.

In case of disconnectable system, the corrosion addition in areas of friction, chocks, etc., may be increased at the Society satisfaction.

1.4.2 Load cases

The structural model is to take into account the following loads:

- Mooring loads

  Mooring loads are to be determined in extreme conditions and are to be distributed according to the designer recommendation and to NR493, Appendix 3
- Hull girder loads

  Hull girder loads to be taken into account are those with a probability level of $10^{-8.7}$, if relevant
- Local external loads, if relevant, i.e. sea pressures, liquid pressures (ballast and cargo) with accelerations given in Ch 1, Sec 4, including:
  - upright ship condition
  - inclined ship condition
- Internal loads

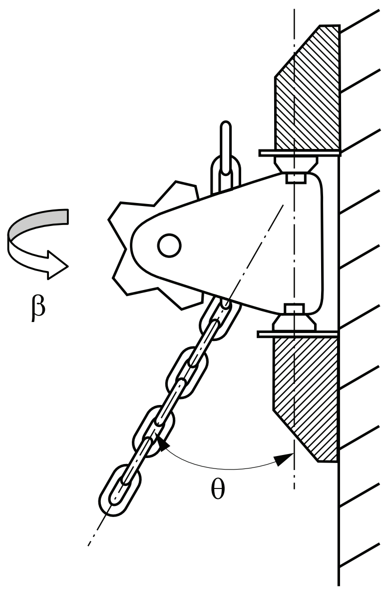
  The calculation is to be carried out for at least the two following draughts:
  - minimum draught
  - maximum draught.

Design loading conditions defined in Tab 1 may be used as a guidance.

Table 1 : Guidance for design loading conditions for mooring system

<table>
<tr><th rowspan="2">Load case</th><th rowspan="2">System condition</th><th colspan="3">Design loads</th><th rowspan="2">Basic allowable stress factor α (3)</th></tr>
<tr><th>Mooring line loads</th><th>Fairlead angles (see Fig 2)</th><th>Environment to be considered</th></tr>
<tr><td>Design / Installation</td><td>Mooring line installation load on fairlead sheave</td><td>One mooring line with installation load (1)
Other mooring lines with pretension</td><td>Installation angles</td><td>1 year return period</td><td>α = 0,8</td></tr>
<tr><td>Design / Intact</td><td>Normal operation</td><td>Design tension on each mooring line</td><td>• Wrap angle range:
θ_{min} : pretension
θ_{max}: to be determined by mooring analysis (default value: 90°)
• Pivot angle range:
β_{min}, β_{max}: according to manufacturer specification (2)</td><td>100 years return period</td><td>α = 0,8</td></tr>
<tr><td>Design / Damaged</td><td>One broken mooring line</td><td>One mooring line broken
Other lines with design tension (mooring analysis with one line broken to be considered)</td><td>• Wrap angle range:
θ_{min} : pretension
θ_{max}: to be determined by mooring analysis (default value: 90°)
• Pivot angle range:
β_{min}, β_{max}: according to manufacturer specification (2)</td><td>100 years return period</td><td>α = 0,8</td></tr>
<tr><td>Accidental</td><td>Minimum Breaking Load (MBL) on one mooring line</td><td>One mooring line with MBL
Adjacent lines with intact design tension</td><td>• Wrap angle range:
θ_{min} : pretension
θ_{max}: to be determined by mooring analysis (default value: 90°)
• Pivot angle range:
β_{min}, β_{max}: according to manufacturer specification (2)</td><td>100 years return period</td><td>α = 1,0</td></tr>
<tr><td colspan="6">(1) The installation design load is defined as the greater of:
• 1,33 times the SWL of the considered equipment
• the brake load of the winch or the holding capacity of the jacking system used for tensioning.
(2) The maximum values of β obtained by mooring analysis may also be used.
(3) As defined in Pt B, Ch 3, Sec 3, [5]. Factor α is given in this Table as an indication of safety level for each design loading condition.
Note 1: For each load case, wave loads are to be combined as follows:
• maximum draft with adjacent empty capacities and load case a+ (hogging equilibrium)
• minimum draft with adjacent fully loaded and load cases a- and b (sagging equilibrium).</td></tr>
</table>

Figure 2 : Wrap (θ) and pivot (β) angle definition



1.4.3 Checking criteria

Allowable stresses are those given in Pt B, Ch 3, Sec 3, [5].

Buckling is to be checked according to Pt B, Ch 3, Sec 3, [6].

For fatigue analysis, the damage ratio is to be not greater than those given in Ch 1, Sec 10, Tab 1.

1.4.4 Materials and testing

For the steel grade selection, the structure supporting the equipment of the mooring system is considered as offshore area (see Ch 1, Sec 3).

2 Supports for hull attachments and appurtenances

2.1 General

2.1.1 The present Article [2] is applicable to all major supports for hull attachments, such as:

- topsides
- risers and their protectors
- flare tower (see [2.1.4])
- lifting appliances (see [2.1.5])
- offloading stations
- helideck
- boat landing platforms / stairtowers.

2.1.2 The structure supporting the attachments is to be able to withstand the forces calculated for static, towing, operation and damage conditions. They are to be calculated by the constructing shipyard or attachment designer.

As a general rule, the affected supporting structure under the deck or inboard the side shell is to be considered as offshore area as defined in Ch 1, Sec 3, [1.1]. The strength assessment is to cover also the ship areas adjacent to the offshore areas as deemed necessary.

Cut outs in local structure in way of hull attachments are to be closed by full collar plates.

2.1.3 As a rule, the forces are to be calculated by the designer in the following four conditions:

- static conditions,with $\alpha = 0,6$
- design conditions, with $\alpha = 0,8$
- transit towing conditions, with $\alpha = 0,8$
- accidental cases, with $\alpha = 1,0$

where:

α : Basic allowable stress factor defined in Pt B, Ch 3, Sec 3, [5].

2.1.4 Flare tower foundation

For flare tower foundation, design loading conditions defined in Tab 2 may be used as a guidance.

2.1.5 Lifting appliances foundations

For lifting appliances foundations, design loading conditions defined in Ship Rules Pt E, Ch 8, Sec 4 are to be considered.

Table 2 : Guidance for design loading conditions for flare tower foundation

Load case	System condition	Environment to be considered	Design loads	Basic allowable stress factors **(1)**
Design	On site intact hull condition	100 year return period	Hull girder loads for each considered loading condition. Local loads including: interface loads, internal and external pressures	$\alpha = 0,8$
Design	Transit	10 year return period		$\alpha = 0,8$
Accidental	On site damaged hull condition giving the maximum trim and heel	1 year return period		$\alpha = 1,0$

(1) As defined in Pt B, Ch 3, Sec 3, [5]. Factor α is given in this Table as an indication of safety level for each design loading condition.

Note 1: In case flare tower foundation is located at short distance from other appurtenance items such as adjacent stools and mooring equipment, the interface effects from these items are to be considered.

2.2 Calculations

2.2.1 Finite element calculation

A three-dimensional finite element model of the support structure is to be submitted. A fine mesh of construction details is required.

The extension of the model is to be agreed by the Society.

2.2.2 Load cases

The model is to take into account:

- the design hull girder still water bending moment
- the wave induced bending moment at relevant probability level and, where relevant, the wave induced global hull shear force, according to Ch 1, Sec 5, [3.3]
- the forces generated by the support structure on the hull.

2.2.3 Checking criteria

Allowable stresses are those given in Pt B, Ch 3, Sec 3, [5].

Buckling is to be checked according to Pt B, Ch 3, Sec 3, [6].

For fatigue analysis, the damage ratio is to be not greater than the values given in Ch 1, Sec 10, Tab 1.

2.2.4 Materials

For the steel grade selection, the top side support seat areas are considered as offshore unit specific area (see Ch 1, Sec 3).

2.2.5 Corrosion additions

The structure is to be modelled in net scantlings.

Corrosion additions, as defined in Ch 1, Sec 3, [8] are to be considered as a minimum.

3 Helicopter deck

3.1 General

3.1.1 Application

The requirements of this Article 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.

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.

3.1.2 Arrangement

The requirements for the arrangement of helidecks are given in Pt B, Ch 3, Sec 4, [4].

3.1.3 Structure

The requirements for the structure of helidecks are given in the present Article.

The scantlings of the structure of an helicopter deck or platform, obtained according to [3.4] to [3.6] are to be considered in addition to scantlings obtained from other applicable loads, in particular from sea pressures.

3.1.4 Net scantlings

As specified in Ch 1, Sec 3, [7], 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 1, Sec 3, [8].

3.2 Design principle

3.2.1 General

Local deck strengthening is to be fitted at the connection of diagonals and pillars supporting platform.

3.2.2 Partial safety factors

The partial safety factors to be considered for checking helicopter decks and platforms structures are specified in Tab 3.

Table 3 : 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	1,10

3.3 Design loads

3.3.1 Emergency landing load

The emergency landing force F_{EL} transmitted through one landing gear or one extremity of skid to the helicopter deck or platform is to be obtained, in kN, from the following formula:

$F_{EL} = 1,25\ g\ W_H$

where:

g : Gravity acceleration, in m/s²: $g = 9,81\ m/s^2$

W_H : Maximum weight of the helicopter, in t.

3.3.2 Garage load

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 are to be obtained, in kN, as specified in Tab 4, 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:

  $M = 0,5\ W_H$

3.3.3 Unprotected area

When helicopters are parked in an unprotected area, sea pressures on deck, as per Ch 1, Sec 5, [5.3.2], are to be considered simultaneously with the loads defined in [3.3.2].

3.3.4 Specific loads for helicopter platforms

The still water and inertial forces applied to an helicopter platform are to be determined, in kN, as specified in Tab 5.

Table 4 : 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)**		$F_S = M\ g$	
Upright (positive heave motion) **(1)**	"a"	No inertial force	
	"b"	$F_{W,Z} = \alpha\ M\ a_{Z1}$	in z direction
Inclined (negative roll angle) **(1)**	"c"	$F_{W,Y} = M\ C_{FA}\ a_{Y2}$	in y direction
	"d"	$F_{W,Z} = \alpha\ M\ C_{FA}\ a_{Z2}$	in z direction

(1) This condition defines the force, applied by one landing gear or landing skid, to be considered for the determination of scantlings of plating, ordinary stiffeners and primary supporting members, where:

α : Coefficient taken equal to 0,5

a_{X1}, a_{Z1}, a_{Z1}: Reference values of the accelerations in the upright ship condition, defined in Sec 5, [3.6]

a_{X2}, a_{Y2}, a_{Z2}: Reference values of the accelerations in the inclined ship condition, defined in Sec 5, [3.6]

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"

Table 5 : 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"	$F_{W,X} = (W_H + W_P)\ a_{X1} + 1,2\ A_{HX}$ $F_{W,Z} = (W_H + W_P)\ a_{Z1}$	in x direction in z direction
Inclined condition (negative roll angle)	"c"	$F_{W,Y} = C_{FA}\ (W_H + W_P)\ a_{Y2} + 1,2\ A_{HY}$	in y direction
	"d"	$F_{W,Z} = C_{FA}\ (W_H + W_P)\ a_{Z2}$	in z direction

Note 1:

A_H : Area, in m², of the entire landing area

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 $A_H/3$

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: $W_p = 0,2\ A_H$

3.4 Plating

3.4.1 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 [3.3.1]
- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the garage load, as defined in [3.3.2] and [3.3.3], if applicable.

3.4.2 Net thickness of plating

The net thickness of an helicopter deck or platform subjected to forces defined in [3.4.1] is not to be 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 or skid print area, in m^2.

For helicopter with skids in emergency landing case, only the extremity of skid of 0,3 m x 0,01 m is to be considered.

For other cases, where the print area A_T is not specified by the Designer, the following values are to be taken into account:

- for one tyre: 0,3 m x 0,3 m
- for one skid: 1 m x 0,01 m

ℓ : Length, in m, of the longer side of the plate panel

s : Length, in m, of the shorter side 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

λ : For longitudinally framed plating:

$\lambda = \lambda_L$ as defined in Ch 1, Sec 11, [3.4.1]

For transversely framed plating:

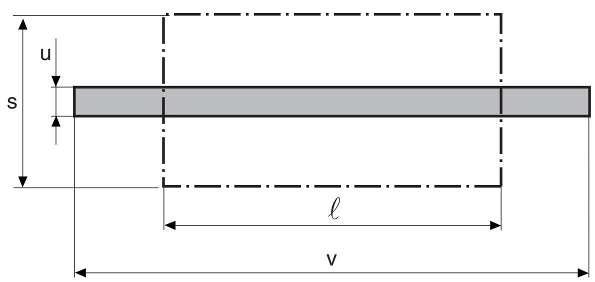
$\lambda = \lambda_T$ as defined in Ch 1, Sec 7, [3.4.1]

and taken equal to 1 in the particular case of a platform.

3.4.3 Helicopter with skids

For helicopters with skids, in the particular case where $v > \ell$, v being equal to the skid length, the skid print outside of the plate panel is to be disregarded. The load and the print area to be considered are to be reduced accordingly. (see Fig 3).

Figure 3 : Skid print with $v > \ell$



3.5 Ordinary stiffeners

3.5.1 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 [3.3.1]
- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$

  where F_s and $F_{w,z}$ are the forces corresponding to the garage load, as defined in [3.3.2] and [3.3.3], if applicable
- $P_0 = \gamma_{s2} F_s + \gamma_{w2} F_{w,z}$

  for an helicopter platform, where F_s and $F_{w,z}$ are the forces defined in [3.3.4].

3.5.2 Normal and shear stresses

The normal stress σ and the shear stress τ induced by forces defined in [3.5.1] in an ordinary stiffener of an helicopter deck or platform are to be obtained, in N/mm², according to:

$$\sigma = \frac{P_0 \ell}{mW} 10^3 + \sigma_{X1,Wh}$$

$$\tau = \frac{10 P_0}{A_{Sh}}$$

where:

m : Coefficient to be taken equal to:
- m = 6, in the case of an helicopter with wheels
- m = 10, in the case of an helicopter with landing skids.

In addition, in both cases of helicopter with wheels and helicopter with landing skids, the hull girder stresses $\sigma_{X1,Wh}$ are to be taken equal to 0 in the particular case of an helicopter platform.

3.5.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [3.5.2] are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0{,}5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

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 equal to:
- γ_R = 1,02 for garage load
- γ_R = 1,00 for emergency landing load.

3.6 Primary supporting members

3.6.1 Load model

The following loads are to be considered independently:

- emergency landing load, as defined in [3.3.1]
- garage load, as defined in [3.3.2] and [3.3.3], if applicable
- for an helicopter platform, specifics loads as defined in [3.3.4].

The most unfavorable case, i.e. where the maximum number of landing gears is located on the same primary supporting members, is to be considered.

3.6.2 Normal and shear stresses

In both cases of helicopter with wheels and helicopter with landing skids, the normal stress σ and the shear stress τ induced by loads defined in [3.6.1] in a primary supporting member of an helicopter deck or platform are to be obtained as follows:

- for analyses based on finite element models:

  $\sigma = \max(\sigma_1, \sigma_2)$ and $\tau = \tau_{12}$

  where σ_1, σ_2 and τ_{12} are to be obtained according to Ch 1, Sec 9, [6.2]

- for analyses based on beam models:
  $\sigma = \sigma_1$ and $\tau = \tau_{12}$
  where σ_1 and τ_{12} are to be obtained according to Pt B, Ch 7, App 1, [5.2] of the Ship Rules.

In addition, the hull girder stresses are to be taken equal to 0 in the particular case of an helicopter platform.

3.6.3 Checking criteria

It is to be checked that the normal stress σ and the shear stress τ calculated according to [3.6.2] are in compliance with the following formulae:

$$\frac{R_y}{\gamma_R \gamma_m} \geq \sigma$$

$$0,5 \frac{R_y}{\gamma_R \gamma_m} \geq \tau$$

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 equal to:
- γ_R = 1,02 for garage load
- γ_R = 1,00 for emergency landing load.

4 Hull outfitting

4.1 Bulwarks and guard rails

4.1.1 Bulwarks and guard rails are to comply with the requirements of Pt B, Ch 12, Sec 2 of the Ship Rules.

4.1.2 In case of large bulwarks, a direct calculation (including fatigue calculations) may be requested by the Society.

4.2 Towing foundation

4.2.1 The towing foundation is to be in accordance with Pt B, Ch 2, Sec 3, [4.2] and Pt B, Ch 3, Sec 3, [5.4].

5 Launching appliances

5.1 Deck ordinary stiffeners in way of launching appliances used for survival craft or rescue boat

5.1.1 Deck structure in way of such appliances is to be considered as ship area and is to fulfil the requirements of:
- Ch 1, Sec 8, [2.4] for ordinary stiffeners
- Ch 1, Sec 9, [2.3] for primary supporting members.

Section 15 Local Structural Improvements

1 Protection of hull metallic structures

1.1 General

1.1.1 Protection system

It is the responsibility of the party applying for classification to choose the system that will perform the protection of the structure against corrosion.

A protection system is composed of using one or a combination of the following methods:

- application of protective coatings
- cathodic protection
- selection of material.

It is also the responsibility of the party applying for classification to have the system applied in accordance with the manufacturer's requirements.

1.1.2 Protection methods

The protection methods, the design of corrosion protection systems is to be in accordance with the requirements of Part B, Chapter 3.

1.2 Plan for the corrosion

1.2.1 An overall plan for the corrosion protection of the structure is to be prepared and submitted to the Society, in accordance with the provisions of Part B, Chapter 3.

The plan for the corrosion is to cover the following areas of the structure:

- all external areas (submerged, splash zone,...)
- internal areas (ballast, storage tanks,...).

The plan for the corrosion is to take into account:

- the intended duration of operations and conditions of maintenance
- the particular conditions in each area.

In case of a converted unit the plan for the corrosion is also to take into account the initial conditions of structure (unless renewed during conversion work).

1.3 Thickness increments

1.3.1 Thickness increments are to be in accordance with the requirements of Ch 1, Sec 3, [8.2].

2 Post welding treatment

2.1 Scope

2.1.1 General

In normal design and building conditions, post welding treatments are not applied.

The decisions to apply a post welding treatment may be required for specific hot spots, on a case-by-case basis, where the damage ratio is closed to the limit and in case of repair.

2.1.2 Conditions of application

Full penetration welding is to be adopted. Post welding treatment of partial penetrations is not accepted.

The post welding treatment procedure is to be performed according to a recognized standard and approved by the Society.

2.1.3 Mechanical post welding treatment

The following mechanical post welding treatments are accepted:

- grinding
- shot peening
- needle peening
- ultrasonic peening.

In principle, hammer peening is not accepted.

2.1.4 Thermal post welding treatment

The following thermal post welding treatments are accepted:

- TIG refusion
- plasma refusion.

2.2 Grinding of welds for fatigue life improvement

2.2.1 General

The purpose of grinding is to smoothly blend the transition between the plate and the weld face.

Grinding is generally to be burr grinding. However other techniques of grinding may be considered by the Society on a case by case basis.

2.2.2 Grinding practice

The burr radius r is generally to be taken greater than 0,6 t, where t is the plate thickness at the weld toe being ground.

In general, grinding must extend to a depth below any visible undercut. However, the grinding depth d, in mm, is to be not greater than:

- $d = 1$ mm for $t \geq 14$
- $d = 0{,}07\,t$ for $10 \leq t < 14$

where t is the plate thickness, in mm, at the weld toe being ground.

For plate thickness less than 10 mm, grinding is generally not allowed.

After grinding, the weld is to be inspected by the yard quality control in order to check that the finished ground surface is as smooth as possible, with no visible evidence of the original weld toe or undercut or any grinding marks at right angles to the weld toe line. In addition, the Society may require measurements of the remaining thickness in way of the ground weld.

2.2.3 Grinding procedure

The grinding procedure required in Ch 1, Sec 10, [4.3.3] is to specify the following items:

- weld preparation
- grinding tool used
- position of the tool over the weld toe
- location of weld toe on which grinding is applied
- extent of grinding at the ends of attachments
- final weld profile
- final examination technique, including NDE.

2.3 Fatigue resistance assessment

2.3.1 General

These treatments improve the weld toe and the residual stresses leading to an increase of the S-N curve class.

The post weld S-N curve may have a different slope than the as welded S-N curve.

2.3.2 Assessment

The fatigue lifetime of the treated details is to be assessed taking into account the modified S-N curves. The used S-N curves are to be duly justified, by fatigue tests or by a recognized standard.

2.3.3 Experimental S-N curves

When tests are considered to determine the S-N curve, the test program has to be approved by the Society.

Attention is to be paid to the necessary number of samples, and the distribution of the results along the stress range axis to allow a correct determination of the S-N curve slope and standard deviation.

To be homogeneous with the Rules for as welded joints, the design curve will correspond to a curve, at minus 2 standard deviations, and taking into account confidence intervals of the calculated mean and standard deviation.

3 Accidental loads

3.1 Analysis

3.1.1 A risk analysis should be performed to assess the risk of explosion, collision and dropped objects.

3.1.2 As a rule, when finite element analysis are performed, the structural model for the calculations is to be built on net scantlings, as defined in Ch 1, Sec 3, [7].

3.2 Protection to explosions

3.2.1 The verification of the hull structures with respect to explosions are to comply with requirements defined in Pt B, Ch 3, Sec 9, [2].

3.3 Collision

3.3.1 The verification of the hull structures with respect to collision are to comply with requirements defined in Pt B, Ch 3, Sec 9, [3] as applicable for minor or major collisions.

3.4 Dropped objects

3.4.1 The verification of the hull structures with respect to dropped objects are to comply with requirements defined in Pt B, Ch 3, Sec 9, [4].

Section 16 Access, Openings, Ventilation and Venting of Spaces in the Storage Area

1 Access, openings and ventilation

1.1 General

1.1.1 Unless otherwise specified in the present Chapter, access to cofferdams, ballast tanks, cargo tanks, and other compartments in the storage area is to be direct from the open deck and such as to ensure their complete inspection. Openings for cargo tank sounding, washing, ventilation, etc., are to be located above the open deck.

1.1.2 Provisions are to be made to ensure efficient ventilation of each of these spaces. Unless otherwise specified in the present Chapter, portable means are permitted for that purpose. Ventilation fans are to be fitted according to [1.3.7].

1.1.3 The requirement of SOLAS Regulation II-1/3-6 is not necessary to be complied with except if the unit is subject to Enhanced Survey Program as specified in IMO Resolution A.744(18) as amended.

1.2 Arrangement of cargo pump rooms

1.2.1 Cargo pump rooms are to be so arranged as to permit free access to all cargo handling valves and facilitate the hoisting of an injured person from the bottom of the space.

1.2.2 Main ladders are not to be fitted vertically, unless justified otherwise by the size of the cargo pump room.

Rest platforms are to be provided at suitable intervals not more than 10 m in height apart. Ladders are to be fitted with handrails and are to be securely attached to the unit's structure.

1.2.3 Where cargo pumps, ballast pumps and stripping pumps are driven by a machinery which is located outside the cargo pump room, the following arrangement are to be provided:

- drive shafts are to be fitted with flexible couplings or other means suitable to compensate for any misalignment
- the shaft bulkhead or deck penetration is to be fitted with a gas-tight gland of a type approved by the Society. The gland is to be sufficiently lubricated from outside the pump room and so designed as to prevent overheating. The seal parts of the gland are to be of material that cannot initiate sparks
- temperature devices are to be fitted for bulkhead shaft glands, bearings and pump casings.

1.2.4 To discourage personnel from entering the cargo pump room when the ventilation is not in operation, the lightening in the cargo pump room is to be interlocked with ventilation such that ventilation is to be in operation to energize the lightening.

Failure of the ventilation system is not to cause the lightening to go out; emergency lightening, if fitted, is not to be interlocked.

1.2.5 A system for continuous monitoring the concentration of hydrocarbon gases shall be fitted. Sampling points or detector heads shall be located in suitable positions in order that potentially dangerous leakages are readily detected. When the hydrocarbon concentration reaches a preset level, which shall not be higher than 10% of the lower flammable limit, a continuous audible and visual alarm signal shall be automatically effected in the cargo pump room, engine room, cargo control room and in the central control room to alert personnel to the potential hazard.

