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RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

NR483 – JANUARY 2024

PART C
MACHINERY, SYSTEMS AND FIRE PROTECTION

NAVAL SHIPS

BUREAU VERITAS

BUREAU VERITAS RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

NR483 - JANUARY 2024

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.

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NR483

RULES FOR THE CLASSIFICATION OF NAVAL SHIPS

Part C
Machinery, Systems and Fire Protection

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Part C
Machinery, Systems and Fire Protection

CHAPTER 1
MACHINERY

Section 1 General Requirements

1 General

1.1 Application

1.1.1 Part C, Chapter 1 applies to the design, construction, installation, tests and trials of main propulsion and essential auxiliary machinery systems and associated equipment, boilers and pressure vessels, piping systems, and steering and manoeuvring systems installed on board classed ships, as indicated in each Section of this Chapter.

For computerized Machinery systems, requirements contained in Part C, Chapter 3 shall be refered to.

1.2 Additional requirements

1.2.1 Additional requirements for machinery are given in:

- Part D, for the assignment of the service notations
- Part E, for the assignment of additional class notations.

1.3 Documentation to be submitted

1.3.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in the relevant Sections of this Chapter.

1.4 Definitions

1.4.1 Dead ship condition

Dead ship condition is the condition under which the main propulsion plant, boilers and auxiliaries are not in operations due to absence of power.

Note 1: Dead ship condition is the condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc. for bringing the main propulsion into operation and for the restoring of the main power supply are not available.

2 Design and construction

2.1 General

2.1.1 The machinery, boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and shall be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards.

The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

2.1.2 Propulsion machinery and related auxiliaries are to be so designed and installed as to comply with the availability requirements stated in Part D for the service notation of the ship and with the requirements of Part E, Chapter 3 when the ship is to be assigned an **AVM** additional class notation.

2.2 Materials, welding and testing

2.2.1 General

Materials, welding and testing procedures are to be in accordance with the requirements of NR216 Materials and Welding, and those given in the other Sections of this Chapter. In addition, for machinery components fabricated by welding the requirements given in [2.2.2] apply.

2.2.2 Welded machinery components

Welding processes and welders are to be approved by the Society in accordance with NR216 Materials and Welding, Chapter 12 and NR476 Approval testing of welders.

References to welding procedures adopted are to be clearly indicated on the plans submitted for approval.

Joints transmitting loads are to be either:

- full penetration butt-joints welded on both sides, except when an equivalent procedure is approved
- full penetration T- or cruciform joints.

2.3 Vibrations

2.3.1 Special consideration is to be given to the design, construction and installation of propulsion machinery systems and auxiliary machinery so that any mode of their vibrations shall not cause undue stresses in this machinery in the normal operating ranges.

2.4 Operation in inclined position

2.4.1 Main propulsion machinery and all auxiliary machinery essential to the propulsion and the safety of the ship are, as fitted in the ship, be designed to operate when the ship is upright and when inclined at any angle of list either way and trim by bow or stern as stated in Tab 1.

The Society may permit deviations from angles given in Tab 1, taking into consideration the type, size and service conditions of the ship.

Machinery with a horizontal rotation axis is generally to be fitted on board with such axis arranged alongships. If this is not possible, the Manufacturer is to be informed at the time the machinery is ordered.

2.5 Ambient conditions

2.5.1 Machinery and systems covered by the Rules are to be designed to operate properly under the ambient conditions specified in Tab 2, unless otherwise specified in each Section of this Chapter.

Table 1 : Inclination of ship

Installations, components	Angle of inclination (degrees) **(1)**			
	Athwartship		Fore and aft	
	static	dynamic	static	dynamic
Main and auxiliary machinery	15	22,5	5	7,5
Safety equipment, e.g. emergency power installations, emergency fire pumps and their devices Switch gear, electrical and electronic appliances **(3)** and remote control systems	22,5 **(2)**	22,5 **(2)**	10	10

(1) Athwartship and fore-and-aft inclinations may occur simultaneously.
(2) In ships for the carriage of liquefied gases and of chemicals the emergency power supply must also remain operable with the ship flooded to a final athwartship inclination up to a maximum of 30°.
(3) Up to an angle of inclination of 45° no undesired switching operations or operational changes may occur.

Table 2 : Ambient conditions

AIR TEMPERATURE	
Location, arrangement	Temperature range, in °C
In enclosed spaces	between 0 and +45**(2)**
On machinery components, boilers In spaces subject to higher or lower temperatures	according to specific local conditions
On exposed decks	between –25 and +45**(1)**

WATER TEMPERATURE	
Coolant	Temperature, in °C
Sea water or, if applicable, sea water at charge air coolant inlet	up to +32

(1) Electronic appliances are to be designed for an air temperature up to 55°C (for electronic appliances see also Part C, Chapter 2).
(2) Different temperatures may be accepted by the Society in the case of ships intended for restricted service.

2.5.2 The full propulsion capability of the ship is to remain available under the following temperature conditions unless other specification:

- air: from –15 to +35°C
- water: from –2 to +30°C.

2.6 Power of machinery

2.6.1 Unless otherwise stated in each Section of this Chapter, where scantlings of components are based on power, the values to be used are determined as follows:

- for main propulsion machinery, the power/rotational speed for which classification is requested. This power/rotational speed should take in account the most stress-inducing propulsion system configuration mode.
- for auxiliary machinery, the power/rotational speed which is available in service.

2.7 Astern power

2.7.1 Sufficient power for going astern is to be provided to secure proper control of the ship in all normal circumstances.

Note 1: Attention is to be paid to maximum stopping distance and to minimum astern thrust, which may be imposed by the ship specification.

For main propulsion systems with reversing gears, controllable pitch propellers or electrical propeller drive, running astern is not to lead to an overload of propulsion machinery.

During the sea trials, the ability of the main propulsion machinery to reverse the direction of thrust of the propeller is to be demonstrated and recorded (see also Ch 1, Sec 16).

2.8 Safety devices

2.8.1 Where risk from overspeeding of machinery exists, means are to be provided to ensure that the safe speed is not exceeded.

2.8.2 Where main or auxiliary machinery including pressure vessels or any parts of such machinery are subject to internal pressure and may be subject to dangerous overpressure, means shall be provided, where practicable, to protect against such excessive pressure.