1.2.6 All cargo pump rooms shall be provided with bilge level monitoring devices with appropriately located alarms.

High liquid level in the bilges is to activate an audible and visual alarm in the cargo control room and in the central control station.

1.3 Ventilation of cargo pump rooms

1.3.1 Cargo pump rooms are to be provided with a suction type mechanical ventilation system. The ventilation of these rooms is to have sufficient capacity to avoid the 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.

1.3.2 Ventilation ducts are to be so arranged as to avoid air pockets. In particular:

a) The ventilation ducts are to be so arranged that their suction is just above the transverse floor plates or bottom longitudinal in the vicinity of bilges.

b) 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 main 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.

c) The foregoing exhaust system is in association with open grating floor plates to allow the free flow of air.

d) 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.

1.3.3 The ventilation ducts are to be led direct to atmosphere at a safe place on open deck, and are not to pass through gas safe spaces, cargo tanks or slop tanks.

1.3.4 Ventilation exhaust ducts are to discharge upwards in locations at least 8 m from any ventilation intake and opening to gas safe spaces.

Ventilation intakes are to be so arranged as to minimise the possibility of recycling hazardous vapours from ventilation discharge openings.

1.3.5 Protection screens of not more than 13 mm square mesh and fire dampers are to be fitted on ventilation duct intakes and outlets.

1.3.6 Ventilation fans are to be capable of being controlled from outside of cargo pump rooms.

1.3.7 Electric motors driving fans are to be placed outside the ventilation ducts. Ventilation fans are to be of non-sparking type (see Pt C, Ch 4, Sec 1, [3.6.9]).

1.4 Ventilation of pump rooms

1.4.1 Pump rooms other than those considered as equivalent to cargo pump rooms in application of Ch 1, Sec 2, [3.3.2] are to be provided with means of access and ventilation systems at the satisfaction of the Society.

1.4.2 Ventilation of pump rooms containing:

- ballast pumps serving spaces adjacent to cargo or slop tanks, and
- oil fuel pumps,

is to comply with [1.3.1], [1.3.3], [1.3.4], and [1.3.7].

1.5 Cargo compartments

1.5.1 Each cargo tank is to be provided with an access hatch with a clear opening at least equivalent to a circle of 600 mm in diameter.

1.5.2 Covers fitted on all cargo tank openings are to be of sturdy construction, and to ensure tightness for liquid hydrocarbon and water.

1.5.3 Access ladders of cargo tanks are not to be fitted vertically, unless justified otherwise by the size of the tanks.

Rest platforms are to be provided at suitable intervals not more than 10 m in height apart. Ladders are to be fitted with handrails and are to be securely attached to the unit's structure.

1.5.4 The dimensions of vertical access openings in wash tank bulkheads are to be sufficient to allow the passage of one person wearing a self-contained air breathing apparatus. The minimum clear opening is not to be less than 600 mm by 800 mm with a height of not more than 600 mm from the bottom shell plating unless gratings or other footholds are provided.

1.5.5 Aluminium is not permitted for the construction of tank covers. The possible use of reinforced fibreglass covers is to be specially examined by the Society.

1.6 Other compartments

1.6.1 Notwithstanding [1.1.1], access to double bottom tanks is permitted from a pump room, a cargo pump room, a cofferdam or a pipe tunnel or even, under reserve of the agreement of the Society, from a segregated ballast tank.

1.6.2 The pipe tunnels are to comply with the following requirements:

- they are not to communicate with the machinery room where the prime movers of the cargo pumps are located
- 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.

Where there is permanent access from a pipe tunnel to the cargo pump room, a watertight door complying with the requirements of Pt B, Ch 1, Sec 4 and in addition with the following:

- the watertight door is to be capable of being manually closed from outside the main cargo pump room entrance
- the watertight door is to be kept closed during normal operations of the unit except when access to the pipe tunnel is required.

Note 1: A warning notice is to be affixed to the door in order to avoid to be left open.

Pipes tunnel are to be suitable ventilated.

1.6.3 Horizontal access openings, hatches or manholes are to be of sufficient size to allow the free passage of one person wearing a self-contained air breathing apparatus. The clear opening, unless otherwise authorised by the Society, is to be at least equivalent to a circle of 600 mm in diameter.

1.6.4 The minimum clear opening for vertical access is not to be less than 600 mm by 800 mm, unless otherwise authorised by the Society.

1.6.5 Unless other additional arrangements (considered satisfactory by the Society), are provided to facilitate their access, the double bottom tanks are to be provided with at least two separate means of access, in compliance with [1.1.1] and [1.6.1].

1.6.6 Notwithstanding [1.1.1], access manholes to spaces at the non-manned end of the unit classed as hazardous areas are permitted from an enclosed gas safe space, provided that their closing means are gastight and that a warning plate is provided in their vicinity to indicate that the opening of the manholes is only permitted after checking that there are no flammable gases inside the compartment in question.

1.7 Deck spills

1.7.1 Means are to be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by providing a permanent continuous coaming of a suitable height extending from side to side. refer to Ch 1, Sec 17, [7.5.5] d).

1.7.2 Where gutter bars are installed on the weather decks of units and are extended aft as far as the aft bulkhead of superstructures for the purpose of containing cargo spills on deck, the free surface effects caused by containment of a cargo spill during operations or of unit’s movements and accelerations (considering applicable environmental conditions for operations) are to be considered with respect to the vessel's available margin of positive initial stability (refer to Ch 1, Sec 2, [2.1.2]).

1.7.3 Where the gutter bars installed are higher than 300 mm, they are to be treated as bulwarks with freeing ports arranged and provided with effective closures for use during 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.

1.7.4 Means are to be provided to drain and collect to a safe location spills on deck.

1.8 Spaces at non-manned end of the unit-air locks

1.8.1 The enclosed spaces located at the non-manned end of the unit, below the forecastle deck, if any, are not considered in general as hazardous areas, provided they are separated by an air lock from hazardous areas on the open deck.

Note 1: Such an agreement is, in general, only permitted for spaces opposite to accommodation block. In case such an agreement is considered for spaces other than the spaces opposite to accommodation block, it is to be specially examined by the Society.

Note 2: attention is drawn to the fact that such an arrangement may not be allowed by certain national regulations.

1.8.2 An air lock is to comprise two steel doors sufficiently gastight spaced at least 1,5 m but not more than 2,5 m apart. The doors are to be of the self-closing type and without any holding back arrangements.

1.8.3 The air lock is to be mechanically ventilated from a gas safe space and maintained at an overpressure of 0,25 mbar minimum compared to the hazardous area on the open weather deck in accordance with the general provisions of Pt C, Ch 4, Sec 3, [5], and at a lower pressure than that maintained in the protected space which is itself to be ventilated by a mechanical ventilation system with an air renewal rate at least 12 changes per hour.

1.8.4 If the spaces opposite to accommodation block, protected by the same air lock, include several rooms, some of the rooms need not be mechanically ventilated if they are separated from the air lock by a mechanically ventilated space and by a self-closing sufficiently gastight steel door.

1.8.5 The air lock may have more than two doors, in which case, the arrangements stated in [1.8.2] relating to the spacing of the internal and external doors are not required. The arrangement of such an air lock is to be to the satisfaction of the Society.

1.8.6 It is reminded that, in accordance with Part C, Chapter 4, the store for paints is to be fitted with certified safe lighting irrespective of their arrangement.

1.8.7 The ventilation system provided for the air lock and the protected space(s) is to be capable of being controlled from outside the air lock and these spaces. A warning plate is to be provided at the entrance of the air lock indicating that the ventilation is to be switched on at least 15 min before entering the space.

An audible and visual alarm is to be provided to indicate that the external door of the air lock is moved from the closed position when the ventilation system of the air lock or the protected space(s) is stopped, or in case of loss of the positive pressure required in [1.8.3], between the hazardous area on the open deck and the protected spaces.

2 Cargo and slop tanks venting, inerting, purging and gas-freeing

2.1 Cargo and slop tanks venting

2.1.1 Principle

Cargo tanks are to be provided with venting systems entirely distinct from the air pipes of the other compartments of the unit. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur are to be such as to minimise the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard.

2.1.2 Design of venting arrangements

The venting arrangements are to be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks exceeds design parameters and be such as to provide for:

a) the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves, and

b) the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and unloading or ballasting

c) a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or underpressure in the event of failure of the arrangements in item b). Alternatively, pressure sensors may be fitted in each tank protected by the arrangement required in item b), with a monitoring system in the unit's cargo control room or the position from which cargo operations are normally carried out. Such monitoring equipment is also to provide an alarm facility which is activated by detection of overpressure or underpressure conditions within a tank.

Note 1: A pressure/vacuum breaker fitted on the inert gas main may be utilised as the required secondary means of venting. Where the venting arrangements are of the free flow type and the masthead isolation valve is closed for the unloading condition, the inert gas system will serve as the primary underpressure protection with the pressure/vacuum breaker serving as the secondary means.

2.1.3 Combination of venting arrangements

The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

Where the arrangements are combined with other cargo tanks, either stop valves or other acceptable means are to be provided to isolate each cargo tank. Where stop valves are fitted, they are to be provided with locking arrangements which are to be under the control of the responsible officer. There is to be a clear visual indication of the operational status of the valves or other acceptable means. Where tanks have been isolated, it is to be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced. Any isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with [2.1.2].

Note 1: Inadvertent closure or mechanical failure of the isolation valves need not be considered in establishing the secondary means of venting cargo tanks required in [2.1.2].

If cargo loading and ballasting or discharging of a cargo tank or cargo tank group is intended, which is isolated from a common venting system, that cargo tank or cargo tank group is to be fitted with a means for overpressure or underpressure protection as required in [2.1.2].

2.1.4 The venting arrangements are to be connected to the top of each cargo tank and are to be self-draining to the cargo tanks under all normal conditions of trim and list of the unit. Where it may not be possible to provide self-draining lines, permanent arrangements are to be provided to drain the vent lines to a cargo tank.

Plugs or equivalent means are to be provided on the lines after the safety relief valves.

2.1.5 Openings for pressure release

Openings for pressure release required by [2.1.2] are to:

a) have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours but in no case less than 2 m above the cargo tank deck

b) be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard.

Note 1: The provisions of item a) are not applicable to the pressure/ vacuum breaker fitted on the inert gas main (see Note 1 of [2.1.2]) provided its settings are above those of the venting arrangements required by items a) and b) of [2.1.2].

Note 2: If provided, Anchor windlass and chain locker openings constitute an ignition hazard. They are to be located at the distances required by item b) above.

2.1.6 Pressure/vacuum valves

a) Pressure/vacuum valves are to be set at a positive pressure not exceeding 0,021 N/mm^2 and at a negative pressure not exceeding 0,007 N/mm^2.

Note 1: Higher setting values not exceeding 0,07 N/mm^2 may be accepted in positive pressure if the scantlings of the tanks are appropriate.

b) Pressure/vacuum valves required by [2.1.2] may be provided with a bypass when they are located in a vent main or masthead riser. Where such an arrangement is provided, there are to be suitable indicators to show whether the bypass is open or closed.

c) Pressure/vacuum valves are to be of a type approved by the Society.

d) Pressure/vacuum valves are to be readily accessible.

e) Pressure/vacuum valves are to be provided with a manual opening device so that valves can be locked on open position. Locking means on closed position are not permitted.

2.1.7 Vent outlets

Vent outlets for cargo loading, unloading and ballasting required by [2.1.2] are:

a) to permit:
   1) the free flow of vapour mixtures, or
   2) the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/s

b) to be so arranged that the vapour mixture is discharged vertically upwards

c) to be, where the method is by free flow of vapour mixtures, such that the outlet is not less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard

d) to be, where the method is by high velocity discharge, located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery which may constitute an ignition hazard. These outlets are to be provided with high velocity devices of a type approved by the Society

e) to be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The Master is to be provided with information regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks.

Note 1: The height requirements of items c) and d) are not applicable to the pressure/vacuum breaker fitted on the inert gas main (see Note 1 of [2.1.2]) provided its settings are above those of the venting arrangements required by items a) and b) of [2.1.2].

Note 2: If provided, anchor windlass and chain locker openings constitute an ignition hazard. They are to be located at the distances required by items c) and d).

2.1.8 High velocity valves

a) High velocity valves are to be readily accessible.

b) High velocity valves not required to be fitted with flame arresters (see [2.1.9]) are not to be capable of being locked on open position.

2.1.9 Prevention of the passage of flame into tanks

a) The venting system is to be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices shall be to the satisfaction of the Society for compliance with IMO MSC Circular 677.

Note 1: The above requirement is not applicable to the pressure/ vacuum breaker fitted on the inert gas main (see Note 1 of [2.1.2]) provided its settings are above those of the venting arrangements required by items a) and b) of [2.1.2].

Note 2: Attention is to be provided to additional tests required for detonation flame arrestors located in line.

b) A flame arresting device integral to the venting system may be accepted.

c) Flame screens and flame arresters are to be designed for easy overhauling and cleaning.

2.1.10 Prevention of liquids rising in the venting system

a) Provisions are to be made to prevent liquid rising in the venting system (refer to Ch 1, Sec 18, [6.2]).

b) Cargo tanks gas venting systems are not to be used for overflow purposes.

c) Spill valves are not considered equivalent to an overflow system.

2.1.11 Additional provisions for units fitted with an inert gas system

a) On units 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) 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) 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.

b) The location and design of the devices referred to in item a) are to be in accordance with requirements [2.1.1] to [2.1.10].

2.2 Cargo and slop tanks inerting, purging and/or gas-freeing crude oil tanks

2.2.1 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. Accordingly, the provisions of [2.2.2] and [2.2.3], as applicable, are to be complied with.

b) The arrangements for inerting, purging or gas-freeing of empty tanks as required in Ch 1, Sec 18, [4] are to be to the satisfaction of the Society and are to be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimized.

c) 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.

d) 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.

2.2.2 Units provided with an inert gas system

The following provisions apply to units 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 [2.2.2]. 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 cross-sectional area of such gas outlet pipe referred to in item a) 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.

c) Each gas outlet referred to in item b) is to be fitted with suitable blanking arrangements.

d) The arrangement of inert gas and cargo piping systems is to comply with the provisions of Ch 1, Sec 12, [4.4.7], item f).

e) The cargo tanks are first to be purged in accordance with the provisions of items a) to d) 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.

2.2.3 Units not provided with an inert gas system

When the unit is not provided with an inert gas system, the operation is to be such that the flammable vapour is discharged initially:

a) through the vent outlets as specified in [2.1.7], or

b) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas-freeing operation, or

c) through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/s and which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration at the outlet has been reduced to 30% of the lower flammable limit, gas-freeing may thereafter be continued at cargo tank deck level.

3 Cargo tanks vents recovery system (COTVR)

3.1 Application

3.1.1 This Article applies to COTVR systems fitted to boost cargo gas or vapour mixture to the process or low pressure (LP) flare system in lieu of sending them to the standard cargo venting system.

3.2 Scope

3.2.1 The limit of the scope of Classification (without **PROC** notation) is generally downstream the COTVR at the isolation valve referred to in [3.7.4].

3.3 General requirements

3.3.1 The COTVR system is to be designed, constructed and tested to the satisfaction of the Society.

3.3.2 Throughout the present, the term "crude oil tanks" includes also slop tanks and process tanks.

3.3.3 Detailed instruction manuals are to be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the COTVR system and its application to the cargo tanks system. The manuals are to include guidance on procedures to be followed in the event of a fault or failure of the COTVR system.

3.3.4 The following documents are to be submitted for review:

- process and Instrumentation diagrams of the COTVR system and of its connection to the cargo tanks system, to the IG system, to the HC blanket gas system, if any, and to the flare system
- cause and effect diagram for the system
- settings of the pressure / vacuum protection devices
- HAZID and HAZOP studies of the system.

3.3.5 Piping, fittings and mechanical parts of this COTVR system are to comply with the relevant requirements of Part C, Chapter 1.

3.3.6 Equipment must be suitable for the hazardous area where they are located.

3.3.7 The COTVR system is to remain within the cargo area.

3.3.8 Depending on findings of the HAZOP studies, the Society may raise additional requirements.

3.4 Capacity

3.4.1 The system is to be capable of boosting cargo tank vents to the process or LP flare system at a rate of at least 125% of the maximum loading capacity of the unit expressed as a flow rate.

3.5 Materials and constructive measures

3.5.1 Those parts of piping, fittings, recovery equipment, blowers, filters, non-return devices and other drain pipes which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

3.5.2 Constructive measures are to be taken to minimize the risk of ignition from generation of static electricity by the system itself.

3.6 Particles removal devices

3.6.1 Filters or equivalent devices are to be fitted to minimize the amount of water and other particles carried over to the cargo tanks vents recovery equipment.

3.7 COTVR piping system

3.7.1 Branch piping from each cargo tank should be connected to the COTVR main. This branch piping is to be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they are to be provided with locking arrangements which are to be under the control of the responsible officer. There is to be a clear visual indication of the operational status of the valve or other acceptable means. Where tanks have been isolated, it is to be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced. Any isolation must continue to permit the flow caused by thermal variations in a cargo tanks.

In case of COTVR is connected to the dirty inert gas header, above referred valves may be the ones of the IG system. Isolation mean as per [3.7.3] is nevertheless to be provided.

3.7.2 Piping systems are to be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

3.7.3 Arrangements are to be made to ensure an effective isolation of the Vent Recovery Unit from the upstream systems (cargo tanks/cargo venting/Inert gas/HC blanket gas systems). This may consist in a shut-down valve.

3.7.4 Arrangements are to be made to ensure an effective isolation of the Vent Recovery Unit from the downstream systems (process systems/LP flare system). This may consist in a shut-down valve.

3.7.5 The COTVR system is to be so designed that the minimum and maximum pressures which it can exert on any cargo tank will not exceed the test pressures of any cargo tank.

3.8 Instrumentation

3.8.1 A pressure device to regulate the capacity of the recovery equipment or a gas regulating valve is to be fitted.

3.8.2 Devices and alarms are to be provided for continuously recording and indicating:

a) The temperature and pressure upstream the shutdown valve mentioned in [3.7.3] whenever the system is operating
b) The temperature and pressure upstream the shutdown valve mentioned in [3.7.4]
c) The oxygen content of the gas recovery equipment
d) The failure of the blowers
e) The water level in the devices mentioned in [3.6].

3.8.3 The alarms referred to in [3.8.2] are to be fitted in the cargo central station.

3.9 Safeguards

3.9.1 Automatic stop of the blower as well as closing shutdown valves mentioned in [3.7.3]and [3.7.4] is to be arranged in case of:

- High-high pressure in respect to [3.8.2] item a) and b)
- Low-low pressure in respect to [3.8.2] item a) and b)
- High- high temperature in respect to [3.8.2] item a) and b)
- When content of oxygen exceeds 5% in respect to [3.8.2] item c)
- Failure in respect to [3.8.2] item d)
- High level alarm in respect to [3.8.2] item e).

Section 17 Equipment and Safety Particulars

1 General

1.1

1.1.1 The equipment is to comply with the applicable National Rules and, for items covered by classification, with requirements of Part C.

The present Section gives particular requirements to be met in addition to Part C requirements.

2 Hazardous areas

2.1 General

2.1.1 The present Article [2] is applicable to hazardous areas due to cargo storage.

For hazardous areas due to other causes refer to Part C, Chapter 4.

2.1.2 For definitions used in the present Article [2], refer to Pt C, Ch 4, Sec 3.

2.1.3 Attention is drawn on the fact that provisions of IMO Regulations for hazardous areas of oil tankers and liquefied gas carriers, as well as those of the Ship Rules applicable to the same, are applicable to units intended to receive a combination of service and structural type notations including **oil tanker ESP** (or **liquefied gas carrier**) **/ offshore ship**).

2.2 Classification of hazardous areas due to oil storage and offloading

2.2.1 For the purpose of machinery and electrical installations, hazardous areas are classified as in [2.2.2] to [2.2.4].

2.2.2 Hazardous area zone 0 are the interiors of cargo tanks, slop tanks, any pipework of pressure-relief or other venting systems for cargo and slop tanks, pipes and equipment containing the cargo or developing flammable gases or vapours.

2.2.3 Hazardous areas zone 1 are:

a) void spaces adjacent to, above or below, integral cargo tanks
b) hold spaces containing independent cargo tanks
c) cofferdams and permanent (for example, segregated) ballast tanks adjacent to cargo tanks
d) cargo pump rooms
e) enclosed or semi-enclosed spaces, immediately above cargo tanks (for example, between decks) or having bulkheads above and in line with cargo tank bulkheads, unless protected by a diagonal plate acceptable to the Society
f) enclosed or semi-enclosed spaces immediately above cargo pump rooms or above vertical cofferdams adjacent to cargo tanks, unless separated by a gas-tight deck and suitable ventilated
g) spaces, other than cofferdams, adjacent to and below the top of a cargo tank (for example, trunks, passageways and holds)
h) areas on open deck, or semi-enclosed spaces on open deck, within 3 m of any cargo tank outlet, gas, vapour outlet (see Note 1 below), cargo manifold valve, cargo valve, cargo pipe flange, cargo pump room ventilation outlets and cargo tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation

Note 1: Such areas are, for example, all areas within 3 m of cargo tank hatches, sight ports, tank cleaning opening, ullage openings, sounding pipes, cargo vapour outlets.

i) areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet intended for the passage of large volumes of gas or vapour mixture during cargo loading and unloading and ballasting (for example flare facility), within a vertical cylinder of unlimited height and 6 m radius centred upon the centre of the outlet, and within a hemisphere of 6 m radius below the outlet
j) areas on open deck, or semi-enclosed spaces on open deck within 1,5 m of cargo pump room entrances, cargo pump room ventilation inlet, openings into cofferdams or other zone 1 space
k) areas on open deck within 3 m spillage coamings surrounding cargo manifold connections
l) areas on open deck over all the cargo (including all ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breath of the unit plus 3 m fore and aft of the forward-most cargo tank and aft of the aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck
m) compartments for cargo hoses
n) enclosed or semi-enclosed spaces in which pipes containing cargoes are located.

2.2.4 Hazardous areas zone 2 are:

a) areas of 1,5 m surrounding the zone 1 spaces defined in [2.2.3] item h)

b) spaces 4 m beyond the cylinder and 4 m beyond the sphere defined in [2.2.3] item i)

c) areas in open deck extending to the coaming fitted to keep any spills on deck and away from the accommodation and service areas and 3 m beyond these up to a height of 2,4 m above the deck

d) areas on open deck over all the cargo and slop tanks (including all ballast tanks within the cargo tank area) where unrestricted natural ventilation is guaranteed and to the full breath of the unit plus 3 m fore and aft of the forward-most cargo tank and aft of the aft-most cargo tank bulkhead, up to a height of 2,4 m above the deck, surrounding open or semi-enclosed spaces of zone 1

e) spaces forward of the open deck areas the reference of which is made in [2.2.3] item l) and [2.2.4] item d), below the level of the main deck, and having an opening on to the main deck or at a level less than 0,5 m above the main deck, unless the entrance to such spaces does not face the cargo tank area and, together with all other openings to the spaces, including ventilating system inlets and exhausts, are situated at least 5 m away from the foremost or aftermost cargo tank and at least 10 m measured horizontally away from any cargo tank outlet and gas outlet and the spaces are mechanically ventilated.

3 Ventilation

3.1 General

3.1.1 Requirements of Pt C, Ch 4, Sec 3, [5] are to be complied with.

4 Gas detection system

4.1 General

4.1.1 Portable gas detectors

The following are to be provided:

- at least two portable flammable gas monitoring devices, each capable of accurately measuring a concentration of flammable gas (%LEL)
- at least two portable oxygen content meters.

Alternatively, at least two gas detectors, each capable of measuring both oxygen and flammable vapour concentrations in air (%LEL), are to be provided.