2.8.3 Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shut-off arrangements in the case of failures, such as lubricating oil supply failure, which could lead rapidly to complete breakdown, serious damage or explosion.

The Society may permit provisions for overriding automatic shut-off devices.

See also the specific requirements given in the other Sections of this Chapter.

2.9 Fuels

2.9.1 Fuel oils employed for engines and boilers are, in general, to have a flash point (determined using the closed cup test) of not less than 60°C.

For ships assigned with a restricted navigation notation, or whenever special precautions are taken to the Society’s satisfaction, fuel oils having a flash point of less than 60°C but not less than 43°C may be used for engines, provided that, from previously effected checks, it is evident that the temperature of spaces where fuel oil is stored or employed will be at least 10°C below the fuel oil flash point at all times.

Fuel oil having flash points of less than 43°C may be employed on board provided that it is stored on an open deck.

3 Arrangement and installation on board

3.1 General

3.1.1 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery, including boilers and pressure vessels.

Suitable demountable openings are to be foreseen in decks and bulkheads for the purpose of disembarking main machinery whose maintenance is intended to be carried out ashore.

Easy access to the various parts of the propulsion machinery is to be provided by means of metallic ladders and gratings fitted with strong and safe handrails.

Spaces containing main and auxiliary machinery are to be provided with adequate lighting and ventilation.

3.1.2 In machinery spaces of Category A, electric switchboard, cabinet or junction box and electric equipment of essential services are to be located above the level corresponding to the lowest generating line of the propeller shaft.

In machinery spaces without propeller shaft this level is corresponding to the lowest generating line of the output shaft of main or auxiliary prime mover installed.

3.2 Floors

3.2.1 Floors in engine rooms are to be made of steel, divided into easily removable panels.

3.3 Bolting down

3.3.1 Bedplates of machinery are to be securely fixed to the supporting structures by means of foundation bolts which are to be distributed as evenly as practicable and of a sufficient number and size so as to ensure a perfect fit.

Where the bedplates bear directly on the inner bottom plating, the bolts are to be fitted with suitable gaskets so as to ensure a tight fit and are to be arranged with their heads within the double bottom.

Continuous contact between bedplates and foundations along the bolting line is to be achieved by means of chocks of suitable thickness, carefully arranged to ensure a complete contact.

The same requirements apply to thrust block and shaft line bearing foundations.

Particular care is to be taken to obtain a perfect levelling and general alignment between the propulsion engines and their shafting (see Ch 1, Sec 7).

3.3.2 Chocking resins are to be type approved.

3.4 Safety devices on moving parts

3.4.1 Suitable protective devices are to be provided in way of moving parts (flywheels, couplings, etc.) in order to avoid injuries to personnel.

3.5 Gauges

3.5.1 All gauges are to be grouped, as far as possible, near each manoeuvring position; in any event, they are to be clearly visible.

3.6 Ventilation in machinery spaces

3.6.1 Machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather condition, including heavy weather, a sufficient supply of air is maintained to the spaces for the safety of personnel and the operation of the machinery, without exceeding the temperature values under Tab 2.

Special attention is to be paid both to air delivery and extraction and to air distribution in the various spaces.

The ventilation is to be so arranged as to prevent any accumulation of flammable gases or vapours.

Machinery air intake is to be ducted from an open space; the size and fittings of ducts are to be such as to satisfy the machinery flow, pressure and quality requirements for developing maximum continuous power.

3.7 Hot surfaces and fire protection

3.7.1 Surfaces, having temperature exceeding 60°C, with which the crew are likely to come into contact during operation are to be suitably protected or insulated.

Surfaces of machinery with temperatures above 220°C, e.g. steam, thermal oil and exhaust gas lines, silencers, exhaust gas boilers and turbochargers, are to be effectively insulated with non-combustible material or equivalently protected to prevent the ignition of combustible materials coming into contact with them. Where the insulation used for this purpose is oil absorbent or may permit the penetration of oil, the insulation is to be encased in steel sheathing or equivalent material.

Fire protection, detection and extinction is to comply with the requirements of Part C, Chapter 4.

3.8 Communications

3.8.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigating bridge, with audible alarm mismatch between order and response.

Appropriate means of communication shall be provided from the navigating bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled.

The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

Where the main propulsion system of the ship is controlled from the navigating bridge by a remote control system, the second means of communication may be the same bridge control system.

The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended.

For ships assigned with a restricted navigation notation these requirements may be relaxed at the Society’s discretion.

3.9 Machinery remote control, alarms and safety systems

3.9.1 For remote control systems of main propulsion machinery and essential auxiliary machinery and relevant alarms and safety systems, the requirements of Part C, Chapter 3 apply.

4 Tests and trials

4.1 Works tests

4.1.1 Equipment and its components are subjected to works tests which are detailed in the relevant Sections of this Chapter and are to be witnessed by the Surveyor.

In particular cases, where such tests cannot be performed in the workshop, the Society may allow them to be carried out on board, provided this is not judged to be in contrast either with the general characteristics of the machinery being tested or with particular features of the shipboard installation. In such cases, the Surveyor entrusted with the acceptance of machinery on board and the purchaser are to be informed in advance and the tests are to be carried out in accordance with the provisions of NR216 Materials and Welding relative to incomplete tests.

All boilers, all parts of machinery, all steam, hydraulic, pneumatic and other systems and their associated fittings which are under internal pressure shall be subjected to appropriate tests including a pressure test before being put into service for the first time as detailed in the other Sections of this Chapter.

4.2 Trials on board

4.2.1 Trials on board of machinery are detailed in Ch 1, Sec 16.

Section 2 Diesel Engines

1 General

1.1 Application

1.1.1 Diesel engines listed below are to be designed, constructed, installed, tested and certified in accordance with the requirements of this Section, under the supervision and to the satisfaction of a Surveyor of the Society:

a) main propulsion engines

b) engines driving electric generators, including emergency generators

c) engines driving other auxiliaries essential for safety and navigation when they develop a power of 110 kW and over.

All other engines are to be designed and constructed according to sound marine practice, with the equipment required in [2.4.4], and delivered with the relevant works' certificate (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]).

Engines intended for propulsion of lifeboats and compression ignition engines intended for propulsion of rescue boats are to comply with the relevant Rules requirements.