These devices are to be of a type approved by the Society.

4.1.2 Fixed automatic gas detection and alarm system

A fixed automatic gas detection and alarm system is to be provided to the satisfaction of the Society so arranged as to monitor continuously all enclosed areas of the unit in which an accumulation of flammable gas may be expected to occur, and capable of indicating at the main control point by audible and visual means the presence and location of an accumulation.

The same system is to be provided at ventilation inlets to safe areas.

4.1.3 In addition to the provisions of [4.1.1], for units 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.

4.2 Arrangements for gas measurement in double-hull spaces and double-bottom spaces

4.2.1 In selecting portable instruments for measuring oxygen and flammable vapour concentrations, due attention shall be given to their use in combination with the fixed gas sampling line systems referred to in [4.2.2].

4.2.2 Where the atmosphere in double-hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines. The configuration of gas sampling lines shall be adapted to the design of such spaces.

4.2.3 The materials of construction and dimensions of gas sampling lines shall be such as to prevent restriction. Where plastic materials are used, they shall be electrically conductive.

4.3 Arrangements for fixed hydrocarbon gas detection systems in double-hull and double-bottom spaces of units

4.3.1 In addition to the requirements in [4.1] and [4.2], the units shall be provided with a fixed hydrocarbon gas detection in accordance with Pt C, Ch 4, Sec 5 for measuring hydrocarbon gas concentrations in all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks.

Note 1: The term "cargo tanks" in the phrase "spaces adjacent to the cargo tanks" includes slop tanks except those arranged for the storage of oily water only.

Note 2: The term "spaces" in the phrase "spaces under the bulkhead deck adjacent to cargo tanks" includes dry compartments such as ballast pump-rooms and bow thruster rooms and any tanks such as freshwater tanks, but excludes fuel oil tanks.

Note 3: The term "adjacent" in the phrase "adjacent to the cargo tanks" includes ballast tanks, void spaces, other tanks or compartments located below the bulkhead deck located adjacent to cargo tanks and includes any spaces or tanks located below the bulkhead deck which form a cruciform (corner to corner) contact with the cargo tanks.

4.3.2 Units provided with constant operative inerting systems for such spaces need not be equipped with fixed hydrocarbon gas detection equipment.

4.3.3 Notwithstanding the above, cargo pump-rooms subject to the provisions of Ch 1, Sec 16, [1.3] need not comply with the requirements of this paragraph.

4.4 Engineering specifications for fixed hydrocarbon gas detection systems in double-hull and double-bottom spaces of units

4.4.1 General

a) The fixed hydrocarbon gas detection system is to be designed, constructed and tested to the satisfaction of the Society based on performance standards developed by IMO (Msc.1 Circ. 1370).

b) The system is to be comprised of a central unit for gas measurement and analysis and gas sampling pipes in all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks.

c) The system may be integrated with the cargo pump-room gas detection system, provided that the spaces referred to in item b) above are sampled at the rate required in [4.4.2], item c) 1). Continuous sampling from other locations may also be considered provided the sampling rate is complied with.

4.4.2 Component requirements

a) Gas sampling lines

1) Common sampling lines to the detection equipment shall not be fitted, except the lines serving each pair of sampling points as required in item 3) below.

2) The materials of construction and the dimensions of gas sampling lines are to be such as to prevent restriction. Where non-metallic materials are used, they shall be electrically conductive. The gas sampling lines shall not be made of aluminium.

3) The configuration of gas sampling lines is to be adapted to the design and size of each space. Except as provided in items 4) and 5) below, the sampling system shall allow for a minimum of two hydrocarbon gas sampling points, one located on the lower and one on the upper part where sampling is required. When required, the upper gas sampling point shall not be located lower than 1 m from the tank top. The position of the lower located gas sampling point shall be above the height of the girder of bottom shell plating but at least 0,5 m from the bottom of the tank and it shall be provided with means to be closed when clogged. In positioning the fixed sampling points, due regard should also be given to the density of vapours of the oil products intended to be transported and the dilution from space purging or ventilation.

4) For units with deadweight of less than 50000 tonnes, the Society may allow the installation of one sampling location for each tank for practical and/or operational reasons.

5) For ballast tanks in the double-bottom, ballast tanks not intended to be partially filled and void spaces, the upper gas sampling point is not required.

6) Means are to be provided to prevent gas sampling lines from clogging when tanks are ballasted by using compressed air flushing to clean the line after switching from ballast to cargo loaded mode. The system shall have an alarm to indicate if the gas sampling lines are clogged.

b) Gas analysis unit

The gas analysis unit shall be located in a safe space and may be located in areas outside the unit's cargo area; for example, in the cargo control room and/or navigation bridge in addition to the hydraulic room when mounted on the forward bulkhead, provided the following requirements are observed:

1) Sampling lines shall not run through gas safe spaces, except where permitted under item 5) below

2) The hydrocarbon gas sampling pipes shall be equipped with flame arresters. Sample hydrocarbon gas is to be led to the atmosphere with outlets arranged in a safe location, not close to a source of ignitions and not close to the accommodation area air intakes

3) Bulkhead penetrations of sample pipes between safe and hazardous areas are to be of a type approved and have same fire integrity as the fire division penetrated. A manual isolating valve, which shall be easily accessible for operation and maintenance, shall be fitted in each of the sampling lines at the bulkhead on the gas safe side

4) The hydrocarbon gas detection equipment including sample piping, sample pumps, solenoids, analysing units etc., shall be located in a reasonably gas-tight cabinet (e.g., fully enclosed steel cabinet with a door with gaskets) which is to be monitored by its own sampling point. At a gas concentration above 30% of the lower flammable limit inside the steel enclosure the entire gas analysing unit is to be automatically shut down; and

5) Where the enclosure cannot be arranged directly on the bulkhead, sample pipes shall be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing unit, and are to be routed on their shortest ways.

c) Gas detection equipment

1) The gas detection equipment is to be designed to sample and analyse from each sampling line of each protected space, sequentially at intervals not exceeding 30 min

2) Means are to be provided to enable measurements with portable instruments, in case the fixed system is out of order or for system calibration. In case the system is out of order, procedures shall be in place to continue to monitor the atmosphere with portable instruments and to record the measurement results

3) Audible and visual alarms are to be initiated in the cargo control room, navigation bridge and at the analysing unit when the vapour concentration in a given space reaches a pre-set value, which shall not be higher than the equivalent of 30% of the lower flammable limit

4) The gas detection equipment shall be so designed that it may readily be tested and calibrated.

5 Electrical installations

5.1 General

5.1.1 Electrical installations for production, storage and offloading surface units are to comply with Part C, Chapter 2 and Part C, Chapter 3.

6 Machinery

6.1 General

6.1.1 As a general rule, internal combustion engines are to be avoided as far as possible inside hazardous areas. Nevertheless, the Society may permit fitting of internal combustion engines inside hazardous areas provided it is satisfied with their safety type accordingly to Pt C, Ch 4, Sec 3, [6].

7 Fire protection

7.1 General

7.1.1 Particular provisions of the present Article are in addition to the provision of Part C which remains applicable, except otherwise justified.

7.1.2 The fire protection of the storage area is to be provided by a fixed foam fire extinguishing system complying with [7.5].

7.1.3 For units fitted with bow or stern cargo transfer installations, refer to [7.2.5] and Ch 1, Sec 18, [7] for the protection of the corresponding zones.

7.2 Passive fire protection

7.2.1 As a general rule, requirements of Part C, Chapter 4 are applicable. Nevertheless, Tab 1 and Tab 2 for fire integrity of bulkheads and decks are to replace Pt C, Ch 4, Sec 4, Tab 1 and Pt C, Ch 4, Sec 4, Tab 2.

Definitions of fire categories of the spaces are those given in Pt C, Ch 4, Sec 4, [1.2.2] item b), plus the following one:

(12) Cargo pump rooms are spaces containing cargo pumps and entrances and trunks to such spaces.

7.2.2 Entrances, air inlets and openings to accommodation spaces, service spaces, control spaces and machinery spaces are not to face the storage area. They are to be located on the transverse bulkhead not facing the storage area or on the outboard side of the superstructure or deckhouse at a distance equal to at least 4% of the unit's length but not less than 3 m from the end of the superstructure or deckhouse facing the storage area. This distance, however, need not exceed 5 m.

7.2.3 The Society may permit access doors in boundary bulkheads facing the storage area or within the 5 m limits specified in [7.2.2], to main cargo stations and to such service spaces as provision rooms, store rooms and lockers, provided they do not give access directly or indirectly to any other spaces containing or provided for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapour ignition. The boundary of such space is to be insulated to "A-60" standard, with the exception of the boundary facing the storage area. Bolted plates for the removal of machinery may be fitted within the limits specified in [7.2.2].

Note 1: An access to a deck foam system room (including the foam tank and the control station) can be permitted within the limits mentioned in [7.2.2], provided that the conditions listed in [7.2.3] are satisfied and that the door is located flush with the bulkhead.

7.2.4 Windows and sidescuttles facing the storage area and the sides of the superstructures and deckhouses within the limits specified in [7.2.2] are to be of non-opening type. Such windows and sidescuttles are to be constructed of "A-60" class standard.

Table 1 : Fire integrity of bulkheads separating adjacent spaces

Spaces		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Control stations	(1)	A-0 [d]	A-0	A-60	A-0	A-15	A-60	A-15	A-60 [e]	A-60	*	A-0	A-60
Corridors	(2)		C	B-0	A-0 [b]	B-0	A-60	A-0	A-0 [e]	A-0	*	B-0	A-60
Accommodation spaces	(3)			C	A-0 [b]	B-0	A-60	A-0	A-0 [e]	A-0	*	C	A-60
Stairways	(4)				A-0 [b]	A-0 [b]	A-60	A-0	A-0 [e]	A-0	*	A-0 [b]	A-60
Service spaces (low risk)	(5)					C	A-60	A-0	A-0	A-0	*	B-0	A-60
Machinery spaces of category A	(6)						* [a]	A-0 [a]	A-60	A-60	*	A-0	A-0
Other machinery spaces	(7)							A-0 [a] [b]	A-0	A-0	*	A-0	A-0
Hazardous areas	(8)								–	A-0	*	A-0	A-0
Service spaces (high risk)	(9)									A-0 [c]	*	A-0	A-60
Open decks	(10)										–	*	*
Sanitary and similar spaces	(11)											C	A-60
Cargo pump room	(12)												*

[a] : Where the space contains an emergency power source or components of an emergency power source that adjoins a space containing a unit's service generator or the components of a unit's service generator, the boundary bulkheads between those spaces is to be "A-60" class division.

[b] : Except otherwise accepted in Part C, Chapter 4.

[c] : Where spaces are of the same numerical category and superscript (c) appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose e.g. in category (i). A galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.

[d] : Bulkheads separating the navigating bridge, chartroom and radio room from each other may be "B-0" rating.

[e] : An engineering evaluation is to be conducted in accordance with Pt C, Ch 4, Sec 4, [4.1.1]. In no case the bulkhead or deck rating is to be less than the value indicated in the tables. See Part C, Chapter 4.

Note 1: When an asterisk * appears in the table, the division is required to be of steel or equivalent material but not required to be of "A" class standard. However, where a 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 2 : Fire integrity of decks separating adjacent spaces

Spaces below		Space above											
		(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
Control stations	**(1)**	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0 [e]	A-0	*	A-0	XXX
Corridors	**(2)**	A-0	*	*	A-0	*	A-60	A-0	A-0 [e]	A-0	*	*	XXX
Accommodation spaces	**(3)**	A-60	A-0	*	A-0	*	A-60	A-0	A-0 [e]	A-0	*	*	XXX
Stairways	**(4)**	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0 [e]	A-0	*	A-0	XXX
Service spaces (low risk)	**(5)**	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0	XXX
Machinery spaces of category A	**(6)**	A-60	A-60	A-60	A-60	A-60	* [a]	A-60	A-60	A-60	*	A-0	XXX
Other machinery spaces	**(7)**	A-15	A-0	A-0	A-0	A-0	A-0 [a]	* [a]	A-0	A-0	*	A-0	XXX
Hazardous areas	**(8)**	A-60 [e]	A-0 [e]	A-0 [e]	A-0 [e]	A-0	A-60	A-0	–	A-0	–	A-0	A-0
Service spaces (high risk)	**(9)**	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0 [c]	*	A-0	XXX
Open decks	**(10)**	*	*	*	*	*	*	*	–	*	–	*	XXX
Sanitary and similar spaces	**(11)**	A-0	A-0		A-0		A-0	A-0	A-0	A-0	*	*	XXX
Cargo pump room	**(12)**	XXX	XXX	XXX	XXX	XXX	A-0	A-0	A-0	A-0	*	–	*

Note 1: Refer to Tab 1
Note 2: "XXX" in the cells indicates that corresponding vicinities are prohibited.

7.2.5 When a loading or offloading connection is provided at the manned end of the unit, entrances, air inlets and openings to accommodation spaces, service and machinery spaces and control stations are not to face the cargo transfer connection location. They are to be located on the outboard side of the superstructure or deckhouse at a distance equal to at least 4% of the unit's length but not less than 3 m from the end of the superstructure or deckhouse facing the connection. This distance, however, need not exceed 5 m.

Sidescuttles facing the connection location and on the side of the superstructure or deckhouse within the distance mentioned above are to be of the non-opening type. In addition, during the use of the transfer arrangements, all doors, ports and other openings on the corresponding superstructure or deckhouse side are to be kept closed.

Air pipes and other openings to enclosed spaces not listed above are to be shielded from any spray which may come from a burst hose or connection.

7.2.6 The location and arrangement of the galleys are to be such that there is a minimum risk of fire.

7.2.7 Air intakes and air outlets of machinery spaces are to be located as far aft as practicable and, in any case, outside the limits specified in [7.2.2].

7.3 Fire water pumps

7.3.1 The requirements of Pt C, Ch 4, Sec 6 relative to fire water pumps and mains are applicable, together with additional requirements of [7.3.2] and [7.3.3].

7.3.2 Within the storage area, isolation valves are to be fitted in the fire main at intervals of not more than 40 m to preserve the integrity of the fire main system in case of fire or explosion.

7.3.3 Operation of a deck foam system at its required output is to permit the simultaneous use of the minimum required number jets of water at the required pressure from the fire main and the process deluge system if any.

7.4 Cargo pump rooms

7.4.1 Each cargo pump room is to be provided with a fixed fire extinguishing system operated from a readily accessible position outside the pump room.

7.4.2 The fixed fire extinguishing system required in [7.4.1] is to be one of the following fixed fire-extinguishing systems operated from a readily accessible position outside the cargo pump room. Cargo pumps room are to be provided with a system suitable for machinery spaces of category A:

- Either a carbon dioxide or another extinguishing medium system complying with the applicable provisions of Pt C, Ch 4, Sec 11, [4] and with the following:
  - the audible signal mentioned in Pt C, Ch 4, Sec 11, [4.1.1] item b)2), if of electrical type, is to be of certified safe type. A light signal is not required but, if it is provided, it is also to be of a certified safe type

    When the audible signal is of pneumatic type, it must not be activated by the fire extinguishing medium but by clean dry air
  - 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, or
- a high expansion foam system complying with the provisions of Pt C, Ch 4, Sec 11, [5.1.2], provided that the foam concentrate supply is suitable for extinguishing fires involving the cargo stored, or
- a fixed pressure water-spraying system complying with Pt C, Ch 4, Sec 11, [6.1.1] or Pt C, Ch 4, Sec 11, [6.1.2].

7.4.3 Where the extinguishing medium used in the crude oil 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.

7.4.4 Two portable foam extinguishers or equivalent are to be provided for each pump room; one is to be fitted near the pumps and the other near the access to the pump room.

7.5 Fixed deck foam system

7.5.1 Definitions

a) An applicator is a hose and nozzle that can be held and directed by hand.

b) A foam solution is a homogeneous mixture of water and foam concentrate in the proper proportions.

7.5.2 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 shall permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main. Where the deck foam system is supplied by a common line from the fire main, additional foam concentrate shall 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 shall be possible on deck over the full length of the ship, in the accommodation spaces, service spaces, control stations and machinery spaces.

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.

d) Foam from the fixed foam system is to be supplied by means of monitors and/or deluge system and foam applicators.

e) Foam applicators are to be provided to ensure flexibility of action during fire-fighting operations and to cover areas screened and/or deluge system.

7.5.3 Foam solution – Foam concentrate

a) The supply rate of the foam solution is not to be less than the greatest of the following:
   1) 0,6 l/min/m² of storage deck area, where storage deck area means the maximum breadth of the unit multiplied by the total longitudinal extent of the cargo and slop tank spaces
   2) 6 l/min/m² of the horizontal sectional area of the single tank having the largest such area
   3) 3 l/min/m² of the horizontal sectional area of group of tanks to be protected simultaneously as defined by the worst case fire scenario
   4) if the fixed deck foam system is ensured by an arrangement of monitors, 3 l/min/m² 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 min of foam generation on storage units fitted with an inert gas installation or at least 30 min of foam generation on storage units not fitted with an inert gas installation when using solution rates stipulated in item a), whichever is the greatest.

c) When medium expansion ratio foam (between 21 to 1 and 200 to 1 expansion ratio) is employed, the application rate of the foam and the capacity of a monitor installation shall be to the satisfaction of the Society.

d) The water supply to this fixed deck foam system shall be of a quality so that adverse effects on foam formation, stability or performances do not occur.

e) The foam concentrate supplied on board shall be approved by the Society (Refer to the Guidelines for performance and testing criteria and surveys of foam concentrates for fixed fire-extinguishing systems (MSC.1/Circ.1312)) for the cargoes intended to be carried. Type B foam concentrates shall be supplied for the protection of crude oil, petroleum products and non-polar solvent cargoes. Type A foam concentrates shall be supplied for polar solvent cargoes, as listed in the table of chapter 17 of the IBC Code. Only one type of foam concentrate shall be supplied, and it shall be effective for the maximum possible number of cargoes intended to be carried. For cargoes for which foam is not effective or is incompatible, additional arrangements to the satisfaction of the Society shall be provided.

f) Liquid cargoes with a flashpoint not exceeding 60°C for which a regular foam fire-fighting system is not effective are to comply with the provisions of regulation II-2/1.6.2.1 of the SOLAS Convention.

7.5.4 Monitors, nozzles of deluge systems and applicators

a) When an arrangement of monitor is provided, at least 50% of the foam solution supply rate required in items a)1) and a)2) of [7.5.3] is to be delivered from each monitor.

b) When an arrangement of monitor is provided, the capacity of any monitor is to be at least 3 l/min of foam solution per square meter of the deck area protected by that monitor, such area being entirely forward of the monitor. Such capacity is not to be less than 1250 l/min.

c) The capacity of any applicator is to be not less than 400 l/min and the applicator throw in still air conditions is not to be less than 15 m.

Note 1: The flow delivered from one applicator shall be limited by the reaction force at the working pressure that one operator can withstand. As a recommendation, the applicator reaction usually limits the solution flow to about 1150 l/min.

d) The capacity of the deluge system is to be compliant with [7.5.3]item a)3).

e) Foam applicators, nozzles and monitors are to be of type approved by the Society.

f) Prototype tests of the monitors and foam applicators are to be performed to ensure the foam expansion and drainage time of the foam produced does not differ by more than ± 10 per cent from that determined in [7.5.3], item e).

7.5.5 Arrangement and installation

a) The foam concentrate is to be stored in an accessible location unlikely to be damaged in the event of fire or explosion and not having direct opening or exposure to the protected areas.

b) The arrangement of the deck foam system ducting shall be such that a fire or explosion in the protected areas will not affect the foam generating equipment.

c) Monitors

   1) The number and position of monitors are to be such as to comply with [7.5.2] item a).

   2) The area protected by a monitor is considered located entirely forward of the monitor.

   3) The distance from the monitor to the farthest extremity of the protected area forward of that monitor is not to be more than 75% of the monitor throw in still air conditions.

   4) A monitor and hose connection for a foam applicator are to be situated both port and starboard at the front of the accommodation spaces facing the storage area. The monitors and hose connections shall be aft of any cargo tanks, but may be located in the cargo area above pump-rooms, cofferdams, ballast tanks and void spaces adjacent to cargo tanks if capable of protecting the deck below and aft of each other.

   5) The number of foam applicators provided is not to be less than four. The number and disposition of foam main outlets is to be such that foam from at least two applicators can be directed on to any cargo tank deck area.

d) Deluge systems

   1) The number and position of foam nozzles are to be such as to comply with [7.5.2].

   2) The foam deluge system may be separated in several sections by means of remote control stop valves.

   3) A coaming of a sufficient height is to be provided on the cargo tank deck in order to avoid the spillage of flammable liquids. This coaming should be in line with the fire zones identified during the fire scenario analysis mentioned in [7.5.3] item a)3). See Ch 1, Sec 16, [1.7].

Note 1: For the design of the fire zones, reference is made to the provisions of NFPA 101 and 101A code.

e) Isolation valves are to be provided in the foam main, and in the fire main when this is an integral part of the deck foam system, immediately forward of any monitor position to isolate damage section of those mains.

f) The main control station for the system is to be suitably located outside the storage area, adjacent to the accommodation spaces and readily accessible and operable in the event of a fire in the areas protected.

7.6 Emergency and offloading control station

7.6.1 At least one emergency control station is to be provided, at a suitable manned location outside hazardous areas.
If two emergency control stations are provided, the second one is to be placed at the same location as the loading control station.

7.6.2 Offloading control stations are to be provided with all necessary instruments for safe and easy operation of handling systems, fully independent from instruments necessary for propulsion (if any) and operation of auxiliary engines.
These control stations are to be permanently fitted with:

- indicators showing if remote controlled valves are closed or open
- means of communication with open deck, pump room(s), machinery spaces and control room.

Besides which, indicators showing if valves are closed or open are to be fitted on all locally manoeuvrable valves.

8 Life saving appliances

8.1 Life saving appliances

8.1.1 In addition to requirements of Pt C, Ch 4, Sec 12 applicable for units intended to receive **LSA** additional class notation, lifeboats are to be of a totally enclosed fire resistant type

9 Temporary refuge

9.1 General

9.1.1 Temporary refuge is a facility where the personnel can muster temporarily and prepare for the evacuation of the unit. The emergency response is to be communicated and controlled from the temporary refuge.

9.1.2 At least one main temporary refuge is to be fitted onboard the unit. Depending on the unit dimensions and arrangements of means of escape, the Society may require a secondary refuge.

9.1.3 The main temporary refuge is to be located in the accommodation area, being generally a part of the living quarters. The whole accommodation building may be designed as temporary refuge.

9.1.4 The main temporary refuge is to include the following facilities:

- main muster area
- standby control room
- emergency response centre.

9.1.5 At least two separate means of escape are to be provided to evacuate from the temporary refuge to the deck level and to the helideck. One of these means of escape may be an emergency escape door, to be used only in the case of emergency.

9.1.6 All the doors used for the normal access to the spaces in the main temporary refuge are to be equipped with positive pressurised air locks.

9.1.7 When a secondary refuge is fitted, suitable means of communication with the main temporary refuge are to be provided.

Section 18 Piping Systems

1 General

1.1 Application

1.1.1 Bilge, ballast, scupper, oil fuel, cargo and other piping systems are to comply with the applicable requirements of Part C, Chapter 1 and of other documents referred to in this Chapter; requirements of the present Section are additional ones.

1.1.2 Production piping systems are to comply, in addition to requirements of Article [3], with applicable requirements of NR459, Process Systems on Board Offshore Units and Installations.

1.2 Separation of systems

1.2.1 Piping systems carrying non-hazardous fluids are generally to be separate from piping systems which may contain hazardous fluids. Cross connection of the piping systems may be permitted where means for avoiding possible contamination of the non-hazardous fluid system by the hazardous fluid are provided.