Other procedures proposed or accepted by the ship Owner will be also considered on a case by case basis.

In addition to the requirements of this Section, those given in Ch 1, Sec 1 apply.

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1 for engine type approval.

Plans listed under items 2 and 3 in Tab 1 are also to contain details of the lubricating oil sump in order to demonstrate compliance with Ch 1, Sec 1, [2.4].

Where changes are made to an engine type for which the documents listed in Tab 1 have already been examined or approved, the engine Manufacturer is to resubmit to the Society for consideration and approval only those documents concerning the engine parts which have undergone substantial changes.

If the engines are manufactured by a licensee, the licensee is to submit, for each engine type, a list of all the drawings specified in Tab 1, indicating for each drawing the relevant number and revision status from both licensor and licensee.

Where the licensee proposes design modifications to components, the associated documents are to be submitted by the licensee to the Society for approval or for information purposes. In the case of significant modifications, the licensee is to provide the Society with a statement confirming the licensor's acceptance of the changes. In all cases, the licensee is to provide the Surveyor entrusted to carry out the testing, with a complete set of the documents specified in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A**(1)**	Document	Document details
1	I	Engine particulars as per the Society form "Particulars of diesel engines" or equivalent form	–
2	I	Engine transverse cross-section	Max inclination angles, oil surface lines, oil suction strum position
3	I	Engine longitudinal section	Max inclination angles, oil surface lines, oil suction strum position
4	I / A	Bedplate or crankcase, cast or welded For welded bedplates or cranks, welding details and instructions	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
5	A	Thrust bearing assembly **(2)**	–
6	I / A	Thrust bearing bedplate, cast or welded. For welded bedplates or cranks, welding details and instructions **(2)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
7	I / A	Frame/column, cast or welded with welding details and instructions **(3)**	Design of welded joints, electrodes used, welding sequence, heat treatment, non-destructive examinations
8	I	Tie rod	–
9	I	Cylinder cover, assembly	–

No.	I/A**(1)**	Document	Document details
10	I	Cylinder jacket or engine block **(3)** **(4)**	–
11	I	Cylinder liner **(4)**	–
12	A	Crankshaft, details, for each cylinder number	–
13	A	Crankshaft, assembly, for each cylinder number	–
14	A	Thrust shaft or intermediate shaft (if integral with engine)	–
15	A	Coupling bolts	–
16	A	Counterweights (if not integral with crankshaft), with associated fastening bolts	Bolt fastening instructions
17	I	Connecting rod	–
18	I	Connecting rod, assembly **(4)**	Bolt fastening instructions
19	I	Crosshead, assembly **(4)**	–
20	I	Piston rod, assembly **(4)**	–
21	I	Piston, assembly	–
22	I	Camshaft drive, assembly	–
23	A	Material specifications of main parts of engine, with detailed information on: - non-destructive tests, and - pressure tests	Required for items 4, 7, 8, 9, 10, 11, 12, 15, 18, 21, including acceptable defects and repair procedures Required for items 4, 7, 9, 10, 11, 21 and for injection pumps and exhaust manifold
24	A	Arrangement of foundation bolts (for main engines only)	–
25	A	Schematic layout or other equivalent documents for starting air system on the engine **(5)**	–
26	A	Schematic layout or other equivalent documents for fuel oil system on the engine **(5)**	–
27	A	Schematic layout or other equivalent documents for lubricating oil system on the engine **(5)**	–
28	A	Schematic layout or other equivalent documents for cooling water system on the engine **(5)**	–
29	A	Schematic diagram of engine control and safety system on the engine **(5)** (see also [2.10])	List, specification and layout of sensors, automatic controls and other control and safety devices
30	I	Shielding and insulation of exhaust pipes, assembly	–
31	A	Shielding of high pressure fuel pipes, assembly (see also [2.7.2])	Recovery and leak detection devices
32	A	Crankcase explosion relief valves **(6)** (see also [2.4.4])	Volume of crankcase and other spaces (camshaft drive, scavenge, etc.)
33	I	Operation and service manuals	–
34	I	Data sheet for torsional vibration calculations	Inertia and stiffness
35	I	Bearing load calculation or oil film thickness calculation	–

(1) A = to be submitted for approval ; I = to be submitted for information.
Where two indications I / A are given, the first refers to cast design and the second to welded design.
(2) To be submitted only if the thrust bearing is not integral with the engine and not integrated in the engine bedplate.
(3) Only for one cylinder.
(4) To be submitted only if sufficient details are not shown on the engine transverse and longitudinal cross-sections.
(5) Dimensions and materials of pipes, capacity and head of pumps and compressors and any additional functional information are to be included. The layout of the entire system is also required, if this is part of the goods to be supplied by the engine Manufacturer.
(6) Required only for engines with cylinder bore of 200 mm and above or crankcase gross volume of 0,6 m^3 and above.

1.3 Definitions

1.3.1 Engine type

In general, the type of an engine is defined by the following characteristics:

- the cylinder diameter
- the piston stroke
- the method of injection (direct or indirect injection)
- the kind of fuel (liquid, gaseous or dual-fuel)
- the working cycle (4-stroke, 2-stroke)
- the gas exchange (naturally aspirated or supercharged)
- the maximum continuous power per cylinder at the corresponding speed and/or brake mean effective pressure corresponding to the above-mentioned maximum continuous power
- the method of pressure charging
- the charging air cooling system (with or without intercooler, number of stages, etc.)
- cylinder arrangement (in-line or V-type).

1.3.2 Engine power

The maximum continuous power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering continuously, at nominal maximum speed, in the period of time between two consecutive overhauls.

Power, speed and the period of time between two consecutive overhauls are to be stated by the Manufacturer and agreed by the Society.

Note 1: Power corrections are to be made in accordance with ISO 3046 standard.

The rated power is the maximum power at ambient reference conditions [1.3.3] which the engine is capable of delivering as set after works trials (fuel stop power) at the maximum speed allowed by the governor.

The rated power for engines driving electric generators is the nominal power, taken at the net of overload, at ambient reference conditions [1.3.3], which the engine is capable of delivering as set after the works trials [4.5].

1.3.3 Ambient reference conditions

The power of engines as per [1.1.1], items a), b) and c) is to be referred to the following conditions:

- barometric pressure = 0,1 MPa
- relative humidity = 60%
- ambient air temperature = 45°C
- sea water temperature (and temperature at inlet of sea water cooled charge air cooler) = 32°C.

In the case of ships assigned with a navigation notation other than unrestricted navigation, different temperatures may be accepted by the Society.

The engine Manufacturer is not expected to provide the above ambient conditions at a test bed. The rating is to be adjusted according to a recognised standard accepted by the Society.

1.3.4 Same type of engines

Two diesel engines are considered to be of the same type when they do not substantially differ in design and construction characteristics, such as those listed in the engine type definition as per [1.3.4], it being taken for granted that the documentation concerning the essential engine components listed in [1.2] and associated materials employed has been submitted, examined and, where necessary, approved by the Society.

2 Design and construction

2.1 General

2.1.1 Operating conditions

Attention is to be paid to the specific operating conditions of the engine (e.g. continuous operation at low load) which may be imposed by the ship specification.

2.2 Materials and welding

2.2.1 Crankshaft materials

In general, crankshafts are to be of forged steel having a tensile strength not less than 400 N/mm^2 and not greater than 1000 N/mm^2.

The use of forged steels of higher tensile strength is subject to special consideration by the Society in each case.

The Society, at its discretion and subject to special conditions (such as restrictions in ship navigation), may accept crankshafts made of cast carbon steel or cast alloyed steel of appropriate quality and manufactured by a suitable procedure having a tensile strength as follows:

- between 400 N/mm^2 and 560 /mm^2 for cast carbon steel
- between 400 N/mm^2 and 700 N/mm^2 for cast alloyed steel.

2.2.2 Welded frames and foundations

Steels used in the fabrication of welded frames and bedplates are to comply with the requirements of NR216 Materials and Welding is to be in accordance with the requirements of Ch 1, Sec 1, [2.2].

2.3 Crankshaft

2.3.1 Check of the scantling

The check of crankshaft strength is to be carried out in accordance with Ch 1, App 1.

Other methods accepted by the ship Owner will be considered on a case by case basis.

2.4 Crankcase

2.4.1 Strength

The scantling of crankcases and crankcase doors is to be designed to be of sufficient strength, and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

2.4.2 Ventilation and drainage

Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted.

Vent pipes, where provided, are to be as small as practicable. If provision is made for the forced extraction of gases from the crankcase (e.g. for detection of explosive mixtures), the vacuum in the crankcase is not to exceed $2{,}5.10^{-4}$ MPa.

Where two or more engines are installed, their vent pipes and lubricating oil drain pipes are to be independent to avoid intercommunication between crankcases.

Lubricating oil drain pipes from the engine sump to the drain tank are to be submerged in the latter at their outlet ends.

2.4.3 Warning notice

A warning notice is to be fitted, preferably on a crankcase door on each side of the engine, or alternatively on the control stand.

This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling of the crankcase.

2.4.4 Crankcase explosion relief valves

a) Diesel engines of a cylinder diameter of 200 mm and above or a crankcase gross volume of 0,6 m^3 and above are to be provided with crankcase explosion relief valves in accordance with the following requirements.

b) Engines having a cylinder bore not exceeding 250 mm, are to have at least one valve near each end, but over eight crankthrows, an additional valve is to be fitted near the middle of the engine. Engines having a cylinder bore exceeding 250 mm, but not exceeding 300 mm, are to have at least one valve in way of each alternate crankthrow, with a minimum of two valves. Engines having a cylinder bore exceeding 300 mm are to have at least one valve in way of each main crankthrow.

c) Additional relief valves are to be fitted on separate spaces of the crankcase, such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces is 0,6 m^3 or above. Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves.

d) The free area of each relief valve is not to be less than 45 cm^2.

e) The combined free area of the valves fitted on an engine is not to be less than 115 cm^2 per cubic metre of the crankcase gross volume. (See Note 1).

f) Crankcase explosion relief valves are to be provided with lightweight spring-loaded valve discs or other quick-acting and self closing devices to relieve a crankcase of pressure in the event of an internal explosion and to prevent any inrush of air thereafter.

g) The valve discs in crankcase explosion relief valves are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

h) Crankcase explosion relief valves are to be designed and constructed to open quickly and to be fully open at a pressure not greater than 0,02 MPa.

i) Crankcase explosion relief valves are to be provided with a flame arrester that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

j) Crankcase explosion relief valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine.

The purpose of type testing crankcase explosion valves is:

- to verify the effectiveness of the flame arrester
- to verify that the valve closes after an explosion
- to verify that the valve is gas/air tight after an explosion
- to establish the level of overpressure protection provided by the valve.

Where crankcase relief valves are provided with arrangements for shielding emissions from the valve following an explosion, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

k) Crankcase explosion relief valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual is to contain the following information:

- description of valve with details of function and design limits
- copy of type test certification
- installation instructions
- maintenance in service instructions to include testing and renewal of any sealing arrangements
- actions required after a crankcase explosion.

l) A copy of the installation and maintenance manual required in i) above is to be provided on board the unit.

m) Valves are to be provided with suitable markings that include the following information:

- name and address of manufacturer
- designation and size
- month/year of manufacture
- approved installation orientation.

Note 1: The total volume of the stationary parts within the crankcase may be discounted in estimating the crankcase gross volume (rotating and reciprocating components are to be included in the gross volume).

2.5 Cylinder overpressure gauge

2.5.1 Means are to be provided to indicate a predetermined overpressure in the cylinders of engines having a bore exceeding 230 mm.

2.6 Scavenge manifolds

2.6.1 Fire-extinguishing

For two-stroke crosshead type engines, scavenge spaces in open connection (without valves) to the cylinders are to be connected to a fixed fire-extinguishing system, which is to be entirely independent of the fire-extinguishing system of the machinery space.

2.6.2 Blowers

Where a single two-stroke propulsion engine is equipped with an independently driven blower, alternative means to drive the blower or an auxiliary blower are to be provided ready for use.

2.6.3 Relief valves

Scavenge spaces in open connection to the cylinders are to be fitted with explosion relief valves in accordance with [2.4.4].

2.7 Systems

2.7.1 General

In addition to the requirements of the present sub-article, those given in Ch 1, Sec 10 are to be satisfied.

Flexible hoses in the fuel and lubricating oil system are to be limited to the minimum and are to be type approved.