2 Bilge - Ballast - Oil fuel - Scupper lines

2.1 General

2.1.1 Cargo storage tanks are not to be used for ballast purposes except in emergency cases; tanks used for cargo storage are not to be served by the ballasting system of the unit, except as provided for throughout the present Section.

2.1.2 Passage through cargo tanks and slop tanks

a) Unless otherwise specified, bilge, ballast and fuel oil systems serving gas safe spaces located outside the cargo area are not to pass through cargo tanks or slop tanks. They may pass through ballast tanks or void spaces located within the cargo area.

b) Where expressly permitted, ballast pipes passing through cargo tanks are to fulfil the following provisions:

   1) they are to have welded or heavy flanged joints the number of which is to be kept to a minimum

   2) they are of extra reinforced wall thickness as per Pt C, Ch 1, Sec 7

   3) they are adequately supported and protected against mechanical damage.

c) Lines of piping which run through cargo tanks are to be fitted with closing devices.

2.1.3 Unless otherwise specified, bilge, ballast and scupper systems serving spaces or compartments situated within the storage area are to be independent from other systems serving spaces or compartments outside the storage area and are not to lead into such spaces.

2.1.4 Oil fuel piping systems are to be independent from the cargo piping system and, unless otherwise authorised by the Society, independent from the ballast piping system. They are not to led through cargo tanks, slop tanks or process tanks.

2.1.5 As applicable, the forward spaces located forward of the fore cofferdam in gas safe space and, the aftermost spaces located abaft the aft cofferdam in gas safe space, are to be drained in accordance with the applicable requirements of Part C, Chapter 1.

2.1.6 The sea inlets serving the segregated ballast tanks are to be separated from the sea outlets serving the cargo tanks, slop tanks or process tanks.

2.2 Bilge system

2.2.1 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.

2.2.2 Draining of pump room

a) Arrangements are to be provided to drain the pump rooms by means of power pumps or bilge ejectors.

Note 1: On units of less than 500 gross tonnage, the pump rooms may be drained by means of hand pumps with a suction diameter of not less than 50 mm.

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.

e) A high level alarm is to be provided. Refer to item d) of Ch 1, Sec 16, [1.2.6].

2.2.3 Draining of tunnels and pump rooms other than cargo pump rooms

Arrangements are to be provided to drain tunnels and pump rooms other than cargo pump rooms. Cargo pumps may be used for this service under the provisions of [2.2.2], item b).

2.2.4 Draining of cofferdams located at the fore and aft ends of the cargo area

a) When they are not intended to be filled with water ballast, cofferdams located at the fore and aft ends of the cargo spaces are to be fitted with drainage arrangements.

b) Aft cofferdams (and/or fore as applicable) adjacent to the cargo pump room may be drained by a cargo pump in accordance with the provisions of [2.2.2], items b) and c), or by bilge ejectors.

c) Drainage of the after cofferdam (and/or fore cofferdam as applicable) from the engine room bilge system is not permitted.

Note 1: On units of less than 500 gross tonnage, cofferdams may be drained by means of hand pumps with a suction diameter of not less than 50 mm

2.2.5 Drainage of cofferdams or void spaces located within the cargo area

Other cofferdams and void spaces located within the cargo area and not intended to be filled with water ballast are to be fitted with suitable means of drainage.

2.3 Ballast tanks within the cargo area

2.3.1 Tanks within cargo area, intended to be used exclusively for ballast, are, according to [2.1.3] and unless otherwise permitted, to be served by piping and pumping systems independent of cargo and fuel oil piping and pumping systems. Ballast systems serving ballast in the cargo area are to be entirely located within the cargo area and are not to be connected to other piping systems.

Note 1: Ballast pumps are to be located in the cargo pump room, or a similar space within the cargo area not containing any source of ignition

Note 2: Where installed in the cargo pump room, ballast pumps are to comply with [3.2.3].

2.3.2 Two distinct pumping means are to be provided for these tanks, one of which at least, is to be mechanically or hydraulically driven or comprising an ejector used exclusively for this purpose. The second may be a portable means.

2.3.3 For emergency deballasting of the segregated ballast tanks located within the storage area, cargo pumps may be used under the following conditions:
- the connection between ballast pumping system and the cargo pump is not to be permanent and to be located as close as possible to the cargo pump suction
- the connection is to comprise a detachable spool piece, a non-return valve to prevent using the pump to fill tanks, and a shut-off valve located on the ballast pipe side.

2.3.4 Where segregated ballast pipes pass through cargo tanks, namely for the application of [2.3.3], they are to be made of steel of reinforced thickness and their connections are to be of the welded type. Connections by means of heavy flanges may nevertheless be permitted provided they are kept to a minimum. Expansion joints are not to be used for that purpose.

Note 1: Sliding type coupling are not to be used for expansion purposes where ballast lines pass through cargo tanks. Expansion bends only are permitted.

2.3.5 For emergency ballasting of the segregated ballast tanks located within the storage area, the use of a pump located outside the storage area is permitted under the conditions that the filling pipe does not pass through cargo tanks and that connection to ballast tanks is made at the top of these tanks and consists in a detachable spool piece and a non-return valve to prevent siphon effects.

2.3.6 Furthermore, for emergency deballasting or ballasting of the segregated ballast tanks located within the storage area, the use of a pump other than a cargo pump is permitted if located within the storage area and if it only serves spaces or compartments located within the storage area.

2.3.7 When the foremost or aftermost cofferdam, located forward or abaft the cargo tanks, are intended for ballasting, they may be emptied by a ballast pump located inside the machinery compartment or the fore spaces whichever the case, provided that the corresponding suction line is directly connected to that pump and not to any of the machinery compartment mains and that the delivery side is directly connected to the unit's side.

2.3.8 Ends of filling pipes serving ballast tanks located within the storage area are to be as near as possible to the bottom of the tanks in order to minimise the risk of generating static electricity.

2.4 Air and sounding pipes

2.4.1

a) The air and sounding pipes fitted to the following spaces:

- cofferdams located at the fore and aft ends of the cargo spaces
- tanks and cofferdams located within the cargo area and not intended for cargo,

are to be led to the open deck.

b) The air pipes referred to in item a) are to be arranged as per Part C, Chapter 1 and are to be fitted with easily removable flame screens at their outlets.

c) In offshore units of 600 tons deadweight and above, the air and sounding pipes referred to in item a) are not to pass through cargo tanks except in the following cases:

1) short lengths of piping serving ballast tanks

2) lines serving double bottom tanks located within the cargo area, except in the case of oil units of 5 000 tons deadweight and above,

where the following provisions are complied with [2.1.2], item b).

2.5 Ballast tanks located outside the storage area (within gas safe zones)

2.5.1 Tanks within gas safe zones, intended to be used exclusively for ballast, are, according to [2.1.3], unless otherwise permitted, to be served by piping and pumping systems independent from piping and pumping systems serving spaces or compartments within the storage area, and corresponding pipes are not to pass through cargo oil or slop tanks.

2.5.2 Requirement [2.5.1] is applicable, without any possible deviation, namely to compartments located abaft (and/or forward as applicable depending on the location of accommodation blocks) the aft (and/or fore) cofferdam.

2.5.3 However, for tanks other than those mentioned in [2.5.2] pumps exclusively dedicated to segregated ballast tanks located within hazardous areas, may be used for ballast tanks located within gas safe zones, on the conditions that there are no common parts in the two circuits other than those needed for this connection to pumps and unit sea chests.

2.5.4 For the emergency deballasting of the ballast tanks located within gas safe zones, other than those covered by [2.5.2], the piping system serving segregated ballast tanks within hazardous areas, may be used, on the condition that the pipe connection to the tank is fitted as near as possible to the tanks by means of a detachable spool piece and a screw-down non return valve preventing the filling of these tanks by this piping system.

2.5.5 Pipes serving ballast tanks located within gas safe zones may, irrespective of the case covered by [2.5.4], pass through cargo tanks, on the condition that [2.3.4] is complied with. Moreover, the thickness of steel pipes is to be at least 16 mm.

2.5.6 Pipes serving ballast tanks located within gas safe zones, other than those covered by [2.5.2], may pass through segregated ballast tanks within hazardous area but expansion joints are not to be used for pipe connections. The possible use of a cargo pump for emergency deballasting of the tanks in question is to be subjected to [2.3.3].

2.5.7 Attention is drawn to the requirements of Part C, Chapter 1 and of other documents referred to in this Chapter relating to the maintenance of the integrity of the watertight subdivision and unit's stability.

2.6 Fore peak ballast system

2.6.1 The fore peak can be ballasted with the system serving ballast tanks within the storage area, provided:

a) the tank is considered as hazardous

b) the vent pipe openings are located on open deck 3 m away from sources of ignition

c) means are provided, on the open deck, to allow measurement of flammable gas concentrations within the tank by a suitable portable instrument

d) the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:
   - in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign is to be provided at the manhole stating that the fore peak tank may only be opened after:
     - it has been proven to be gas free, or
     - any electrical equipment which is not certified safe in the enclosed space is isolated
   - in case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space can be well ventilated.

2.7 Carriage of ballast in cargo tanks

2.7.1 Every cargo tank is, in general, to be capable of being filled with sea water.

Note 1: Attention is to be provided on the applicable requirements of the MARPOL 73/78 Annex I convention as amended and IMO MEPC Circular 139 (53) for this operation.

2.7.2 Two shut-off valves, at least, are recommended to isolate cargo piping system from sea chests.

2.7.3 Cargo tanks are to be capable of being stripped by two separate means. Cargo pumps may be used for this purpose if their performance characteristics are suitable.

2.7.4 Provisions are to be made, to the Society's satisfaction, to permit efficient draining of tanks at the end of offloading.

2.7.5 The cargo piping system is to be so designed and arranged as to permit efficient cleaning and draining.

2.7.6 The requirements relating to the possible connections between cargo piping system and segregated ballast tank piping system are given in [2.3] and [2.5].

2.7.7 Emergency ballasting of cargo tank may be made by segregated ballast tank pumps on the condition that the connection is made to the top of the tanks and consists of a detachable spool piece and a screw-down valve to prevent siphon effects. The tank filling line is to end as near as possible to the tank bottom in order to reduce the risk of generating static electricity.

2.8 Scupper lines

2.8.1 The passage of scupper pipes or sanitary discharges through cargo tanks is to be avoided as far as practicable. If this is not possible, the number of these pipes is to be reduced to a minimum.

2.8.2 The portions of scupper pipes and sanitary discharges passing through cargo tanks are to be of steel and are to have only welded joints, the number of which is to be kept to a minimum. Furthermore, their thickness is not to be less than 16 mm.

3 Cargo piping and pumping system

3.1 General

3.1.1 A complete system of pumps and piping is to be fitted for handling the cargo oil. Except where expressly permitted, and namely for the bow and stern cargo loading and unloading, this system is not to extend outside the cargo area and is to be independent of any other piping system on board.

3.2 Cargo pumping system

3.2.1 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:
   1) in a dedicated pump room, or
   2) on deck, or
   3) when designed for this purpose, within the cargo tanks.

3.2.2 Use of cargo pumps

a) Except where expressly permitted in [2.2] and [2.3], 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.

3.2.3 Cargo pump drive

a) Prime movers of cargo pumps are not to be located in the cargo area, except in the following cases:

1) steam driven machine supplied with steam having a temperature not exceeding 220°C

2) hydraulic motors

3) electric motors of a certified safe type suitable for installation in hazardous area zone 1 as specified in Ch 1, Sec 17, [2.2] with explosion group and temperature class of at least IIA and T3 as per Pt C, Ch 2, Sec 15, [4].

b) Pumps with a submerged electric motor are not permitted in cargo tanks.

c) Where cargo pumps are driven by a machine which is located outside the cargo pump room, the provisions of Ch 1, Sec 16, [1.2.3] are to be complied with.

3.2.4 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.

c) Pump casings are to be fitted with temperature sensing devices (see Tab 1).

3.2.5 Monitoring of cargo pumps

Cargo pumps are to be monitored as required in Tab 1.

3.2.6 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.

Table 1 : Monitoring of cargo pumps

Equipment, parameter	Alarm**(1)**	Indication**(1)**	Comments
Pump, discharge pressure		L	• on the pump**(2)**, or • next to the unloading control station
Pump casing, temperature	H		visual and audible, in cargo control room or pump control station
Bearings, temperature	H		visual and audible, in cargo control room or pump control station
Bulkhead shaft gland, temperature, if relevant	H		visual and audible, in cargo control room or pump control station

(1) H = high, L = low
(2) and next to the driving machine if located in a separate compartment.

3.3 Cargo piping design

3.3.1 General

Cargo piping is to be designed and constructed according to the requirements of Pt C, Ch 1, Sec 7.

Cargo piping conveying liquids are to comply with the requirements applicable to piping class I, unless otherwise agreed with the Society.

Cargo piping conveying gases are to comply with the requirements applicable to the following piping classes, unless otherwise agreed with the Society:

- Class I, when p> 1,6 MPa or T > 200 °C
- Class II, otherwise.

3.3.2 Materials

a) For the protection of cargo tanks carrying crude oil and petroleum products having a flash point not exceeding 60°C, 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:

   1) within cargo tanks, and

   2) 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.

3.3.3 Connection of cargo pipe length

Cargo pipe lengths may be connected either by means of welded joints or, unless otherwise specified, by means of flange connections.

3.3.4 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:

   1) of an approved type

   2) designed to withstand the maximum internal and external pressure

   3) electrically conductive.

d) Sliding type couplings are not to be used for expansion purposes where lines for cargo oil pass through tanks for segregated ballast.

3.3.5 Valves with remote control

a) Valves with remote control are to comply with Part C, Chapter 1.

Note 1: All valves provided with a remote control are to be capable of being locally operated.

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.

3.3.6 Cargo hoses

a) Cargo hoses are to be of a type approved by the Society for the intended conditions of use.

b) Hoses subject to tank pressure or pump discharge pressure are to be designed for a bursting pressure not less than 5 times the maximum pressure under cargo transfer conditions.

c) Unless bonding arrangements complying with Ch 1, Sec 6 are provided, the ohm electrical resistance of cargo hoses is not to exceed 10^6 Ω.

3.4 Cargo piping arrangement and installation

3.4.1 Cargo pipes passing through tanks or compartments

a) Cargo piping is not to pass through tanks or compartments located outside the cargo area.

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 [2.1.2], item b).

c) Cargo piping may pass through vertical fuel oil tanks adjacent to cargo tanks on condition that the provisions of [2.1.2], item b) are complied with.

d) Cargo piping passing through cargo tanks is subject to the provisions of MARPOL 73/78 Convention Annex I Regulation 24 (6) as recommended to be applied by IMO MEPC Circular 406.

3.4.2 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.

3.4.3 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) Valves are also to be provided where required by the provisions of MARPOL 73/78 Convention Annex I Regulation 24 (5) and (6) as recommended to be applied by IMO MEPC Circular 406.

3.4.4 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 unit's hull.

3.4.5 Draining of cargo pumps and cargo lines

Every unit required to be provided with segregated ballast tanks or fitted with a crude oil washing system is to comply with the following requirements:

a) it is to be equipped with oil piping so designed and installed that oil retention in the lines is minimized, and

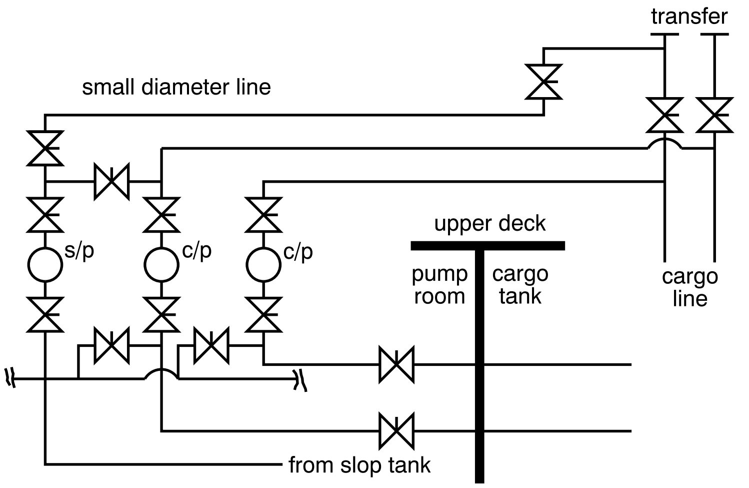
b) means are to be provided to drain all cargo pumps and all oil lines at the completion of cargo discharge, where necessary by connection to a stripping device. The line and pump draining are to be capable of being discharged both by an external transfer and to a cargo tank or a slop tank. For discharge by external transfer, 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 unit's deck manifold valves, both port and starboard, when the cargo is being discharged (see Fig 1).

3.4.6 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.

b) Requirements for inert gas systems are given in Article [4].

Figure 1 : Connection of small diameter line to the manifold valve



4 Inert gas systems

4.1 Application

4.1.1 Units where an inert gas is required

a) Units (in particular storage units such as FPSO, FSO, FSU...) carrying more than 8000 tons of crude oil in bulk in their tanks are to be fitted with an inert gas system complying with the provisions of this Article or with an equivalent fixed installation.

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, loading and offloading and necessary in-tank operations, and
- so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

b) All units operating with a cargo tank cleaning procedure using crude oil washing are to be fitted with an inert gas system complying with the requirements of this Article.

Such system is to be provided in every cargo tank and slop tank.

Units required to be provided with an inert gas system by item a) or b) are to receive the class notation **INERTGAS**.

4.1.2 Units where an inert gas system is not required but provided with the class notation INERTGAS

Inert gas systems provided on units where such systems are not required by [4.1.1] and which are provided with the class notation **INERTGAS** are to comply with the provisions of [4.6].

4.2 Definitions

4.2.1 For the purposes of this Article:

a) Cargo tanks means those cargo tanks, including slop tanks, which carry cargoes, or cargo residues, having a flashpoint not exceeding 60ºC.

b) Inert gas system includes inert gas systems using flue gas, inert gas generators, and nitrogen generators and means the inert gas plant and inert gas distribution together with means for preventing backflow of cargo gases to machinery spaces, fixed and portable measuring instruments and control devices.

c) Gas-safe space is a space in which the entry of gases would produce hazards with regard to flammability or toxicity.

d) Gas-free is a condition in a tank where the content of hydrocarbon or other flammable vapour is less than 1% of the lower flammable limit (LFL), the oxygen content is at least 21%, and no toxic gases are present.

Note 1: Refer to the Revised recommendations for entering enclosed spaces aboard ships (IMO resolution A.1050(27)).

4.3 Requirements for all systems

4.3.1 General

a) The inert gas systems shall be designed, constructed and tested to the satisfaction of the Society. It shall be designed to be capable of rendering and maintaining the atmosphere of the relevant cargo tanks non-flammable.

Note 1: Refer to the Revised standards for the design, testing and locating of devices to prevent the passage of flame into cargo tanks in tankers (MSC/Circ.677, as amended by MSC/Circ.1009 and MSC.1/Circ.1324) and the Revised factors to be taken into consideration when designing cargo tank venting and gas-freeing arrangements (MSC/Circ.731).

b) The system shall be capable of:

1) inerting empty cargo tanks and maintaining the atmosphere in any part of the tank with an oxygen content not exceeding 8% by volume and at a positive pressure in port and at sea except when it is necessary for such a tank to be gas-free;

2) eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas-free;

3) purging empty cargo tanks of hydrocarbon or other flammable vapours, so that subsequent gas-freeing operations will at no time create a flammable atmosphere within the tank;

4) delivering inert gas to the cargo tanks at a rate of at least 125% of the maximum rate of discharge capacity of the ship expressed as a volume, and

5) delivering inert gas with an oxygen content of not more than 5% by volume to the cargo tanks at any required rate of flow.

c) Materials used in inert gas systems shall be suitable for their intended purpose. In particular, those components which may be subjected to corrosive action of the gases and/or liquids are to be either constructed of corrosion-resistant material or lined with rubber, glass fibre epoxy resin or other equivalent coating material.

d) The inert gas supply may be:

1) treated flue gas from main or auxiliary boilers, or

2) gas from an oil or gas-fired gas generator, or

3) gas from nitrogen generators.

The Society may accept systems using inert gases from one or more separate gas generators or other sources or any combination thereof, provided that an equivalent level of safety is achieved. Such systems shall, as far as practicable, comply with the requirements of this article. Systems using stored carbon dioxide shall not be permitted unless the Administration is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.

4.3.2 Safety measures

a) The inert gas system shall be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank.

b) Automatic shutdown of the inert gas system and its components parts shall be arranged on predetermined limits being reached, taking into account the provisions of [4.3.4], [4.4.3] and [4.5.14].

c) Suitable shutoff arrangements shall be provided on the discharge outlet of each generator plant.

d) The system shall be designed to ensure that if the oxygen content exceeds 5% by volume, the inert gas shall be automatically vented to atmosphere.

e) Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If blowers are to be used for gas-freeing, their air inlets shall be provided with blanking arrangements.

f) Where a double block and bleed valve is installed, the system shall ensure upon of loss of power, the block valves are automatically closed and the bleed valve is automatically open.

4.3.3 System components

a) Non-return devices

1) At least two non-return devices shall be fitted in order to prevent the return of vapour and liquid to the inert gas plant, or to any gas-safe spaces.

2) The first non-return device shall be a deck seal of the wet, semi-wet, or dry type or a double-block and bleed arrangement. Two shut-off valves in series with a venting valve in between, may be accepted provided:

- the operation of the valve is automatically executed. Signal(s) for opening/closing is (are) to be taken from the process directly, e.g. inert gas flow or differential pressure; and
- alarm for faulty operation of the valves is provided, e.g. the operation status of “blower stop” and “supply valve(s) open” is an alarm condition.

3) The second non-return device shall be a non-return valve or equivalent capable of preventing the return of vapours and liquids and fitted between the deck water seal (or equivalent device) and the first connection from the inert gas main to a cargo tank. It shall be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided between the non-return valve and the first connection to the cargo tanks to isolate the deck water seal, or equivalent device, from the inert gas main to the cargo tanks.

4) A water seal, if fitted, shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times. The audible and visual alarm on the low level of water in the water seal shall operate at all times.

5) The arrangement of the water seal, or equivalent devices, and its associated fittings shall be such that it will prevent backflow of vapours and liquids and will ensure the proper functioning of the seal under operating conditions.

6) Provision shall be made to ensure that the water seal is protected against freezing, in such a way that the integrity of seal is not impaired by overheating.

7) A water loop or other approved arrangement shall also be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas-safe spaces. Means shall be provided to prevent such loops from being emptied by vacuum.

8) Any water seal, or equivalent device, and loop arrangements shall be capable of preventing return of vapours and liquids to an inert gas plant at a pressure equal to the test pressure of the cargo tanks.

9) The non-return devices shall be located in the cargo area on deck.

b) Inert gas lines

1) The inert gas main may be divided into two or more branches forward of the non-return devices required by item a).

2) The inert gas main shall be fitted with branch piping leading to the cargo tank. Branch piping for inert gas shall be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they shall be provided with locking arrangements. The control system shall provide unambiguous information of the operational status of such valves to at least the control panel required in [4.3.4].

3) Each cargo tank not being inerted shall be capable of being separated from the inert gas main by:

- removing spool-pieces, valves or other pipe sections, and blanking the pipe ends; or
- arrangement of two spectacle flanges in series with provisions for detecting leakage into the pipe between the two spectacle flanges; or
- equivalent arrangements to the satisfaction of the Society, providing at least the same level of protection.

4) Means shall be provided to protect cargo tanks against the effect of overpressure or vacuum caused by thermal variations and/or cargo operations when the cargo tanks are isolated from the inert gas mains.

5) Piping systems shall be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

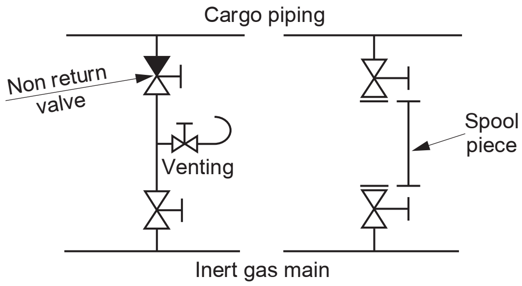
6) Arrangements shall be provided to enable the inert gas main to be connected to an external supply of inert gas. The arrangements shall consist of a 250 mm nominal pipe size bolted flange, isolated from the inert gas main by a valve and located forward of the non-return valve. The design of the flange should conform to the appropriate class in the standards adopted for the design of other external connections in the ship's cargo piping system.