2.7.2 Fuel oil system

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

In fuel oil systems for propulsion machinery, filters are to be fitted and arranged so that an uninterrupted supply of filtered fuel oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

a) All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a shielded piping system capable of containing fuel from a high pressure line failure.

A shielded pipe incorporates an outer pipe into which the high pressure fuel pipe is placed forming a permanent assembly.

The shielded piping system is to include a means for collection of leakages and arrangements are to be provided for an alarm to be given in the event of a fuel line failure.

If flexible hoses are used for shielding purposes, these are to be approved by the Society.

When in fuel oil return piping the pulsation of pressure with peak to peak values exceeds 2 MPa, shielding of this piping is also required as above.

b) For ships classed for restricted navigation, the requirements under a) may be relaxed at the Society's discretion.

2.7.3 Lubricating oil system

Efficient filters are to be fitted in the lubricating oil system when the oil is circulated under pressure.

In such lubricating oil systems for propulsion machinery, filters are to be arranged so that an uninterrupted supply of filtered lubricating oil is ensured during cleaning operations of the filter equipment, except when otherwise stated in Ch 1, Sec 10.

Relief valves discharging back to the suction of the pumps or other equivalent means are to be fitted on the delivery side of the pumps.

The relief valves may be omitted provided that the filters can withstand the maximum pressure that the pump may develop.

Where necessary, the lubricating oil is to be cooled by means of suitable coolers.

2.7.4 Charge air system

a) Requirements relevant to design, construction, arrangement, installation, tests and certification of exhaust gas turbochargers are given in Ch 1, Sec 15.

b) When two-stroke propulsion engines are supercharged by exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering turbocharger casings and causing damage to blades and nozzle rings.

2.8 Starting air system

2.8.1 The requirements given in [3.1] apply.

2.9 Cooling system

2.9.1 The requirements given in Ch 1, Sec 10, [10] apply.

2.10 Control and monitoring

2.10.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 3 apply.

2.10.2 Governors of main and auxiliary engines

Each engine, except the auxiliary engines for driving electric generators for which [2.10.5] applies, is to be fitted with a speed governor so adjusted that the engine does not exceed the rated speed by more than 15%.

2.10.3 Overspeed protective devices of main and auxiliary engines

In addition to the speed governor, each

- main propulsion engine having a rated power of 220kW and above, which can be declutched or which drives a controllable pitch propeller, and
- auxiliary engine having a rated power of 220kW and above, except those for driving electric generators, for which [2.10.6] applies,

is to be fitted with a separate overspeed protective device so adjusted that the engine cannot exceed the rated speed n by more than:

- 12% in case of mechanical device
- 15% in case of electrical device.

Equivalent arrangements may be accepted subject to special consideration by the Society in each case.

The overspeed protective device, including its driving mechanism or speed sensor, is to be independent of the governor.

2.10.4 Governors for auxiliary engines driving electric generators

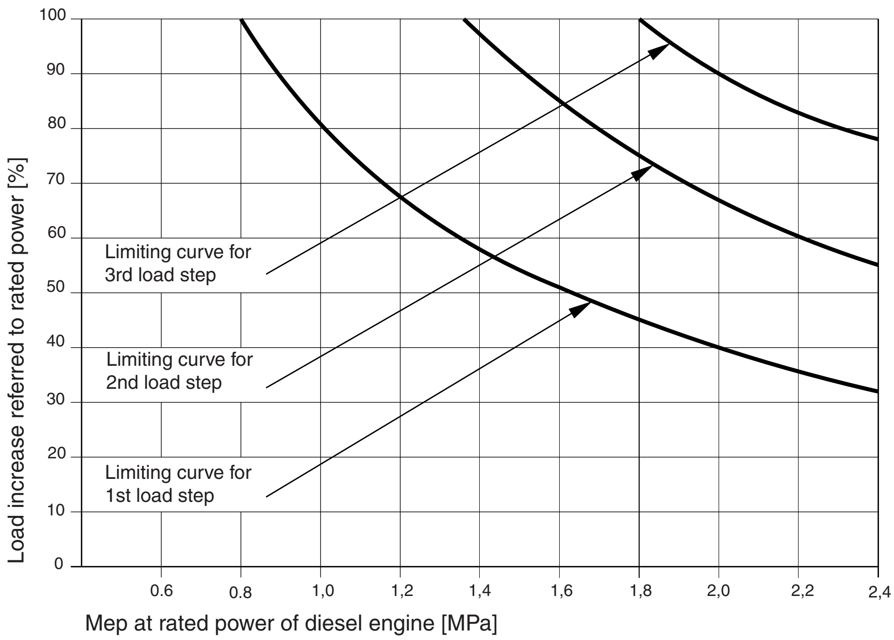
a) Auxiliary engines intended for driving electric generators are to be fitted with a speed governor which prevents any transient speed variations in excess of 10% of the rated speed when the rated power is suddenly thrown off or specific loads are suddenly thrown on.

b) At all loads between no load and rated power, the permanent speed variation is not to be more than 5% of the rated speed.

c) Prime movers are to be selected in such a way that they meet the load demand within the ship's mains and, when running at no load, can satisfy the requirement in item a) above if suddenly loaded to 50% of the rated power of the generator, followed by the remaining 50% after an interval sufficient to restore speed to steady state. Steady state conditions (see Note 1) are to be achieved in not more than 5 s.

Note 1: Steady state conditions are those at which the envelope of speed variation does not exceed ±1% of the declared speed at the new power.

Figure 1 : Limiting curves for loading 4-stroke diesel engines step by step from no load to rated power as a function of the brake mean effective pressure



d) Application of the electrical load in more than 2 load steps can only be allowed if the conditions within the ship's mains permit the use of those auxiliary engines which can only be loaded in more than 2 load steps (see Fig 1 for guidance) and provided that this is already allowed for in the designing stage.

   This is to be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case, due consideration is to be given to the power required for the electrical equipment to be automatically switched on after blackout and to the sequence in which it is connected

   This also applies to generators to be operated in parallel and where the power is to be transferred from one generator to another, in the event that any one generator is to be switched off.

e) When the rated power is suddenly thrown off, steady state conditions should be achieved in not more than 5s.

f) Emergency generator sets must satisfy the governor conditions as per items a) and b) even when their total emergency consumer load is applied suddenly.

g) For alternating current generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

   For alternating current generating sets intended to operate in parallel, facilities are to be provided to adjust the governor sufficiently finely to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.10.5 Overspeed protective devices of auxiliary engines driving electric generators

In addition to the speed governor, auxiliary engines of rated power equal to or greater than 220 kW driving electric generators are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

This device is to automatically shut down the engine.