7) If a connection is fitted between the inert gas main and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. This shall consist of two shutoff valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks.

8) The valve separating the inert gas main from the cargo main and which is on the cargo main side shall be a non-return valve with a positive means of closure (see Fig 2).

9) Inert gas piping systems shall not pass through accommodation, service and control station spaces.

Figure 2 : Effective isolation between cargo and inert gas piping



4.3.4 Indicators and alarms

a) The operation status of the inert gas system shall be indicated in a control panel.

b) Instrumentation shall be fitted for continuously indicating and permanently recording, when inert gas is being supplied:

   1) the pressure of the inert gas mains forward of the non-return devices; and

   2) the oxygen content of the inert gas.

c) The indicating and recording devices shall be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

d) In addition, meters shall be fitted:

   1) in the central control station, and navigating bridge if any, to indicate at all times the pressure referred to in item b) 1); and

   2) in the machinery control room or in the machinery space to indicate the oxygen content referred to in item b) 2).

e) Audible and visual alarms

   1) Audible and visual alarms shall be provided, based on the system designed, to indicate:

      - oxygen content in excess of 5% by volume (see also item e) 2));
      - failure of the power supply to the indicating devices as referred to in item b);
      - gas pressure less than 100 mm water gauge (see also item e) 2));
      - high-gas pressure; and
      - failure of the power supply to the automatic control system (see also item e) 2)).

   2) The alarms required in item e) 1) for:

      - oxygen content
      - gas pressure less than 100 mm water gauge, and
      - failure of the power supply to the automatic control system,

      shall be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

   3) An audible alarm system independent of that required in item e) 1) for gas pressure less than 100 mm water gauge, or automatic shutdown of cargo pumps shall be provided to operate on predetermined limits of low pressure in the inert gas main being reached.

   4) Two oxygen sensors shall be positioned at appropriate locations in the space or spaces containing the inert gas system. If the oxygen level falls below 19%, these sensors shall trigger alarms, which shall be both visible and audible inside and outside the space or spaces and shall be placed in such a position that they are immediately received by responsible members of the crew.

4.3.5 Instruction manuals

Detailed instruction manuals shall be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system.

Note 1: Refer to the Revised Guidelines for inert gas systems (MSC/Circ.353), as amended by MSC/Circ.387.

The manuals shall include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

4.4 Requirements for flue gas and inert gas generator systems

4.4.1 Application

In addition to the provisions in [4.3], for inert gas systems using flue gas or inert gas generators, the provisions of this sub-article shall apply.

4.4.2 System requirements

a) Inert gas generators

1) Two fuel oil pumps shall be fitted to the inert gas generator. Suitable fuel in sufficient quantity shall be provided for the inert gas generators.

2) The inert gas generators shall be located outside the cargo tank area. Spaces containing inert gas generators shall have no direct access to accommodation service or control station spaces, but may be located in machinery spaces. If they are not located in machinery spaces, such a compartment shall be separated by a gastight steel bulkhead and/or deck from accommodation, service and control station spaces. Adequate positive-pressure-type mechanical ventilation shall be provided for such a compartment.

b) Gas regulating valves

1) A gas regulating valve shall be fitted in the inert gas main. This valve shall be automatically controlled to close, as required in [4.3.2], item b). It shall also be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the inert gas flow rate.

2) The gas regulating valve shall be located at the forward bulkhead of the forward most gas-safe space through which the inert gas main passes.

c) Cooling and scrubbing arrangement

1) Means shall be fitted which will effectively cool the volume of gas specified in [4.3.1], item b) and remove solids and sulphur combustion products. The cooling water arrangements shall be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision shall also be made for an alternative supply of cooling water.

2) Filters or equivalent devices shall be fitted to minimize the amount of water carried over to the inert gas blowers.

d) Blowers

1) At least two inert gas blowers shall be fitted and be capable of delivering to the cargo tanks at least the volume of gas required by [4.3.1], item b). For systems fitted with inert gas generators the Society may permit only one blower if that system is capable of delivering the total volume of gas required by [4.3.1], item b) to the cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.

2) Where inert gas generators are served by positive displacement blowers, a pressure relief device shall be provided to prevent excess pressure being developed on the discharge side of the blower.

3) When two blowers are provided, the total required capacity of the inert gas system shall be divided evenly between the two and in no case is one blower to have a capacity less than 1/3 of the total required.

e) Inert gas isolating valves

For systems using flue gas, flue gas isolating valves shall be fitted in the inert gas mains between the boiler uptakes and the flue gas scrubber. These valves shall be provided with indicators to show whether they are open or shut, and precautions shall be taken to maintain them gastight and keep the seatings clear of soot. Arrangements shall be made to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

f) Prevention of flue gas leakage

1) Special consideration shall be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.

2) To permit safe maintenance, an additional water seal or other effective means of preventing flue gas leakage shall be fitted between the flue gas isolating valves and scrubber or incorporated in the gas entry to the scrubber.

4.4.3 Indicators and alarms

a) In addition to the requirements in [4.3.4], item b), means shall be provided for continuously indicating the temperature of the inert gas at the discharge side of the system, whenever it is operating.

b) In addition to the requirements in [4.3.4], item e), audible and visual alarms shall be provided to indicate:

- insufficient fuel oil supply to the oil-fired inert gas generator;
- failure of the power supply to the generator;
- low water pressure or low water flow rate to the cooling and scrubbing arrangement;
- high water level in the cooling and scrubbing arrangement;
- high gas temperature;
- failure of the inert gas blowers; and
- low water level in the water seal.

4.5 Requirements for nitrogen generator systems when inert gas is required

4.5.1 The following requirements apply where a nitrogen generator system is fitted on board as required by [4.1.1]. For the purpose, the inert gas is to be produced by separating air into its component gases by passing compressed air through a bundle of hollow fibres, semi-permeable membranes or adsorber materials.

4.5.2 In addition to the provisions in [4.3], for inert gas systems using nitrogen generators, the provisions of the present Article apply.

4.5.3 the nitrogen generator system is to comply with Ch 1, Sec 16, [2.2.2]and Ch 1, Sec 16, [2.1.11].

4.5.4 A nitrogen generator is to consist of a feed air treatment system and any number of membrane or adsorber modules in parallel necessary to meet the requirements of [4.3.1], item b) 4).

4.5.5 The nitrogen generator is to be capable of delivering high purity nitrogen in accordance with, item b) 5). In addition to, item d), the system is to be fitted with automatic means to discharge “off-spec” gas to the atmosphere during start-up and abnormal operation.

4.5.6 The system shall be provided with one or more compressors to generate enough positive pressure to be capable of delivering the total volume of gas required by [4.3.1], item b).

4.5.7 Where two compressors are provided, the total required capacity of the system is preferably to be divided equally between the two compressors, and in no case is one compressor to have a capacity less than 1/3 of the total capacity required.

4.5.8 A feed air treatment system shall be fitted to remove free water, particles and traces of oil from the compressed air.

4.5.9 It is also to preserve the specification temperature.

4.5.10 The oxygen-enriched air from the nitrogen generator and the nitrogen-product enriched gas from the protective devices of the nitrogen receiver are to be discharged to a safe location on the open deck.

Note 1: “safe location” needs to address the two types of discharges separately:

- oxygen-enriched air from the nitrogen generator - safe locations on the open deck are:
  - outside of hazardous area;
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets
- nitrogen-product enriched gas from the protective devices of the nitrogen receiver - safe locations on the open deck are:
  - not within 3m of areas traversed by personnel; and
  - not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

4.5.11 In order to permit maintenance, means of isolation are to be fitted between the generator and the receiver.

4.5.12 The air compressor and nitrogen generator may be installed in the engine-room or in a separate compartment. A separate compartment and any installed equipment shall be treated as an “Other machinery space” with respect to fire protection. Where a separate compartment is provided for the nitrogen generator, the compartment shall be fitted with an independent mechanical extraction ventilation system providing six air changes per hour. The compartment is to have no direct access to accommodation spaces, service spaces and control stations.

4.5.13 Where a nitrogen receiver or a buffer tank is installed, it may be installed in a dedicated compartment, in a separate compartment containing the air compressor and the generator, in the engine room, or in the cargo area. Where the nitrogen receiver or a buffer tank is installed in an enclosed space, the access shall be arranged only from the open deck and the access door shall open outwards. Adequate, independent mechanical ventilation, of the extraction type, shall be provided for such a compartment.

4.5.14 Indicators and alarms

a) In addition to the requirements in [4.3.4], item b), instrumentation is to be provided for continuously indicating the temperature and pressure of air at the suction side of the nitrogen generator.

b) In addition to the requirements in [4.3.4], item e), audible and visual alarms shall be provided to include:
   - failure of the electric heater, if fitted;
   - low feed-air pressure or flow from the compressor;
   - high-air temperature; and
   - high condensate level at automatic drain of water separator.

4.6 Requirements for nitrogen generator / inert gas system when fitted but not required

4.6.1 Nitrogen/inert gas systems fitted on units for which an inert gas system is not required are to comply with the following requirements.

4.6.2 Requirements of:

- [4.3.2], item b)
- [4.3.2], item d)
- [4.3.4], item b)
- [4.3.4], item c)
- [4.3.4], item e) 1) regarding oxygen content and power supply to the indicating devices
- [4.3.4], item e) 4)
- [4.5.6], [4.5.8], [4.5.12], [4.5.13] and
- [4.5.14]

apply to the systems.

5 Hydrocarbon blanket gas system

5.1 General

5.1.1 Application

In addition to the inert gas system required in the present Section, an hydrocarbon blanket gas system may be installed. It will help to reduce Volatile Organic Compound (VOC) releases to atmosphere.

If a hydrocarbon blanket gas system is installed, a cargo tank vents recovery system referred to in Ch 1, Sec 16, [3] shall also be fitted.

5.1.2 Principles

The principle of the hydrocarbon blanket gas system is to replace the use of inert gas with pure hydrocarbon (HC) blanket gas in the cargo tanks and to recover the off gas.

Gas from the process will be used as blanket gas during cargo tank offloading. During loading the gas emitted from the cargo tanks will be recovered and recycled in the process plant.

5.1.3 General prescriptions

a) The inert gas system required by the provision of [4.1.1] will remain as a backup system in case the hydrocarbon blanket gas sources are not available (e.g. production stopped), or if there is a need to gas free cargo tanks for purposes such as maintenance.

b) When using inert gas as blanket gas, the blanket gas recovery system is to be shutdown to prevent inert gas entering the re-compression train.

c) The hydrocarbon blanket gas system is to be designed, constructed and tested to the satisfaction of the Society.

d) Throughout the present [5], the term “cargo tanks” includes also slop tanks.

e) Detailed instruction manuals are to be provided on board, covering the operations (including first time start up, change-over from inert to hydrocarbon blanket gas and gas freeing), safety and maintenance requirements.

f) Piping, fittings and mechanical parts of this hydrocarbon blanket gas system are to comply with [3.3.1] and are to be designed for the hydrocarbon blanket gas maximum possible supply temperature and pressure.

g) Equipment must be suitable for the hazardous area where they are located.

h) This hydrocarbon blanket gas system is to remain within the cargo area.

i) The limit of the scope of Classification (without **PROC** notation) is generally:
   - upstream at the gas regulating valve referred to in [5.6.1]
   - downstream as defined in Ch 1, Sec 16, [3.2.1].

j) Depending on the findings of the HAZOP studies, the Society may raise additional requirements.

5.1.4 Documents to be submitted

The following documents are to be submitted for review:

- process and instrumentation diagrams of the hydrocarbon blanket gas system and of its connection to the cargo tanks system, to the inert gas system, to the venting systems and to the cargo tank vents recovery system referred to in Ch 1, Sec 16, [3]
- cause and effect diagram for the system
- settings of the pressure/vacuum protection devices
- HAZID and HAZOP studies of the system
- explosion hazard study which investigates hydrocarbon leaks from tank hatches or hydrocarbon blanket gas pipes.

5.2 Materials

5.2.1 Coating of the cargo tanks shall be suitable for the hydrocarbon blanket gas composition.

5.3 Piping system

5.3.1 Piping systems are to be so designed as to prevent the accumulation of hydrocarbon blanket gas in the pipelines under all normal conditions.

5.3.2 Arrangements are to be made to limit the carriage of water present in hydrocarbon blanket gas in the cargo tanks.

5.3.3 Arrangements are to be made to ensure an effective isolation of the cargo tanks and the hydrocarbon blanket gas supply source. This may consist in a fast closing shut-down valve.

5.4 Capacity of the system

5.4.1 The hydrocarbon blanket gas supply capacity shall be at least 125% of maximum offloading rate at cargo tank conditions.

5.5 Venting arrangement and pressure/ vacuum protection

5.5.1 As a general rule, the venting and pressure/vacuum protection systems are to be so designed that the minimum and maximum pressures exerted on any cargo tank considering the process systems will not exceed the test pressures of any cargo tank.

5.5.2 As a general rule, the arrangement of the venting and pressure/vacuum protection systems shall ensure that no flammable mixtures will be present in the cargo tanks.

5.5.3 Relief capacity of the venting arrangements required in Ch 1, Sec 16, [2.2] shall be designed considering the possible maximum hydrocarbon blanket gas supply if one tank is loaded with all gas connections isolated.

5.5.4 The vacuum protection system is to be designed considering a flow rate equal to the maximum offloading rate from the cargo tanks.

5.5.5 Settings of the pressure/vacuum protection system shall take into account the hydrocarbon blanket gas supply and recovery and shall remain within the range defined in Ch 1, Sec 16, [2.1.7].

5.5.6 Cargo vents, if discharged to the atmosphere, shall be led to well-ventilated safe areas.

5.6 Instrumentation

5.6.1 A gas regulating valve is to be fitted in the hydrocarbon blanket gas supply line upstream the shutdown valve mentioned in [5.3.3].

5.6.2 In addition to instrumentation devices and alarms required in Ch 1, Sec 16, [3.8.2] the following are to be provided for continuously recording and indicating:

a) pressure in each individual cargo tank protected by the hydrocarbon blanket gas system

   The pressure loss from the cargo tank to this transmitter is to be as low as possible.

b) temperature of the hydrocarbon blanket supply gas upstream the gas regulating valve mentioned in [5.6.1]

c) oxygen content in each individual cargo tank protected by the hydrocarbon blanket gas system.

Note 1: The oxygen analysis continuously performed on a tank by tank sequential basis is acceptable.

5.6.3 The alarms referred to in [5.6.2] are to be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

5.7 Safeguards

5.7.1 In addition to safeguards required in Ch 1, Sec 16, [3.9] the following are to be provided:

a) automatic shutdown of the shutdown valve mentioned in [5.3.3] and of the hydrocarbon blanket gas system is to be arranged on predetermined limits being reached in respect of [5.6.2], item a) (High)

b) automatic shutdown of the cargo offloading or transfer pumps is to be arranged on predetermined limits being reached in respect of [5.6.2], item a) (Low)

c) automatic shutdown of the cargo offloading or transfer pumps is to be arranged in respect of [5.6.2] item c), when the oxygen content exceeds 5% by volume

d) automatic shutdown of the hydrocarbon blanket gas supply is to be arranged in respect of Ch 1, Sec 16, [3.8.2] item e) (failure of the recovery equipment)].

Note 1: These requirements may be adapted based on the findings and conclusions of the HAZOP report.

5.8 Miscellaneous

5.8.1 An adequate automatic gas detection system complying with Pt C, Ch 4, Sec 5, [4] is to be fitted on the main cargo deck.

5.8.2 Any tank that is prepared for maintenance/inspection activities is to be kept isolated from all the other tanks hydrocarbon blanket.

5.8.3 Depending on findings of the HAZOP studies, the Society may raise additional requirements.

6 Cargo and slop tanks fittings

6.1 Application

6.1.1 Requirements of the present [6] are complementary to relevant requirements of Part C, Chapter 1 which remain applicable.

6.2 Protection of cargo and slop tanks against overfilling

6.2.1 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 [6.3].

6.2.2 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 central control room, where provided.

6.2.3 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 [6.2.1] 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 [6.3]. 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 [6.2.1] are considered as complied with.

6.3 Cargo and slop tanks level gauging systems

6.3.1 General

a) Each cargo or slop tank is to be fitted with a level gauging system indicating the liquid level along the entire height of the tank. Unless otherwise specified, the gauge may be portable or fixed with local reading.

b) Gauging devices and their remote reading systems are to be type approved.

c) Ullage openings and other gauging devices likely to release cargo vapour to the atmosphere are not to be arranged in enclosed spaces.

6.3.2 Definitions

a) A “restricted gauging device” means a device which penetrates the tank and which, when in use, permits a small quantity of vapour or liquid to be exposed to the atmosphere. When not in use, the device is completely closed. Examples are sounding pipes.

b) A “closed gauging device” means a device which is separated from the tank atmosphere and keeps tank contents from being released. It may:

   1) penetrate the tank, such as float-type systems, electric probe, magnetic probe or protected sight glass

   2) not penetrate the tank, such as ultrasonic or radar devices.

c) An “indirect gauging device” means a device which determines the level of liquid, for instance by means of weighing or pipe flow meter.

6.3.3 Units fitted with an inert gas system

a) In units fitted 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.

6.3.4 Units not fitted with an inert gas system

a) In units not fitted with an inert gas system, the gauging devices are to be of the closed or restricted types. Ullage openings may be used only as a reserve sounding means and are to be fitted with a watertight closing appliance.

b) Where restricted gauging devices are used, provisions are to be made to:

1) avoid dangerous escape of liquid or vapour under pressure when using the device

2) relieve the pressure in the tank before the device is operated.

c) Where used, sounding pipes are to be fitted with a self-closing blanking device.

6.4 Heating systems intended for cargo and slop tanks

6.4.1 General

a) Heating systems intended for cargo are to comply with the relevant requirements of Part C, Chapter 1.

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 Pt C, Ch 1, Sec 7. They are to have welded connections only.

6.4.2 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:

a) they are to be independent of other unit services, except cargo heating or cooling systems, and are not to enter machinery spaces, or

b) 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.

6.4.3 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:

a) means for detection of flammable vapours

b) a vent pipe led to the open and provided with a flame arrester.

6.4.4 Thermal oil heating

Thermal oil heating systems serving cargo tanks are to be arranged by means of a separate secondary system, located completely within the cargo area. However, a single circuit system may be accepted, provided that:

a) the system is so arranged as to ensure a positive pressure in the coil of at least 3 meter water column above the static head of the cargo when the circulating pump is not in operation

b) means are provided in the expansion tank for detection of flammable cargo vapours. Portable equipment may be accepted

c) valves for the individual heating coils are provided with a locking arrangement to ensure that the coils are under static pressure at all times.

6.5 Cleaning of cargo and slop tanks

6.5.1 Adequate means are to be provided for cleaning the cargo tanks.

6.5.2 Units having a storage capacity of 20 000 tons of crude oil and above is to be fitted with a cargo tanks cleaning system using crude oil washing complying with the following requirements. Unless the cargo stored in such unit is not suitable for crude oil washing, the unit is to operate the system with the following requirements.

Note 1: The crude oil washing installation and associated equipment and arrangements are to comply with the requirements of MARPOL 73/78 Annex I convention and IMO Resolution A.446(XI) as amended by Resolutions A.497(XII) and A.897(21). The sentence of resolution A. 446(XI) paragraph 4.4.4 "... Suitable arrangements for hand dipping are to be provided at the aftermost portion of a cargo tank..." is to be read "...Suitable arrangements for hand dipping are to be provided at the lowest portion of a tank at the operating trim..."

6.5.3 Every offshore unit operating with crude oil washing system is to be provided with an Operations and Equipment Manual detailing the system and equipment and specifying operational procedures such a manual is to be to the satisfaction of the Society and is to contain all the information set out in Note 1 of [6.5.2]. If an alteration affecting the crude oil washing system is made, the Operating and Equipment Manual is to be revised accordingly.

Note 1: For the Standard format of the Crude Oil Washing Operation and Equipment Manual reference is made to the IMO Resolution MEPC.3(XII) as amended by IMO Resolution MEPC.81(43).

6.5.4 Fixed or portable tank washing machines are to be of a type approved by the Society.

Note 1: Washing machines are to be made of steel or other electricity conducting materials with a limited propensity to produce sparks on contact.

6.5.5 Fixed washing machines are to be installed and secured to the satisfaction of the Society. They are to be isolated by a valve or equivalent device.

6.5.6 Washing pipes are to be built, fitted, inspected and tested in accordance with the requirements of Part C, Chapter 1 and of other documents referred to in this Chapter applicable to pressure piping, depending of the kind of washing fluid, water or crude oil.

6.5.7 Washing machines of floating storage units using a crude oil washing system are to be fixed.

6.5.8 Crude oil washing pipes are to satisfy the requirements of [3] applicable to cargo pipes. However, crude oil washing machines may be connected to water washing pipes, provided that isolating arrangements, such as a valve and a detachable pipe section, are fitted to isolate water pipes.

6.5.9 Crude oil washing pipes, if used for water washing operations, are to be fitted with efficient drainage means.

6.5.10 If crude oil and water washing pipes are not separated, the washing water heater is to be placed outside the engine room and is to be isolated by valves or other equivalent clearly marked arrangements.

6.5.11 The installation of the washing systems is to comply with the following provisions:

a) tank cleaning openings are not to be arranged in enclosed spaces

b) the complete installation is permanently earthed to the hull.

6.6 Cathodic protection

6.6.1 Unless specially authorised by the Society, impressed current cathodic protection systems are not to be used in cargo oil or slop tanks.

6.6.2 Aluminium or magnesium alloy anodes are not to be used in cargo and slop tanks.

6.6.3 Aluminium anodes are permitted in cargo and slop tanks only if their potential energy does not exceed 0,275 kJ, the height of the anode being measured from the tank bottom to the centre of the anode and its weight being the total weight, including the securing devices.

Where an aluminium anode is fitted above an horizontal surface such as a bulkhead stiffener, and provided that the stiffener measures at least 1 m in width and comprises a flange extending at least 75 mm above its horizontal surface, the anode height may be measured to the horizontal surface of the stiffener.

Aluminium anodes are not to be located under access hatches or washing holes unless they are protected by the adjacent structure.

6.6.4 In all cases, the anodes are to be properly secured to the structure.

6.6.5 As a general rule, the requirements of the present [6.6] are applicable also to compartments adjacent to cargo or slop tanks.

6.7 Aluminium paints

6.7.1 Aluminium paints are not to be used in cargo and slop tanks, pump rooms, cofferdams, or wherever dangerous vapours may gather unless it is justified by tests that the paints utilised do not increase the risk of spark production.

7 Bow or stern cargo oil transfer

7.1 General

7.1.1 Bow or stern cargo transfer installations are to comply with the applicable requirements of [3] and [7.2]. Portable arrangements are not permitted.

7.2 Piping requirements

7.2.1 Cargo piping outside the storage area is to be clearly identified and fitted with shut-off valves at connections to the cargo piping system within the storage area and, where applicable, at junctions with flexible hose(s) or articulated piping used for connection with single point mooring or riser.

Note 1: The piping outside the cargo area is to be fitted with a shut-off valve at its connection with the piping system within the cargo area and separating means such as blank flanges or removable spool pieces are to be provided when the piping is not in use, irrespective of the number and type of valves in the line.

7.2.2 Article [3] is applicable. Moreover, pipe connections outside the storage area are to be of welded type only.

7.2.3 Arrangements are to be made to allow piping to be efficiently drained and purged.

7.3 Openings

7.3.1 Openings are to comply with Ch 1, Sec 17, [7.2.5].

7.4 Coamings

7.4.1 Continuous coamings of suitable height are to be fitted to keep spills on deck and away from the accommodation and service areas.

Escape routes are not to terminate within the limits of these coamings or within a distance of 3 m from them.

The zones within the limits and a distance of 3 m beyond these coamings are considered as hazardous zones 1 or 2, according to Ch 1, Sec 17, [2.2].

7.5 Fire fighting

7.5.1 Where the loading and offloading areas of the unit are not protected by the fixed deck foam system required in Ch 1, Sec 17, [7.5], 2 additional foam monitors or applicators are to be provided to protect these areas.

7.6 Fire-fighting system

7.6.1 The fixed foam fire-fighting system provided for the application of Ch 1, Sec 17, [7.5] is to permit the protection of the transfer zone by at least two foam applicators.

7.7 Remote shut-down

7.7.1 Provision is to be made for the remote shut-down of cargo pumps from the cargo transfer location.

Means of communication between the loading control station and the cargo transfer location are to be provided and certified safe, if necessary.

Section 19 Use of Process Gas and Crude Oil as Fuel

1 General

1.1 Application

1.1.1 This Section addresses the design of machinery fuelled with process gas or crude oil, as well as the arrangement of the spaces where such machinery is located.

1.2 Additional requirements

1.2.1 Additional requirements for machinery are given in Pt C, Ch 1, App 4 and NR467 Pt C, Ch 1, App 2, which address the design of dual fuel engines supplied by low pressure gas and dual fuel gas turbines.

1.3 Documents to be submitted

1.3.1 The drawings and documents to be submitted for gas fuelled installations are listed in NR481, Design and Installation of Dual Fuel Engines Using Low Pressure Gas.

1.3.2 The drawings and documents to be submitted for crude oil fuelled installations are to include at least:
- general arrangement of the engine or boiler compartment
- general arrangement of the auxiliary compartment
- diagram and PID for crude oil and fuel oil (HFO/MDO) systems inside auxiliary compartment and engine or boiler compartment
- ventilation diagram and location of the crude oil vapour detectors
- details of the pipe ducting system (on the engine or boiler and external) and hoods, where provided
- details of the leakage detection system
- specification of the engines or boilers, auxiliary systems, electrical equipment, etc.
- risk analysis covering the operation of the engines on crude oil as well as the possible presence of crude oil vapours in the machinery spaces.

1.4 Definitions

1.4.1 Low pressure / high pressure gas

Low pressure gas means gas with a maximum service pressure less than or equal to 50 bar gauge.

1.4.2 Engine

"Engine" means either a diesel engine or a gas turbine.

1.4.3 Dual fuel engine (or boiler)

A dual fuel engine (or boiler) is an engine (or boiler) which can be operated with liquid fuel (MDO or HFO) and gaseous fuel.

1.4.4 Crude oil engine (or boiler)

A crude oil engine (or boiler) is an engine (or boiler) which can be operated either with liquid fuel (MDO or HFO) or with crude oil, successively.

2 Requirements applicable to process gas and to crude oil

2.1 Principle

2.1.1 Engines (or boilers) intended to burn process gas or crude oil are also to be capable of burning bunker fuel oils (MDO or HFO) in case of failure of the process gas or crude oil supply.

2.1.2 The arrangement of the machinery spaces containing dual fuel or crude oil engines or boilers, the distribution of the engines or boilers and the design of the safety systems are to be such that, in case of any gas or crude oil vapours leakage, the automatic safety actions will not result in all engines or boilers being disabled. Provisions are to be made to maintain the essential services of the unit in such case.

2.1.3 The use of gases heavier than air is not permitted in machinery spaces, except if it is demonstrated that the geometry of the space bottom and the arrangement of the ventilation system preclude any risk of gas accumulation.

2.2 Ventilation

2.2.1 Spaces in which gas fuel or crude oil is utilized are to be fitted with a mechanical ventilation system and are to be arranged in such a way as to prevent the formation of dead spaces. Such ventilation is to be particularly effective in the vicinity of electrical equipment and machinery or of other equipment or machinery which may generate sparks. Such a ventilation system is to be separated from those intended for other spaces.

2.3 Gas detection

2.3.1 Combustible gas detectors are to be fitted in all machinery spaces where gas or crude oil is utilized, particularly in the zones where air circulation is reduced. Hydrogen sulphide detectors are also to be fitted unless means for sulphur removal are provided. The gas detection systems is to comply with the requirement of Pt C, Ch 4, Sec 5, [4].

2.3.2 Gas detectors are also to be provided where required in Articles [3] and [4], i.e. in ducts containing gas or crude oil pipes, hoods, etc.

2.4 Electrical equipment

2.4.1 Electrical equipment installed in gas dangerous areas or in areas which may become dangerous (such as hoods, ducts or covers in which gas or crude-oil piping is placed) is to be of certified safe type as required by Pt C, Ch 2, Sec 15.

3 Use of process gas

3.1 Gas conditioning and storage conditions

3.1.1 General

The installations required for conditioning the gas for use in boilers or engines (heating, compression, etc.) and possible storage are to be situated on the weather deck in the storage area, due precautions being taken for the protection of these installations against the sea and for their free access under normal circumstances. If those installations are situated in closed rooms on the weather deck, such rooms are to be efficiently exhaust ventilated by means of a mechanical ventilating system completely independent from the other ventilation systems of the unit and fitted with gas detectors. These rooms are to communicate with the outside only.

The scantlings and construction of the various pressure parts of the installation are to comply with the applicable requirements of the present chapter and of Pt C, Ch 1, Sec 3 (pressure equipment) and Pt C, Ch 1, Sec 7 (piping systems).

3.1.2 Heaters - Coolers

Operation of the heaters/coolers is to be automatically regulated according to the temperature of the gas at the outlets.

Before their possible return to the machinery compartments, the heating/cooling fluids are, normally, to pass through a gas freeing tank fitted with a pipe provided with a gas detector and exhausting to the open air.

3.1.3 Compressors

Discharge of the compressors is to be automatically stopped:

- when the suction pressure falls below the atmospheric pressure or a pressure determined as a function of the setting of the crude oil tank vacuum safety valves
- when the discharge pressure or the pressure in the crude oil tanks reaches a value determined as a function of the setting of the safety valves fitted on the high pressure side of the compressors or on the crude oil storage tanks
- in case of lowering of the temperature of the gas at the heater outlets.

The compressors are to be capable of being remotely stopped from a place easily accessible at all times as well as from the machinery compartment.

3.1.4 Reducing valves

The reducing valves provided on the gas system are to be installed as specified in [3.1.1].

The reducing valves are to be fitted on the low pressure side.

3.1.5 Protection against overpressure

The usual overpressure safety devices are to be fitted. This is applicable, in particular, to safety valves on the compressors, crude oil storage tanks and, possibly, heaters, all such safety valves discharging in the open air.

3.2 Gas fuel supply to engines and boilers

3.2.1 General

Gas fuel piping for engine and boiler supply is not to pass through accommodation spaces, services spaces, or control stations. Gas fuel piping may pass through or extend into other spaces provided its design fulfils the provisions of Tab 1.

If a gas leak occurs, the gas fuel supply should not be restored until the leak has been found and repaired. Instructions to this effect should be placed in a prominent position in the machinery spaces.

Table 1 : Design principle of the gas fuel piping

Working pressure (bar)	Nature of the gas	
	Lighter than air	Heavier than air
≤10	• double-walled piping according to [3.2.2], or • safeguarded machinery spaces according to [3.2.3] **(1)**	double-walled piping according to [3.2.2]
>10	double-walled piping according to [3.2.2]	
(1) "Safeguarded machinery spaces" arrangement is subject to the agreement of the Flag Administration.		

3.2.2 Double-walled piping arrangement

a) *Double-walled piping systems are to fulfil one of the following:*

1) *the gas fuel piping should be of a double-wall piping system with the gas fuel contained in the inner pipe. The space between the concentric pipes should be pressurized with inert gas at a pressure greater than the gas fuel pressure. Suitable alarms should be provided to indicate the loss of inert gas pressure between the pipes.* The pressure in the space between the concentric pipes is to be continuously monitored. An alarm is to be issued and the two automatic valves on the gas fuel line and the master gas valve referred to in [3.2.7] are to be closed before the pressure drops to below the inner pipe pressure. At the same time, the interlocked venting valve is to be opened. The inside of the gas fuel supply piping system between the master gas valve and the engine is to be automatically purged with inert gas when the master gas valve is closed*; or*

2) *the gas fuel piping should be installed within a ventilated pipe or duct. The air space between the gas fuel piping and inner wall of this pipe or duct should be equipped with mechanical exhaust ventilation having a capacity of at least 30 air changes par hour. The ventilation system should be arranged to maintain a pressure less than the atmospheric pressure. The fan motors should be placed outside the ventilated pipe or duct. The ventilation outlet should be placed in a position where no flammable gas-air mixture may be ignited. The ventilation should always be in operation when there is gas fuel in the piping. Continuous gas detection should be provided to indicate leaks. It should activate the alarm at 30% of the lower flammable limit and shut down the gas the master gas fuel valve referred to in [3.2.7] before the gas concentration reaches 60% of the lower flammable limit. The master gas fuel valve should close automatically if the required air flow is not established and maintained by the exhaust ventilation system.*

   The air intakes of the mechanical ventilation system are to be provided with non-return devices effective for gas fuel leaks. However, if a gas detector is fitted at the air intake, this requirement may be dispensed with.

   The materials, construction and strength of protection pipes or ducts and mechanical ventilation systems are to be sufficiently durable against bursting and rapid expansion of high pressure gas in the event of gas pipe burst.

b) *The double-wall piping system of the ventilated pipe or duct provided for the gas fuel piping should terminate at the ventilation hood or casing required by [3.2.9].*

3.2.3 Arrangement of the "safeguarded machinery spaces"

Where permitted, safeguarded machinery spaces arranged in accordance with the following provisions may be accepted as an alternative to [3.2.2]:

a) Volume of the machinery spaces

   The volume of the machinery spaces is to be kept as low as practicable, to facilitate the ventilation and gas detection.

b) Piping arrangement

   Pipes are to be installed as far as practicable from hot surfaces and electrical equipment.

c) Ventilation

   The machinery spaces are to be fitted with a ventilation system of the extraction type complying with the following provisions:

   - the ventilation system is to maintain a pressure less than that of the adjacent spaces, this pressure being permanently monitored
   - the capacity of the ventilation system is to be at least 30 changes per hour
   - the ventilation system is to be so arranged as to ensure an immediate and effective evacuation of the leaked gas, whatever the location and the extent of the piping damage. In particular, the possibility of gas accumulation in dead spaces is to be precluded

- the exhaust fans are to be of a non-sparking type
- the prime movers of the exhaust fans are to be located outside the concerned space and outside the exhaust ducts serving the compartment. Alternatively, intrinsically safe motors may be used
- the exhaust duct is to be led to a location where there is no risk of ignition.

d) Electrical equipment

The electrical equipment not pertaining to the engine and which is required for the safety of the compartment (such as lighting or ventilation) is to be of a safe type.

In case of gas detection with a concentration reaching 60 percent of the LFL, the other electrical equipment situated in the compartment is to be de-energized by switching off their electrical supply.

e) Gas monitoring systems

At least one gas monitoring system is to be provided in way of each engine, and one in the compartment at the exhaust air outlet.

Gas monitoring systems are to of the continuous type. They are to be so designed as to avoid any false detection. Voting systems or equivalent arrangement are to be considered for this purpose.

f) Validation tests

The efficiency of the ventilation system and gas monitoring installation is to be demonstrated by means of appropriate analysis or tests for all operating cases (number of engines in operation, power developed by the engines, ventilation rate). In particular, the following parameters are to be validated:

- position of the ventilation inlets and outlets
- distribution of the ventilation flows
- number and distribution of the gas detectors.

3.2.4 Class of the gas piping

Class of the gas piping is to comply with the provisions of Tab 2.

Table 2 : Class of gas piping

Gas piping type	Class I	Class II	Class III
Double wall type with pressurized and inerted external pipe (see [3.2.2], item a)1))			
• internal pipe		X	
• external pipe		X	
Double wall type with inerted external pipe or duct (see [3.2.2], item a)2))			
• internal pipe		X	
• external pipe or duct			X
Gas pipe arranged according to the "safeguarded machinery space" (see [3.2.3])	X		
Open-ended gas vent lines			X

3.2.5 Materials

Materials used in gas supply lines are to comply with the relevant provisions of IGC Code, Chapters 5 and 6.

3.2.6 Pipe connections

a) Class I pipes

Class I pipes are to be connected by means of full penetration butt-welded joints. However, welded neck flanges (type A1 according to Pt C, Ch 1, Sec 7, Fig 1) restricted to the minimum necessary for mounting and dismantling purposes may be accepted. All welded joints are to be fully radiographied.

b) Class II pipes

Class II pipes may be connected as required in item a) or by means of slip-on or socked welded flanges. Other piping connections may be accepted by the Society on a case by case basis.

Note 1: Screwed couplings of a type approved by the Society may be used only for accessory lines and instrumentation lines with external diameters of 25 mm or less.

3.2.7 Automatic shut-off valves

a) Block-and-bleed valves

Each gas utilization unit should be provided with a set of three automatic valves. Two of these valves should be in series in the gas fuel pipe to the consuming equipment. The third valve should be in a pipe that vents, to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series. These valves should be arranged so that abnormal pressure in the gas fuel supply line, or failure of the valve control actuating medium will cause the two gas fuel *valves which are in series to close automatically and the vent valve to open automatically. Alternatively, the function of one of the valves in series and the vent valve can be incorporated into one valve body so arranged that, when one of the above conditions occurs, flow to the gas utilization unit will be blocked and the vent opened. The three shutoff valves should be arranged for manual reset.*

Note 1: Block-and-bleed valves are also to be fitted on the pilot burners supply lines.

b) Master gas valves

A master gas fuel valve that can be closed from within the machinery space should be provided within the cargo area. The valve should be arranged so as to close automatically if leakage of gas is detected, or loss of ventilation for the duct or casing or loss of pressurization of the double-wall gas fuel piping occurs.

3.2.8 Gas pressure regulation

When supplying engines, the gas fuel system is to be provided with a pressure regulation system allowing a gas supply to the engines at the required pressure without significant fluctuations, irrespective of the number of engines in operation and of the developed power. Where necessary a buffer tank is to be fitted.

3.2.9 Ventilation hoods and casings

A ventilation hood or casing should be provided for the areas occupied by flanges, valves, etc., and for the gas fuel piping, at the gas fuel utilization units, such as boilers, diesel engines or gas turbines. If this ventilation hood or casing is not served by the exhaust ventilation fan serving the ventilated pipe or duct as specified in [3.2.2] a)2), then it should be equipped with an exhaust ventilation system and continuous gas detection should be provided to indicate leaks and to shut down the gas fuel supply to the machinery space in accordance with [3.2.2] a)2). The master gas fuel valve required by [3.2.7] b) should close automatically if the required air flow is not established and maintained by the exhaust ventilation system.

Note 1: When the machinery space is arranged according to the “safeguarded machinery spaces” principle (see [3.2.3]), the ventilation hood or casing is not required.

In the case of gas fuel lighter than air, *the ventilated hood or casing is to be installed or mounted to permit the ventilating air to sweep across the gas utilization unit and be exhausted at the top of the ventilation hood or casing.*

In the case of gas fuel heavier than air, the ventilated hood or casing is to be so arranged as to permit the ventilating air to sweep across the engine or turbine and be exhausted at the bottom of the ventilation hood or casing.

3.3 Dual fuel engines

3.3.1 Dual fuel engines are to be type-approved by the Society.

3.3.2 Dual fuel engines are to be designed so as to operate safely with any gas composition within the unit specification range, taking into account the possible variations of the gas composition during the process operations. Tests are to be conducted to demonstrate their ability in this respect.

3.3.3 The fuel supply is to be capable of being switched over from gas fuel to oil fuel while the engine is running at any load, without significant fluctuation of the engine output nor of the rotational speed.

3.3.4 Prior to a normal stop, the engine is to be switched over from gas fuel to oil fuel.

3.3.5 After each gas operation of the engine not followed by a oil fuel operation, the engine including the exhaust system is to be purged during a sufficient time in order to discharge the gas which may be present.

3.3.6 Engines are to be fitted with a control system allowing a steady running with stable combustion, with any gas composition within the unit specification range, throughout the operating speed range of the engine, in particular at low loads.

3.3.7 Engines are to be so designed and controlled as to avoid any excessive gas delivery to the engine, which may result in the engine overspeed, in particular while the engine is running with gas fuel and oil fuel at the same time.

3.3.8 Gas piping located on the engine is to comply with the provisions of [3.2].

3.4 Dual fuel boilers

3.4.1 Liquid fuel pilot burner

For dual-fuel boilers, a liquid fuel pilot burner is normally to be permanently in service on the boiler when the boiler is working and a safety device is to be fitted to prevent gas supply when this burner is not in service.

However, the gas supply to the boiler without the pilot burner in service may be admitted, subJect to the following arrangements:

- the gas burners are to be ignited by the liquid fuel burners
- the eventual switching to the liquid fuel is to be automatic and as fast as possible in order to shorten the duration of the power loss, taking into account the possible durations for scavenging and pressure recovery

- for this purpose, the liquid fuel burners and their supply piping are always to be kept available during stand-by while gas firing
- the flame detection is to be efficient for all firing conditions
- in the event of a complete loss of flame in the furnace, the ignition procedure of the liquid fuel burners must include an efficient scavenging of the furnace.

3.4.2 Safety devices

Safety devices are to be provided for the automatic stopping of the gas supply to the boiler in the following cases:

- abnormal variation in the pressure of the gas
- abnormal variation in the pressure of the air
- stopping of the forced draught fans
- extinction of the gas burners.

Each burner is to be fitted with a quick closing cock or valve, so designed that the burner cannot possibly be withdrawn without the gas supply being automatically cut off.

Precautions are to be taken to ensure the stability of the flame of the gas burners, specially at low load. A device is to be provided to maintain the ratio air-gas at a suitable value.

Safety devices are to be provided to prevent each boiler from being fired before the combustion chamber is suitably air scavenged.

3.4.3 Automatic burning installations

Automatic burning installations will be subject to special examination by the Society.

3.4.4 Design of combustion chambers

Combustion chambers are to be so designed as to avoid dead zones where gas might accumulate. The Society reserves the right to require gas detectors in such zones, if these cannot be avoided, and additional air inlets to scavenge these zones if necessary.

4 Use of crude oil

4.1 General

4.1.1 Crude oil may be used as fuel for main or auxiliary boilers and for engines according to the following requirements. For this purpose all arrangement drawings of a crude oil installation with pipeline layout and safety equipment are to be submitted for approval in each case.

4.1.2 Crude oil or slops may be taken directly from cargo tanks or from other suitable tanks. These tanks are to be fitted in the cargo tank area and are to be separated from non-gas dangerous areas by means of cofferdams with gas-tight bulkheads.

4.1.3 The construction and workmanship of the engines and boilers, including their burners, are to be proved to be satisfactory operation with crude oil.

4.1.4 Arrangement are to be made to prevent crude oil effluents or vapours from reaching any gas safe compartment or contaminating non-hazardous fluid systems.

4.2 Arrangement of machinery spaces

4.2.1 Boilers and engines supplied with crude oil are to be located in a dedicated space, referred to as “crude oil machinery space”, separated from other machinery spaces by gas-tight bulkheads. This space is not to contain electric and steam prime movers of pumps, of separators, etc., except when steam temperature is less than 220°C.

4.2.2 The whole system of pumps, strainers, separators and heaters, if any, are to be fitted in the cargo pump room or in another room, to be considered as dangerous, and separated from other machinery spaces by gas-tight bulkheads.

4.3 Pumps

4.3.1 Pumps are to be fitted with a pressure relief bypass from delivery to suction side and it is to be possible to stop them by a remote control placed in a position near the boiler fronts, engine local control position or machinery control room and from outside the machinery spaces.

4.3.2 Where drive shafts pass through pump room bulkhead or deck plating, type-approved gas-tight glands are to be fitted. The glands are to be efficiently lubricated from outside the pump room.

4.4 Heating arrangements

4.4.1 General

All crude oil and slop heating systems are to be built, fitted and tested in accordance with the provisions of Pt C, Ch 1, Sec 7. Refer also to Ch 1, Sec 18, [6.4].

The heating medium temperature is not to exceed 220°C.

Heating pipes, unless otherwise accepted by the Society, are to be fitted with valves or equivalent arrangements to isolate them from each tank and manually adjust the flow.

Means are to be provided to prevent the heating medium supply to the tank heating coils when the product which is not to be heated.

Tank heating system is to be so designed that, when in service, the pressure maintained in the system is higher than that exerted by crude oil.

The heating piping system is to be so arranged as to be easily drained in case of contamination by crude oil.

4.4.2 Observation tank

When crude oil is heated by steam or hot water, the outlet of the heating coils is to be led to a separate observation tank installed together with the components mentioned in [4.2.1].

This tank is to be closed and located in a well ventilated position. It is to be fitted with:

- adequate lighting
- a venting pipe led to the atmosphere in a safe position according to Ch 1, Sec 16 and with the outlet fitted with a suitable flame proof wire gauze of corrosion resistant material which is to be easily removable for cleaning
- arrangements for sampling.

4.4.3 Tank heating arrangements

Heating system pipes are to penetrate crude oil storage tanks only at the top.

Pipes fitted inside tanks are to be of reinforced thickness and built of material suitable for heated fluids. Pipe connections inside crude oil or slop tanks, unless otherwise authorised by the Society, are to be hard-soldered or welded, depending on the type of material.

4.4.4 Control and monitoring

Each tank equipped with a heating system is to be provided with arrangements which permit the measurement of the liquid temperature. Portable arrangements may be used, unless otherwise specified by the Society. In that case, the tank opening is to be of a restricted type.

When it is necessary to preheat crude oil or slops, their temperature is to be automatically controlled and a high temperature alarm is to be fitted.

4.5 Piping system

4.5.1 Pipe thickness

The piping for crude oil or slops and the draining pipes referred to in [4.5.5], [4.6.3] and [4.7.3] are to have a thickness complying with Tab 3.

4.5.2 Pipe connections

Crude oil pipes connections are to be of the heavy flange type. They are to be kept to the minimum necessary for inspection and maintenance.

Table 3 : Minimum thickness of crude oil pipes

External diameter d_e of pipe, in mm	Minimum thickness t, in mm
$d_e \leq 82,5$	6,3
$88,9 < d_e \leq 108,0$	7,1
$114,3 < d_e \leq 139,7$	8,0
$152,4 < d_e$	8,8

4.5.3 Master valve

A quick closing master valve is to be fitted on the crude oil supply to each boiler or engine manifold.

4.5.4 Crude oil return and overflow pipes

Crude oil return and overflow pipes are not to discharge into fuel oil tanks. When using fuel oil for delivery to and return from boilers, fuel oil burning units are to be fitted in the boiler room.

Fuel oil delivery to, and returns from, boilers and engines are to be effected by means of a mechanical interlocking device so that running on fuel oil automatically excludes running on crude oil or vice versa.

4.5.5 Crude oil draining pipes and drain tanks

Tanks collecting crude oil drains are to be located in the pump room or in another suitable space, to be considered as dangerous. Such tanks are to be fitted with a vent pipe led to the open in a safe position and with the outlet fitted with wire gauze made of material resistant to corrosion and easily dismountable for cleaning.

Draining pipes are to be fitted with arrangements to prevent the return of gas to the machinery spaces.

4.6 Additional requirements for boilers

4.6.1 Piping arrangement

Within the crude oil machinery spaces and other machinery spaces, crude oil pipes are to be fitted within a metal duct, which is to be gastight and tightly connected to the fore bulkhead separating the pump room and to the tray. This duct (and the enclosed piping) is to be fitted at a distance from the ship's side of at least 20% of the vessel's beam amidships and be at an inclination rising towards the boiler so that the oil naturally returns towards the pump room in the case of leakage or failure in delivery pressure. It is to be fitted with inspection openings with gastight doors in way of connections of pipes within it, with an automatic closing drain-trap placed on the pump room side, set in such a way as to discharge leakage of crude oil into the pump room.