2.10.6 Use of electronic governors

a) Type approval

   Provisions are to be made for controlling the engine speed in case of failure of the electrical supply.

   Electronic governors and their actuators are to be type approved by the Society.

b) Electronic governors for main propulsion engines

   If an electronic governor is fitted to ensure continuous speed control or resumption of control after a fault, an additional separate governor is to be provided unless the engine has a manually operated fuel admission control system suitable for its control.

   A fault in the governor system is not to lead to sudden major changes in propulsion power or direction of propeller rotation.

   Alarms are to be fitted to indicate faults in the governor system.

   The acceptance of electronic governors not in compliance with the above requirements will be considered by the Society on a case by case basis, when fitted on ships with two or more main propulsion engines.

c) Electronic governors for auxiliary engines driving electric generators

In the event of a fault in the electronic governor system the fuel admission is to be set to “zero”.

Alarms are to be fitted to indicate faults in the governor system.

The acceptance of electronic governors fitted on engines driving emergency generators will be considered by the Society on a case by case basis.

2.10.7 Summary tables

Diesel engines installed on ships without automation notations are to be equipped with monitoring equipment as detailed in Tab 2 and Tab 3 for main propulsion, in Tab 4 for auxiliary services and in Tab 5 for emergency services.

The alarms are to be visual and audible.

The indicators are to be fitted at a normally attended position (on the engine or at the local control station).

Table 2 : Monitoring of main propulsion slow speed diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shutdown	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Fuel rack position		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L **(4)**	local					
	LL			X			
Lubricating oil to cross-head bearing pressure when separate	L **(4)**	local					
	LL			X			
Lubricating oil to camshaft pressure when separate	L **(4)**	local					
	LL			X			
Turbocharger lubricating oil inlet pressure		local					
Lubricating oil inlet temperature		local					
Thrust bearing pads or bearing outlet temperature	H	local					
Main, crank, cross-head bearing, oil outlet temp	H						
Cylinder fresh cooling water system inlet pressure	L	local**(3)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local					
	HH		X				
Piston coolant inlet pressure on each cylinder **(1)**	L	local					
Piston coolant outlet temperature on each cylinder**(1)**		local					
Piston coolant outlet flow on each cylinder **(1) (2)**	L						
Speed of turbocharger		local					
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local**(5)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) Not required, if the coolant is oil taken from the main cooling system of the engine.
(2) Where outlet flow cannot be monitored due to engine design, alternative arrangement may be accepted.
(3) For engines of 220 KW and above.
(4) Audible and visual alarm.
(5) Indication is required after each cylinder, for engines of 500 kW per cylinder and above.

Table 3 : Monitoring of main propulsion medium or high speed diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shutdown	Control	Stand by Start	Stop
Fuel oil pressure after filter (engine inlet)		local					
Fuel oil viscosity before injection pumps or fuel oil temperature before injection pumps (for engine running on heavy fuel)		local					
Fuel rack position		local					
Leakage from high pressure pipes where required	H						
Lubricating oil to main bearing and thrust bearing pressure	L **(2)**	local					
	LL			X			
Lubricating oil filter differential pressure	H	local					
Turbocharger lubricating oil inlet pressure **(4)**		local					
Lubricating oil inlet temperature		local					
Cylinder fresh cooling water system inlet pressure	L	local**(1)**					
Cylinder fresh cooling water outlet temperature or, when common cooling space without individual stop valves, the common cylinder water outlet temperature	H	local					
	HH		X				
Cylinder fresh cooling water, expansion tank level	L	local					
	LL		X				
Scavenging air receiver pressure		local					
Scavenging air box temperature (detection of fire in receiver)		local					
Exhaust gas temperature		local**(3)**					
Engine speed / direction of speed (when reversible)		local					
	H			X			
Fault in the electronic governor system	X						

(1) For engines of 220 kW and above.
(2) Audible and visual alarm.
(3) Indication is required after each cylinder, for engines of 500 kW per cylinder and above.
(4) If without integrated self-contained oil lubrication system.

Table 4 : Monitoring of diesel engines used for auxiliary services

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil pressure		local					
Fuel oil leakage from pressure pipes	H						
Lubricating oil pressure	L	local		X**(1)**			
Pressure or flow of cooling water, if not connected to main system	L	local					
Temperature of cooling water or cooling air		local					
Cylinder fresh cooling water, expansion tank level	L	local					
	LL		X				
Engine speed		local					
	H			X			
Exhaust gas temperature		local					
Fault in the electronic governor system	X						

(1) Not applicable to emergency generator set.

Table 5 : Monitoring of emergency diesel engines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil leakage from pressure pipes	H						
Lubricating oil temperature**(1)**	H	local					
Lubricating oil pressure	L	local					
Oil mist concentration in crankcase **(2)**	H	local					
Pressure or flow of cooling water **(1)**	L	local					
Temperature of cooling water or cooling air		local					
Engine speed		local					
	H			X**(1)**			
Fault in the electronic governor system	X						

(1) Not applicable to emergency generator set of less than 220 kW.
(2) For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.
Note 1: The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.
Note 2: Regardless of the engine output, if shutdowns additional to those above specified except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.
Note 3: The alarm system is to function in accordance with **AUT** notation, with additional requirements that grouped alarms are to be arranged on the bridge.
Note 4: In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.
Note 5: The local indications are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

3 Arrangement and installation

3.1 Starting arrangements

3.1.1 Mechanical air starting

a) The total capacity of air receivers of each propulsion line is to be sufficient to provide, without replenishment, not less than 12 consecutive starts alternating between ahead and astern of main engines of the reversible type, and not less than 6 consecutive starts of main non-reversible type engines connected to a controllable pitch propeller or other device enabling the start without opposite torque.

When other users such as auxiliary engine starting systems, control systems, whistle etc. are connected to the starting air receivers of main propulsion engines, their air consumption is also to be taken into account.