In order to detect leakages, level position indicators with relevant alarms are to be fitted on the drainage tank defined in [4.6.3]. Also a vent pipe is to be fitted at the highest part of the duct and is to be led to the open in a safe position. The outlet is to be fitted with a suitable flame proof wire gauze of corrosion resistant material which is to be easily removable for cleaning.

The duct is to be permanently connected to an approved inert gas system or steam supply in order to make possible:

- injection of inert gas or steam in the duct in case of fire or leakage
- purging of the duct before carrying out work on the piping in case of leakage.

4.6.2 Shut-off valves

In way of the bulkhead to which the duct defined in [4.6.1] is connected, delivery and return oil pipes are to be fitted on the pump room side, with shut-off valves remotely controlled from a position near the boiler fronts or from the machinery control room. The remote control valves should be interlocked with the hood exhaust fans (defined in [4.6.4]) to ensure that whenever crude oil is circulating the fans are running.

4.6.3 Trays and gutterways

Boilers are to be fitted with a tray or gutterway of a height to the satisfaction of the Society and placed in such a way as to collect any possible oil leakage from boilers, valves and connections.

Such a tray or gutterway is to be fitted with a suitable flame proof wire gauze, made of corrosion resistant material and easily dismountable for cleaning. Delivery and return oil pipes are to pass through the tray or gutterway by means of a tight penetration and are then to be connected to the oil supply manifolds.

The tray or gutterway is to be fitted with a draining pipe discharging into a collecting tank complying with the provisions of [4.5.5].

4.6.4 Hoods

Boilers are to be fitted with a suitable hood placed in such a way as to enclose as much as possible of the burners, valves and oil pipes, without preventing, on the other side, air inlet to burner register.

The hood, if necessary, is to be fitted with suitable doors placed in such a way as to enable inspection of and access to oil pipes and valves placed behind it. It is to be fitted with a duct leading to the open in a safe position, the outlet of which is to be fitted with a suitable flame wire gauze, easily dismountable for cleaning. At least two mechanically driven exhaust fans having spark proof impellers are to be fitted so that the pressure inside the hood is less than that in the boiler room. The exhaust fans are to be connected with automatic change over in case of stoppage or failure of the one in operation.

The exhaust fan prime movers are to be placed outside the duct and a gas-tight bulkhead penetration is to be arranged for the shaft.

4.6.5 Gas detection

A gas detection plant is to be fitted with intakes:

- in the duct defined in [4.6.1]
- in the hood duct (downstream of the exhaust fans in way of the boilers) referred to in [4.6.4]
- in all zones where ventilation may be reduced.

An optical warning device is to be installed near the boiler fronts and in the machinery control room. An acoustical alarm, audible in the machinery space and control room, is to be provided.

4.6.6 Boiler purging

Means are to be provided for the boiler to be automatically purged before firing.

4.6.7 Pilot burner

One pilot burner in addition to the normal burning control is required.

4.6.8 Fire safety

Independent of the fire extinguishing plant as required by Rules, an additional fire extinguishing plant is to be fitted in the boiler room in such a way that it is possible for an approved fire extinguishing medium to be directed on to the boiler fronts and on to the tray defined in [4.6.3]. The emission of extinguishing medium is to automatically stop the exhaust fan of the boiler hood (see [4.6.2]).

A warning notice must be fitted in an easily visible position near the boiler front. This notice must specify that when an explosive mixture is signalled by the gas detection plant defined in [4.6.5] the watchkeepers are to immediately shut off the remote controlled valves on the crude oil delivery and return pipes in the pump room, stop the relative pumps, inject inert gas into the duct defined in [4.6.1] and turn the boilers to normal running on fuel oil.

4.7 Additional requirements for engines

4.7.1 General

Engines and their crude oil supply system are to comply with the applicable provisions of [4.6] and with the following requirements.

4.7.2 Arrangement of the crude oil piping system fitted to the engine

Crude oil pipes fitted to the engine are to be placed within a duct or covers complying with the provisions of [4.6.1]. However, the duct or covers may not be gas-tight provided that:

- the space within the duct or covers is maintained at a pressure below the pressure in the engine room by means of a mechanical exhaust ventilation system having a capacity of at least 30 changes per hour
- at least 2 exhaust fans are provided with automatic change-over in case of pressure loss
- the fans are of the non-sparking type, and their driving motor are placed outside the duct
- the temperature within the duct or covers is well below the self-ignition temperature of the crude oil
- a pressure sensor is fitted inside the duct or covers to detect any vacuum loss
- a system is provided to detect the presence of crude oil vapour in the duct or covers
- a flame arrester is fitted on the duct venting outlet.

4.7.3 Arrangement for oil leakage collection and detection

Gutterways or suitable grooves are to be arranged in way of the engine crude oil piping for the collection of possible leakages. They are to discharge into a detection well fitted with a high level alarm.

The detection wells are to be fitted with a draining pipe discharging into a collecting tank complying with the provisions of [4.5.5].

4.7.4 Gas detection

Gas detectors are to be fitted:

- in the duct or covers referred to in [4.7.2]
- in all zones where ventilation may be reduced.

4.7.5 Safety arrangements

The crude oil supply is to be shut-off and the engine switched over to fuel oil in the following cases:

- vacuum loss (see [4.7.2])
- crude oil detection (see [4.7.3])
- vapour detection (see [4.7.4]).

4.7.6 Fire safety

The duct or covers are to be fitted with a suitable fire-fighting system.

Where the duct or covers are not gas-tight, the fire-fighting system is to be of the spray water system.

Section 20 Swivels and Risers

1 Swivels

1.1 Pressure swivels

1.1.1 The pressure parts of a pressure swivel are to be designed and manufactured according to the requirements of Pt C, Ch 1, Sec 3 of the Ship Rules or other recognised pressure vessel code.

1.1.2 A pressure swivel is to be isolated from the structural loads due to the anchoring systems.

1.1.3 Piping loads on swivel are to be minimised (e.g. by means of an expansion joint).

1.1.4 Materials of swivel and seals are to be compatible with transported products.

1.1.5 Bearings are to be protected against internal fluids and marine environment. Bearings are to be designed for the rated life of the swivel.

1.1.6 If necessary, pressure seals are to be protected against mechanical aggression.

1.1.7 The sealing system of flammable or toxic products is to constitute, at least, a double barrier against leakage to environment or, for multiple product swivels, between the different products.

Means are to be provided to allow the checking of the sealing system integrity with the swivel in operation. A leak detection and alarm system is to be provided.

1.1.8 Means are to be provided to collect and safely dispose of liquid leaks of flammable products.

1.2 Electrical swivels

1.2.1 Electrical swivels are to be designed and manufactured according to the applicable requirements of Part C, Chapter 2.

1.2.2 Where relevant, electrical swivels are to be suitable for the hazardous area in which they are located.

1.3 Test of pressure swivels

1.3.1 Static resistance tests

A pressure swivel is to be subjected to a pressure resistance static test, according to its design code.

1.3.2 Dynamic tests

Rotation and oscillation tests including rest periods are to be performed at design pressure with measurement of starting and running moments.

At least two complete rotations, or equivalent, in each direction are to be performed. The rotation speed is to be around 1°/s.

1.4 Tests of electrical swivels

1.4.1 Static tests

An electrical swivel is to be subjected to dielectric and insulation resistance tests in accordance with Pt C, Ch 2, Sec 10.

1.4.2 Dynamic tests

A continuity test is to be performed with the swivel in rotation.

2 Marine riser systems

2.1 General

2.1.1 Application

In principle, the limit of classification is the connector of the riser with the pipeline end manifold.

Other limits may be agreed upon and in this case are to be specified on the Certificate of Classification.

The provisions of the present Article [2] are only applicable to marine riser systems connecting production or storage units to sea-bottom equipment and export lines when the additional class notation **RIPRO** is requested.

2.1.2 Definitions

a) Riser system:

The riser system includes the riser itself, its supports and all integrated riser components.

b) Riser:

The riser is the rigid or flexible pipe between the connectors located on the unit and on the sea bottom.

c) Riser components:

The riser components are all the equipment associated with the riser such as clamps, connectors, joints, end fittings, bend stiffeners.

d) Riser supports:

The riser supports are the ancillary structures giving the riser its configuration and securing it to the unit and to the sea bed, such as buoyancy modules and sinkers, arch systems, anchor points, tethers, etc.

2.2 Riser system design

2.2.1 Risers are subject to actions of currents and waves along the line, and primarily, to imposed displacements of riser head attached to the unit. Design analyses are to be carried out in order to ascertain that the design configuration is appropriate and in order to verify that extreme tensions, curvatures, and cyclic actions are within the design limits of the specified product.

The load cases selected for analysis are to be verified as being the most unfavourable combinations of vessel offsets and current/ wave loadings.

An analysis of interference is to be performed in order to verify that all the risers, umbilical and anchor lines remain at an acceptable distance from each other (and from the unit) during operation.

The fatigue life of the riser is to be assessed.

2.3 Riser and riser components

2.3.1 Each marine riser is to be designed, fabricated, tested and installed in accordance with the requirements of a recognised standard, submitted to the agreement of the Society, such as:

a) For rigid riser systems:
- ANSI B 31.4 “Liquid transportation systems for hydrocarbons, liquid petroleum gas, anhydrous ammonia and alcohols”
- ANSI B 31.8 “Gas transmission and distribution piping systems”
- BS 8010 “Code of practice for pipelines”
- API RP 2RD “Design of Risers for Floating Production Systems (FPSs) and Tension-Leg Platforms (TLPs)
- API RP 1111 “Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines (Limit State Design).

b) For non-bonded flexible riser systems:
- Guidance Note NI 364, Non-Bonded Flexible Steel Pipes Used as Flow-Lines
- API Spec 17J “Specification for Unbonded Flexible Pipes”
- API RP 17B “Recommended Practice for Flexible Pipe”.

c) For bonded flexible riser systems:
- OCIMF “Guide to Purchasing, Manufacturing and Testing of Loading and Discharge Hoses for Offshore Moorings” within 100 m waterdepth
- API Spec 17K “Specification for bonded flexible pipe”.

2.4 Riser supports

2.4.1 Equipment for supporting of risers are to be designed in accordance with the relevant provisions of Part B, Chapter 3.

2.4.2 Steel cables and fibre ropes used as tethers and associated fittings are to be designed and constructed in accordance with the relevant provisions of NR493, Classification of Mooring Systems for Permanent Offshore Units.

Appendix 1 Reference Sheets for Special Structural Details

Symbols

H : Height, in m, of a tank, to be taken as the vertical distance from the bottom to the top of the tank
L : Length, in m, as defined in Ch 1, Sec 1, [3.2.6]
T : Maximum draught, in m, as defined in:
- Ch 1, Sec 1, [3.2.10] for site condition
- Ch 1, Sec 1, [3.2.11] for transit condition

T_B : Scantling draught, in m, in light ballast condition.

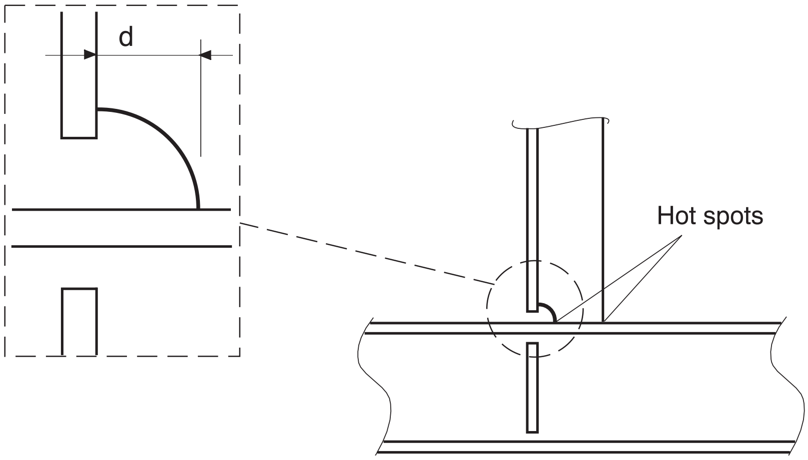
1 Contents

1.1 General

1.1.1 This Appendix includes the reference sheets for structural details located at the end of ordinary stiffeners, as referred to in Ch 1, Sec 10, [4.5.3].

Table 1 : LONGITUDINALLY FRAMED SIDE

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 1.1



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 ≥ 170 m: • with non-watertight collar plate: $K_h = 1,30$ $K_\ell = 1,65$ • with full collar plate (watertight): $K_h = 1,25$ $K_\ell = 1,50$

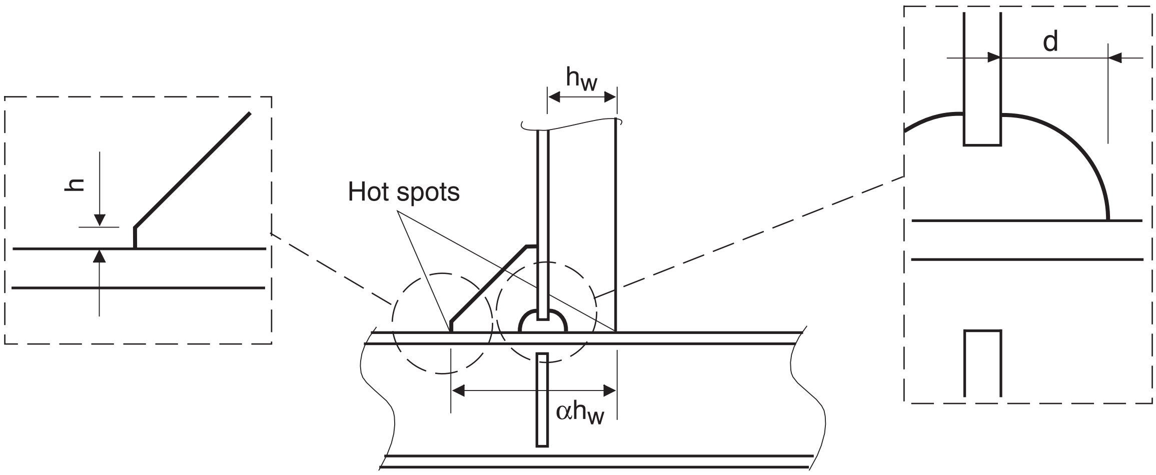
CONSTRUCTION:	NDE:
• Misalignment between side longitudinal and web stiffener ≤ t / 3. • In case of fillet welding, misalignment may be as necessary to allow the required fillet throat size, but ≤ t / 2. For bulbs, a misalignment of 6 mm may be accepted.	Visual examination 100%.

WELDING AND MATERIALS:

Welding requirements:
- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

Table 2 : LONGITUDINALLY FRAMED SIDE

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 1.2



t = minimum thickness among those of the connected elements

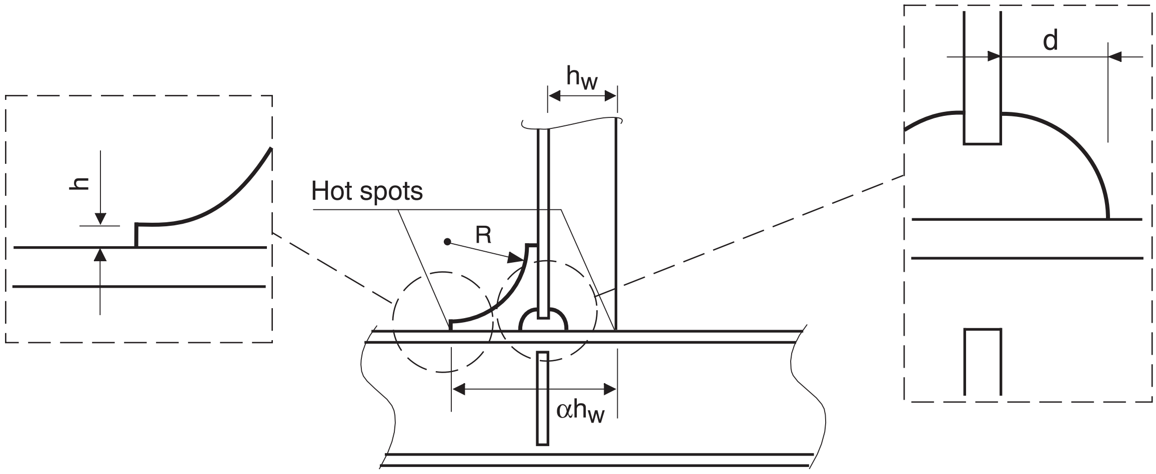
SCANTLINGS:	FATIGUE:
• $\alpha \geq 2$. • Bracket to be symmetric. • h as necessary to allow the required fillet throat size, but ≤ 15 mm. • d to be as small as possible, maximum 35 mm recommended. • Thickness of the bracket to be not less than that of web stiffener.	Fatigue check to be carried out for L ≥ 170 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 3 : LONGITUDINALLY FRAMED SIDE

AREA 1: Side between 0,7TB and 1,15T from the baseline	Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 1.3

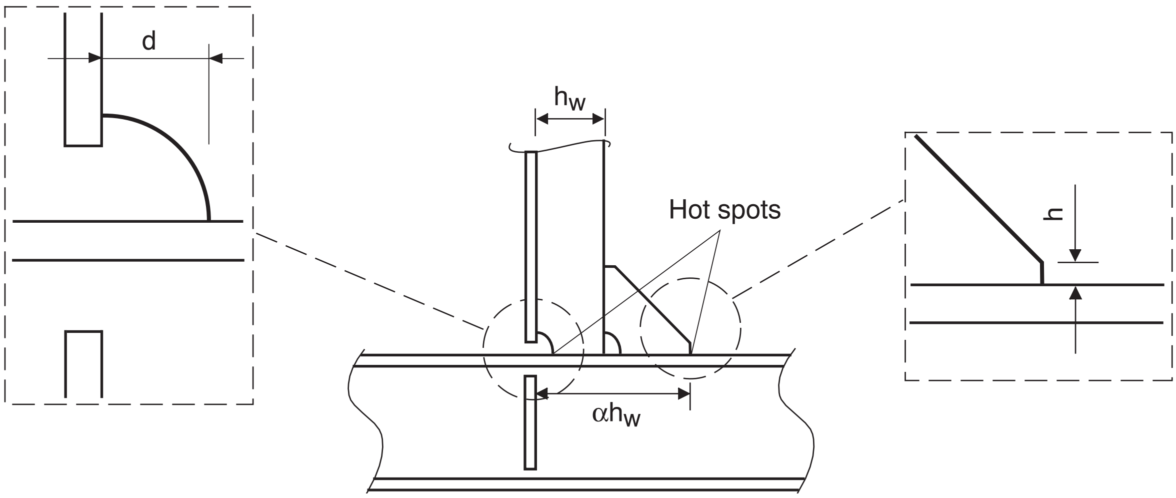


t = minimum thickness among those of the connected elements

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 ≥ 170 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 4 : LONGITUDINALLY FRAMED SIDE

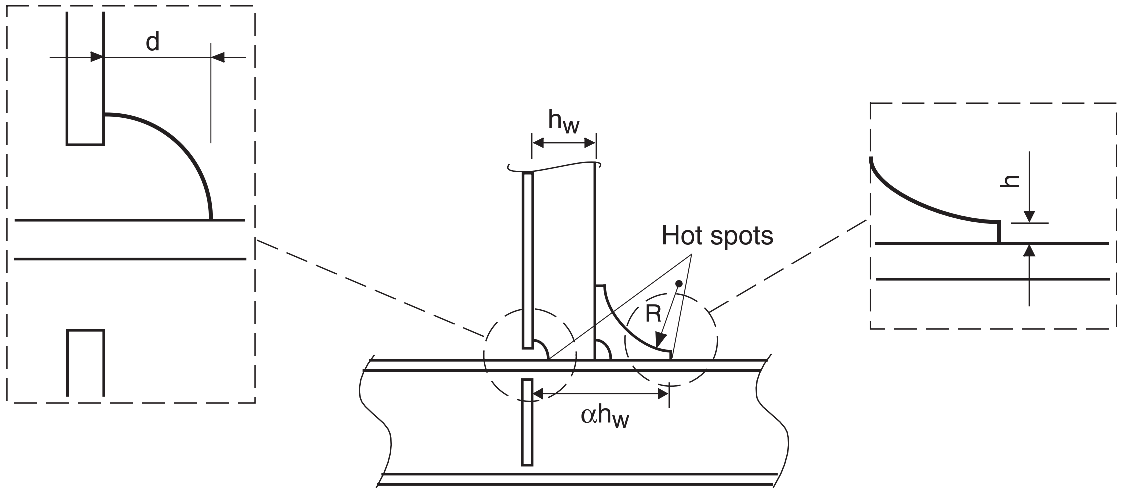
<table>
<tr><td>AREA 1: Side between 0,7T_B and 1,15T from the baseline</td><td>Connection of side longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket</td><td>Sheet 1.4</td></tr>
<tr><td colspan="3">
t = minimum thickness among those of the connected elements</td></tr>
</table>

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 ≥ 170 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 5 : LONGITUDINALLY FRAMED SIDE

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 1.5



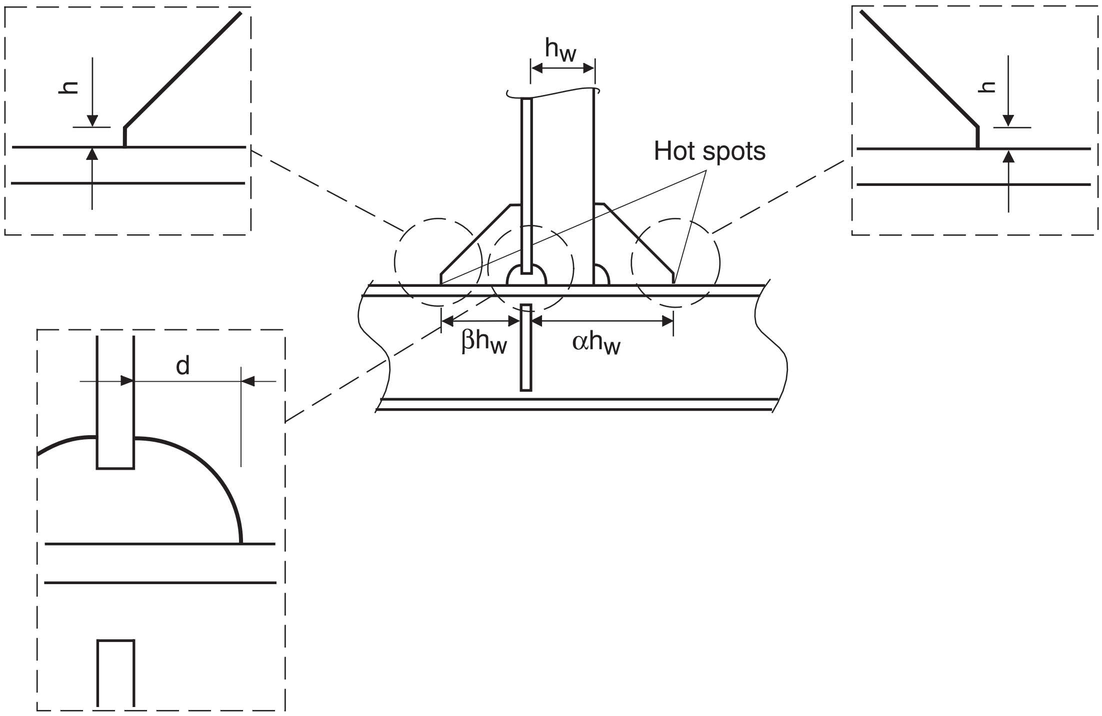
t = minimum thickness among those of the connected elements

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 ≥ 170 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 6 : LONGITUDINALLY FRAMED SIDE