For multi-engine propulsion plants, the capacity of the starting air receivers is to be sufficient to ensure at least 3 consecutive starts per engine. However, the total capacity is not to be less than 12 starts and need not exceed 18 starts.

Regardless of the above, for multi-engine installations the number of starts required for each engine may be reduced subject to the agreement of the Society and depending upon the arrangement of the engines and the transmission of their output to the propellers.

b) The main starting air arrangements for main propulsion or auxiliary diesel engines are to be adequately protected against the effects of backfiring and internal explosion in the starting air pipes. To this end, the following safety devices are to be fitted:

- An isolating non-return valve, or equivalent, at the starting air supply connection to each engine.
- A bursting disc or flame arrester:
  - in way of the starting valve of each cylinder, for direct reversing engines having a main starting air manifold
  - at least at the supply inlet to the starting air manifold, for non-reversing engines.

  The bursting disc or flame arrester above may be omitted for engines having a bore not exceeding 230 mm.

Other protective devices will be specially considered by the Society.

The requirements of this item c) do not apply to engines started by pneumatic motors.

c) Compressed air receivers are to comply with the requirements of Ch 1, Sec 3. Compressed air piping and associated air compressors are to comply with the requirements of Ch 1, Sec 10.

3.1.2 Electrical starting

a) Where main internal combustion engines are arranged for electrical starting, at least two separate batteries are to be fitted.

The arrangement is to be such that the batteries cannot be connected in parallel.

Each battery is to be capable of starting the main engine when in cold and ready to start condition.

The combined capacity of batteries is to be sufficient to provide within 30 min, without recharging, the number of starts required in [3.1.1] b) in the event of air starting.

b) Electrical starting arrangements for auxiliary engines are to have two separate storage batteries or may be supplied by two separate circuits from main engine storage batteries when these are provided. In the case of a single auxiliary engine, one battery is acceptable. The combined capacity of the batteries is to be sufficient for at least three starts for each engine.

c) The starting batteries are only to be used for starting and for the engine's alarm and monitoring. Provision is to be made to maintain the stored energy at all times.

d) Each charging device is to have at least sufficient rating for recharging the required capacity of batteries within 6 hours.

3.1.3 Special requirements for starting arrangements for emergency generating sets

a) Emergency generating sets are to be capable of being readily started in their cold condition at a temperature of 0°C. If this is impracticable, or if lower temperatures are likely to be encountered, provision acceptable to the Society shall be made for the maintenance of heating arrangements, to ensure ready starting of the generating sets.

b) Each emergency generating set arranged to be automatically started shall be equipped with starting devices approved by the Society with a stored energy capability of at least three consecutive starts.

The source of stored energy shall be protected to preclude critical depletion by the automatic starting system, unless a second independent means of starting is provided. In addition, a second source of energy shall be provided for an additional three starts within 30 minutes, unless manual starting can be demonstrated to be effective.

c) The stored energy is to be maintained at all times, as follows:
   - electrical and hydraulic starting systems shall be maintained from the emergency switchboard
   - compressed air starting systems may be maintained by the main or auxiliary compressed air receivers through a suitable non-return valve or by an emergency air compressor which, if electrically driven, is supplied from the emergency switchboard
   - all of these starting, charging and energy storing devices are to be located in the emergency generator space; these devices are not to be used for any purpose other than the operation of the emergency generating set. This does not preclude the supply to the air receiver of the emergency generating set from the main or auxiliary compressed air system through the non-return valve fitted in the emergency generator space.

d) Where automatic starting is not required, manual starting, such as manual cranking, inertia starters, manually charged hydraulic accumulators, or powder charge cartridges, is permissible where this can be demonstrated as being effective.

e) When manual starting is not practicable, the requirements of items b) and c) are to be complied with, except that starting may be manually initiated.

3.2 Turning gear

3.2.1 Each engine is to be provided with hand-operated turning gear; where deemed necessary, the turning gear is to be both hand and mechanically-operated.

The turning gear engagement is to inhibit starting operations.

3.3 Trays

3.3.1 Trays fitted with means of drainage are to be provided in way of the lower part of the crankcase and, in general, in way of the parts of the engine, where oil is likely to spill in order to collect the fuel oil or lubricating oil dripping from the engine.

3.4 Exhaust gas system

3.4.1 In addition to the requirements given in Ch 1, Sec 10, the exhaust system is to be efficiently cooled or insulated in such a way that the surface temperature does not exceed 220°C (see also Ch 1, Sec 1, [3.7]).

3.4.2 Pressure losses in the exhaust ducting are to comply with the limits stated by the engine manufacturer.

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Upon finalisation of the engine design for production of every new engine type intended for installation on board ships, one engine is to be presented for type testing as required below.

A type test carried out for a particular type of engine at any place in any manufacturer's works will be accepted for all engines of the same type (see [1.3.4]) built by licensees and licensors.

In any case, one type test suffices for the whole range of engines having different numbers of cylinders.

Engines which are subjected to type testing are to be tested in accordance with the scope specified below, it being taken for granted that:

- the engine is optimised as required for the conditions of the type test
- the investigations and measurements required for reliable engine operation have been carried out during preliminary internal tests by the engine Manufacturer
- the documentation to be submitted as required in [1.2] has been examined and, when necessary, approved by the Society and the latter has been informed about the nature and extent of investigations carried out during pre-production stages.

4.1.2 At the request of the Manufacturer, an increase in power and/or mean effective pressure up to a maximum of 10% may be accepted by the Society for an engine previously subjected to a type test without any further such test being required, provided the engine reliability has been proved successfully by the service experience of a sufficient number of engines of the same type.

For the purpose of the acceptance of the above performance increase, the Manufacturer is in any case to submit for examination and, where necessary, approval, the documentation listed in [1.2] relevant to any components requiring modification in order to achieve the increased performance.

4.1.3 The Society reserves the right to impose additional requirements or grant dispensations to the following type test programs.

4.2 Type tests of engines not admitted to an alternative inspection scheme

4.2.1 General

Engines which are not admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) are to be type tested in the presence of a Surveyor in accordance with the requirements of [4.2].

The type test is subdivided into three stages, namely:

a) Stage A - Preliminary internal tests carried out by the Manufacturer.