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 1.6



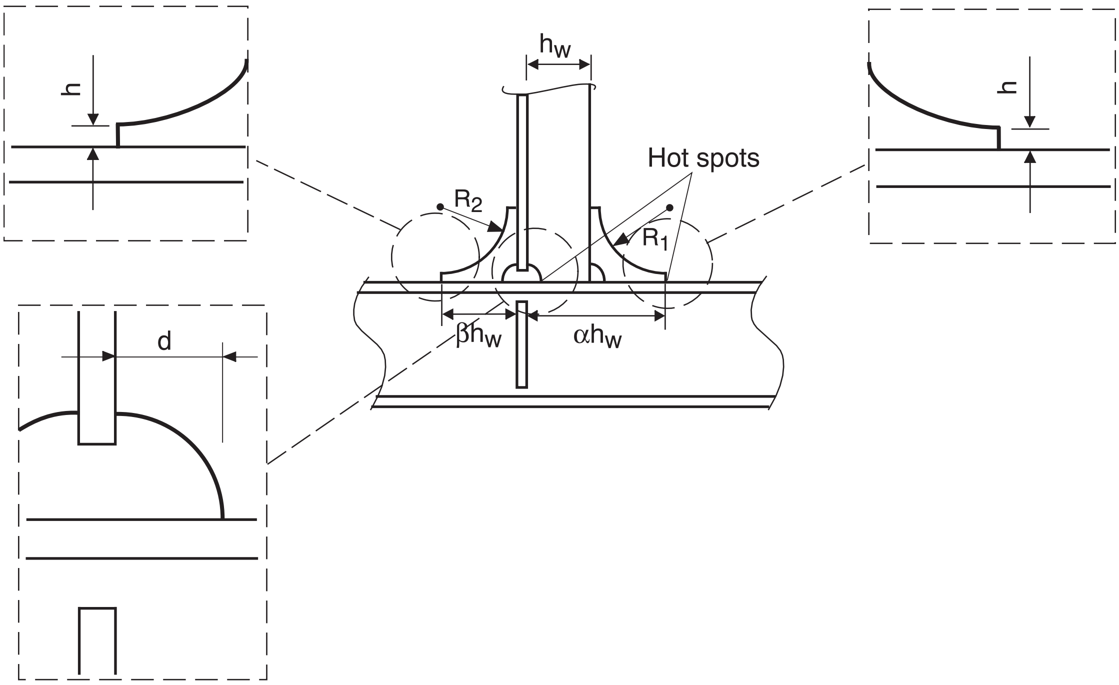
t = minimum thickness among those of the connected elements

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 ≥ 170 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 7 : LONGITUDINALLY FRAMED SIDE

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 1.7



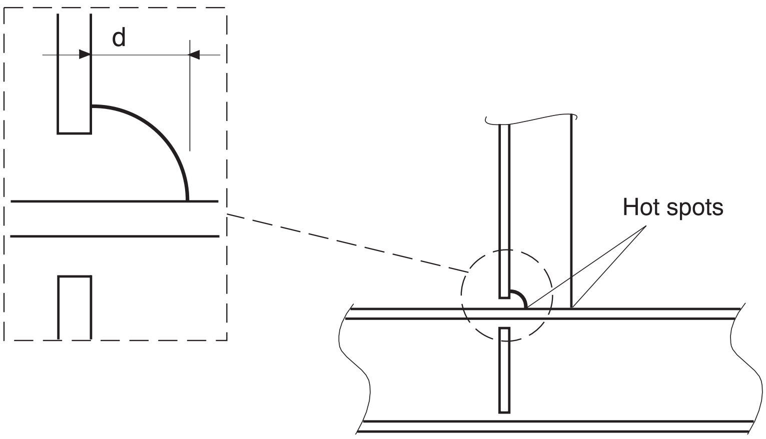
t = minimum thickness among those of the connected elements

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 ≥ 170 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 8 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - No bracket	Sheet 2.1



t = minimum thickness between those of:
- web of longitudinal,
- stiffener of transverse primary supporting member.

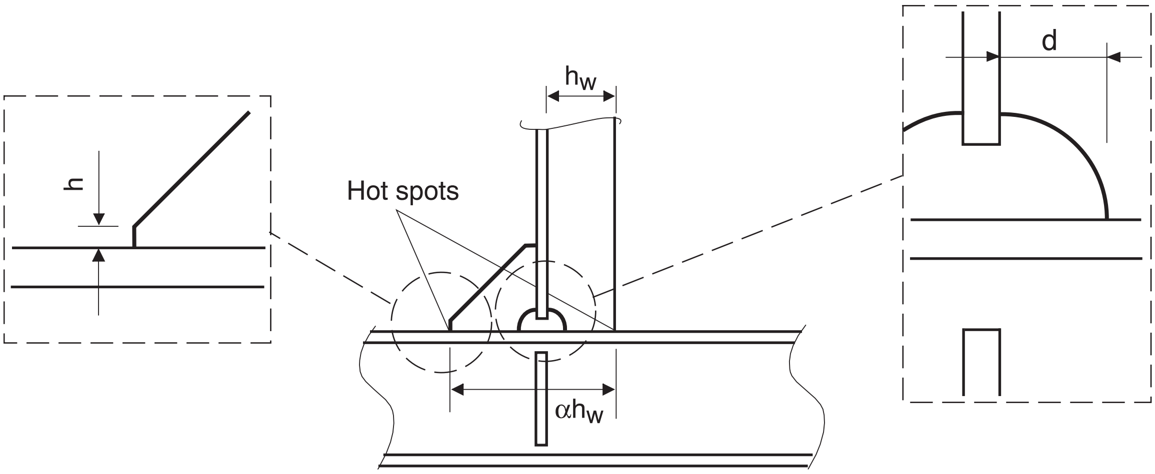
SCANTLINGS:	FATIGUE:
d to be as small as possible, maximum 35 mm recommended.	Fatigue check to be carried out for L ≥ 170 m: • with non-watertight collar plate: K_h = 1,30 K_ℓ = 1,65 • with full collar plate (watertight): K_h = 1,25 K_ℓ = 1,50
CONSTRUCTION:	**NDE:**
• Misalignment between longitudinal 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 9 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

<table>
<tr><td>AREA 2: Inner side and longitudinal bulkheads above 0,5H</td><td>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket</td><td>Sheet 2.2</td></tr>
<tr><td colspan="3">



t = minimum thickness among those of the connected elements</td></tr>
<tr><td>SCANTLINGS:</td><td colspan="2">FATIGUE:</td></tr>
<tr><td>

- $\alpha \geq 2$.
- 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.

</td><td colspan="2">

Fatigue check to be carried out for L ≥ 170 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 $\alpha \geq 2{,}5$
    $K_h = 1{,}10$
    $K_\ell = 1{,}32$

</td></tr>
<tr><td>CONSTRUCTION:</td><td colspan="2">NDE:</td></tr>
<tr><td>

- Misalignment between 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.

</td><td colspan="2">Visual examination 100%.</td></tr>
<tr><td colspan="3">WELDING AND MATERIALS:</td></tr>
<tr><td colspan="3">

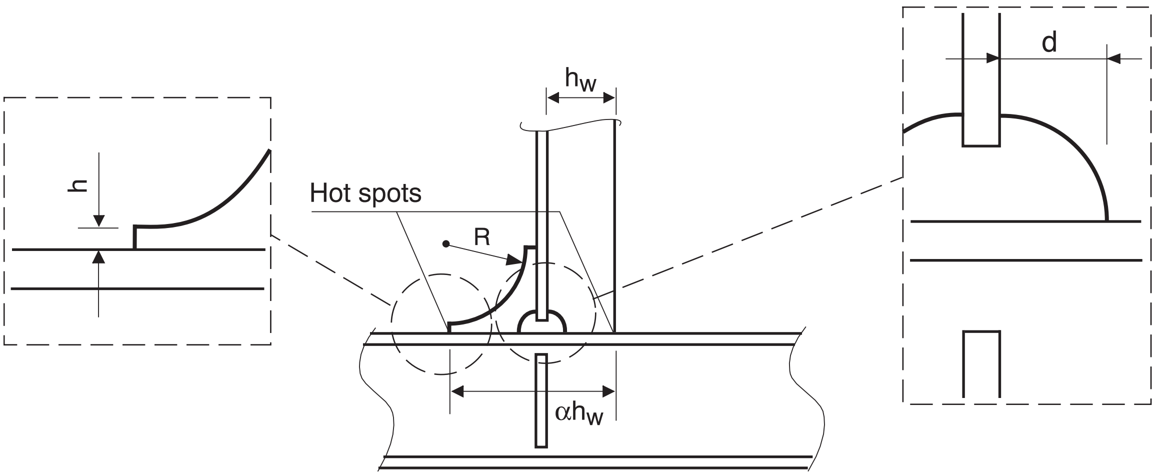
Welding requirements:

- continuous fillet welding,
- weld around the stiffener's toes,
- fair shape of fillet at toes in longitudinal direction.

</td></tr>
</table>

Table 10 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket	Sheet 2.3



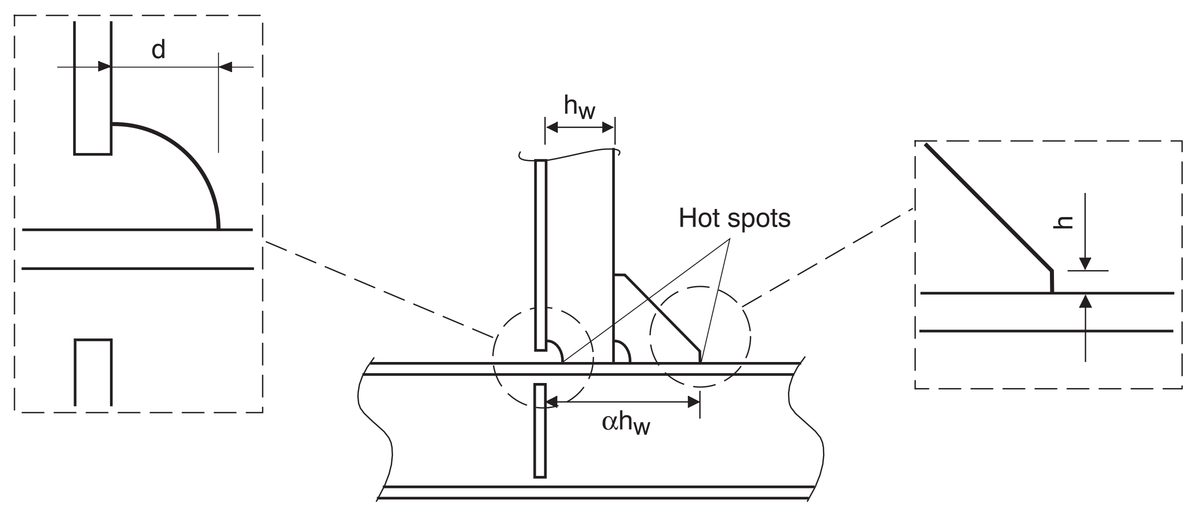
t = minimum thickness among those of the connected elements

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 ≥ 170 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 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 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One bracket	Sheet 2.4



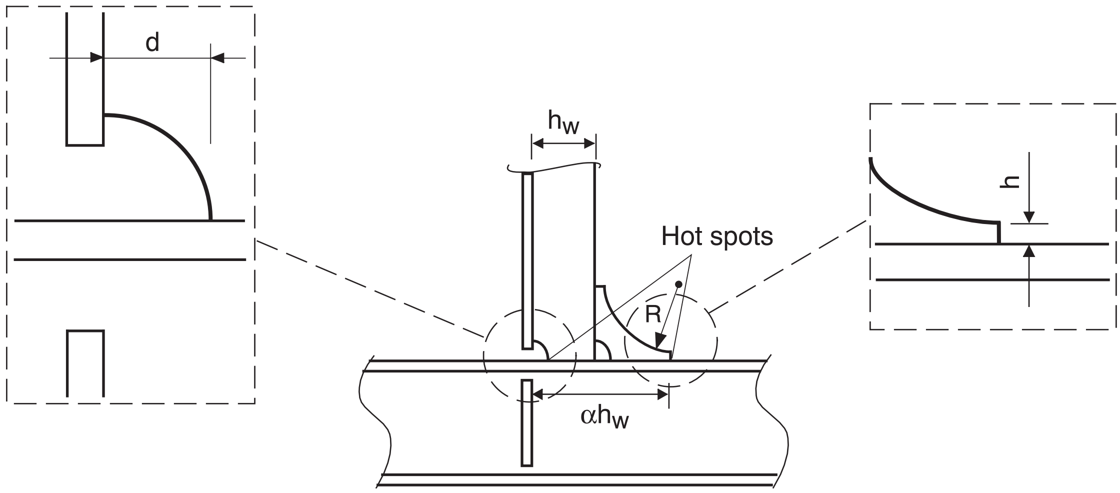
t = minimum thickness among those of the connected elements

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 ≥ 170 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 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 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

<table>
<tr><td>AREA 2: Inner side and longitudinal bulkheads above 0,5H</td><td>Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - One radiused bracket</td><td>Sheet 2.5</td></tr>
<tr><td colspan="3">

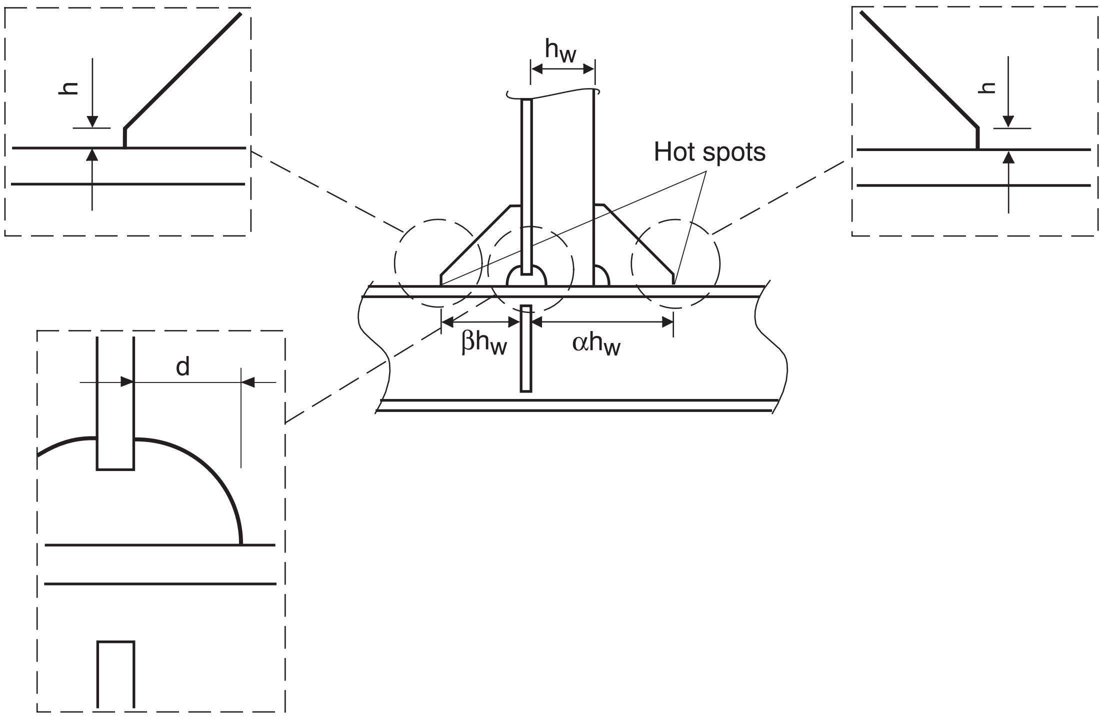
t = minimum thickness among those of the connected elements</td></tr>
</table>

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 ≥ 170 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 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 13 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two brackets	Sheet 2.6

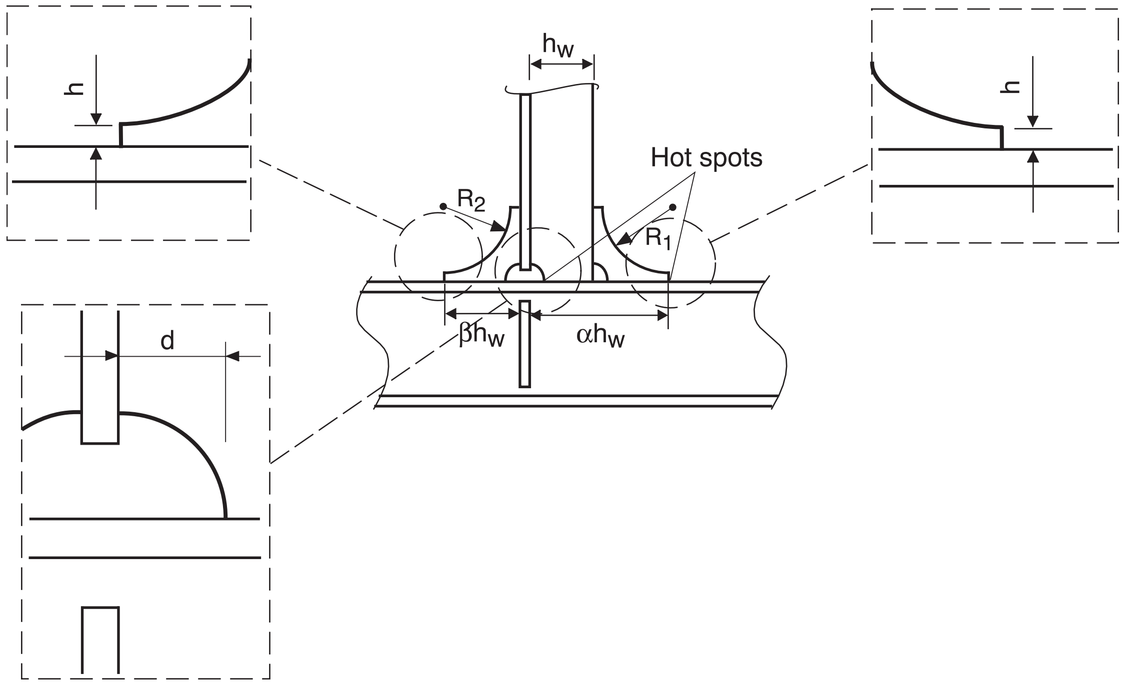


t = minimum thickness among those of the connected elements

<table>
<tr><th>SCANTLINGS:</th><th>FATIGUE:</th></tr>
<tr><td>
• $\alpha \geq 2$.
• $\beta \geq 1$.
• 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.
</td><td>
Fatigue check to be carried out for L ≥ 170 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 $\beta \geq 1,5$
$K_h = K_\ell = 1,05$
</td></tr>
<tr><th>CONSTRUCTION:</th><th>NDE:</th></tr>
<tr><td>
• Misalignment between 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.
</td><td>Visual examination 100%.</td></tr>
<tr><th colspan="2">WELDING AND MATERIALS:</th></tr>
<tr><td colspan="2">
• 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.
</td></tr>
</table>

Table 14 : LONGITUDINALLY FRAMED INNER SIDE OR LONGITUDINAL BULKHEAD

AREA 2: Inner side and longitudinal bulkheads above 0,5H	Connection of inner side or bulkhead longitudinal ordinary stiffeners with stiffeners of transverse primary supporting members - Two radiused brackets	Sheet 2.7



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 ≥ 170 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 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 15 : BOTTOM AND INNER BOTTOM LONGITUDINAL STIFFENERS

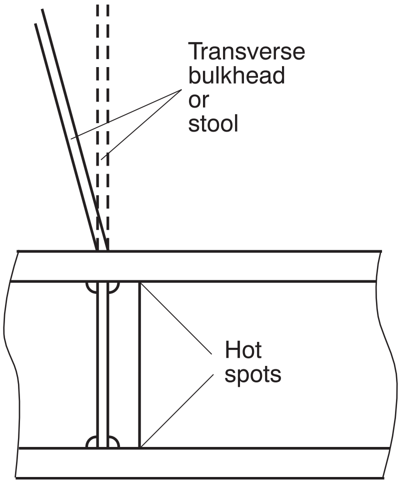
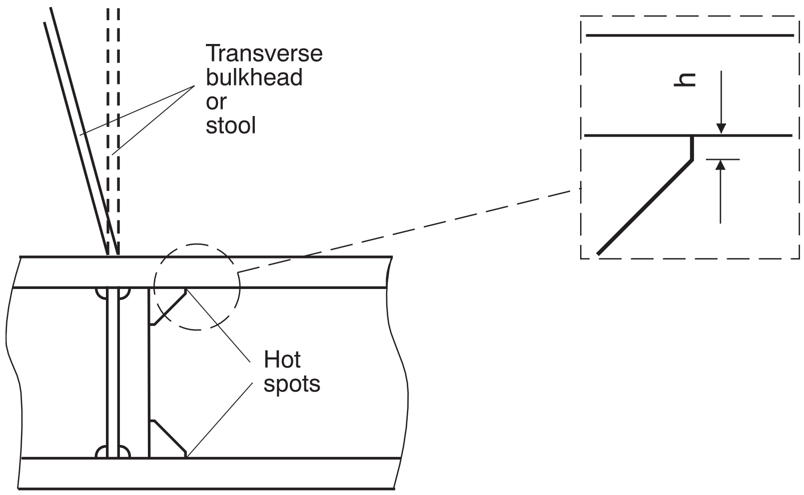
AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - No bracket	Sheet 3.1
	t = minimum thickness between those of: - web of bottom or inner bottom longitudinal, - floor stiffener.	
SCANTLINGS:	**FATIGUE:**	
	Fatigue check to be carried out for L ≥ 170 m: K_h = 1,30 K_ℓ = 1,65	
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 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.		

Table 16 : BOTTOM AND INNER BOTTOM LONGITUDINAL STIFFENERS

AREA 3: Double bottom in way of transverse bulkheads	Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Brackets	Sheet 3.2



t = minimum thickness among those of the connected elements

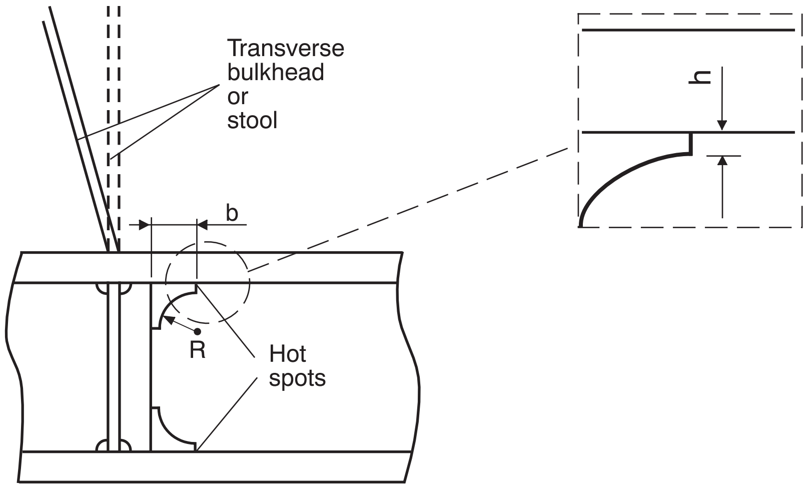
SCANTLINGS:	FATIGUE:
h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 170 m: K_h = 1,30 K_ℓ = 1,55

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 17 : BOTTOM AND INNER BOTTOM LONGITUDINAL STIFFENERS

AREA 3: Double bottom in way of transverse bulkheads	**Connection of bottom and inner bottom longitudinal ordinary stiffeners with floors - Radiused brackets**	**Sheet 3.3**



t = minimum thickness among those of the connected elements

SCANTLINGS:	**FATIGUE:**
• Brackets to be symmetric. • $R \geq 1,5\ b$ • h as necessary to allow the required fillet throat size, but ≤ 15 mm.	Fatigue check to be carried out for L ≥ 170 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.

BUREAU VERITAS MARINE & OFFSHORE

Tour Alto
4 place des Saisons
92400 Courbevoie - France
+33 (0)1 55 24 70 00

marine-offshore.bureauveritas.com/rules-guidelines

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