   Stage A includes functional tests and collection of operating values including the number of testing hours during the internal tests, the results of which are to be presented to the Surveyor during the type test. The number of testing hours of components which are inspected according to [4.2.5] is to be stated by the Manufacturer.

b) Stage B - Type approval test

   The type approval test is to be carried out in the presence of the Surveyor.

c) Stage C - Inspection of main engine components.

After completion of the test programme, the main engine components are to be inspected.

The engine Manufacturer is to compile all results and measurements for the engine tested during the type test in a type test report, which is to be submitted to the Society.

4.2.2 Stage A - Internal tests (function tests and collection of operating data)

During the internal tests the engine is to be operated at the load points considered important by the engine Manufacturer and the relevant operating values are to be recorded (see item a)).

The load points may be selected according to the range of application (see Fig 2).

If an engine can be satisfactorily operated at all load points without using mechanically driven cylinder lubricators, this is to be verified.

For engines which may operate on heavy fuel oil, their suitability for this is to be proved to the satisfaction of the Society.

a) Functional tests under normal operating conditions

   Functional tests under normal operating conditions include:

   1) The load points 25%, 50%, 75%, 100% and 110% of the maximum continuous power for which type approval is requested, to be carried out:

      - along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
      - at constant speed, for engines intended for generating sets.

   2) The limit points of the permissible operating range.

      These limit points are to be defined by the engine Manufacturer.

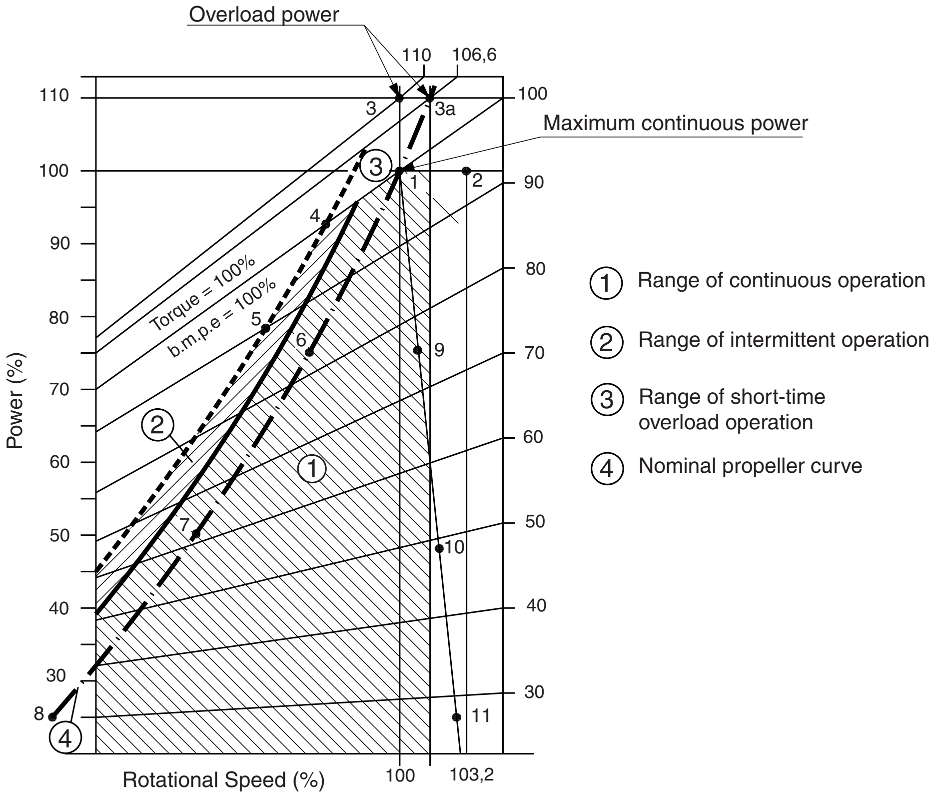
   The maximum continuous power P is defined in [1.3.2].

b) Tests under emergency operating conditions

   For turbocharged engines, the achievable continuous output is to be determined for a situation when one turbocharger is damaged, i.e.:

   - for engines with one turbocharger, when the rotor is blocked or removed
   - for engines with two or more turbochargers, when the damaged turbocharger is shut off.

Figure 2 : Power/speed diagram



4.2.3 Stage B - Type approval tests in the presence of the Surveyor

During the type test, the tests listed below are to be carried out in the presence of the Surveyor and the results are to be recorded in a report signed by both the engine Manufacturer and the Surveyor.

For engines not yet adequately experienced in service the scope of test will be agreed on a case by case basis.

Any departures from this programme are to be agreed upon by the engine Manufacturer and the Society.

a) Load points

The load points at which the engine is to be operated according to the power/speed diagram (see Fig 2) are those listed below. The data to be measured and recorded when testing the engine at various load points are to include all necessary parameters for engine operation.

The operating time per load point depends on the engine characteristics (achievement of steady-state condition) and the time for collection of the operating values.

Normally, an operating time of 0,5 hour per load point can be assumed.

At the maximum continuous power as per the following item 1) an operating time of two hours is required. Two sets of readings are to be taken at a minimum interval of one hour.

1) Test at maximum continuous power P: i.e. 100% output at 100% torque and 100% speed, corresponding to load point 1 in the diagram in Fig 2.

2) Test at 100% power at maximum permissible speed, corresponding to load point 2 in the diagram in Fig 2.

3) Test at maximum permissible torque (normally 110% of nominal torque T) at 100% speed, corresponding to load point 3 in the diagram in Fig 2; or test at maximum permissible power (normally 110% of P) and speed according to the nominal propeller curve, corresponding to load point 3a in the diagram in Fig 2.

4) Test at minimum permissible speed at 100% of torque T, corresponding to load point 4 in the diagram in Fig 2.

5) Test at minimum permissible speed at 90% of torque T, corresponding to load point 5 in the diagram in Fig 2.

6) Tests at part loads, e.g. 75%, 50%, 25% of maximum continuous power P and speed according to the nominal propeller curve, corresponding to load points 6, 7 and 8 in the diagram in Fig 2; and tests at the above part loads and at speed n with constant governor setting, corresponding to load points 9, 10 and 11 in the diagram in Fig 2.

b) Tests under emergency operating conditions

These are tests at maximum achievable power when operating along the nominal propeller curve and when operating with constant governor setting for speed n, in emergency operating conditions as stated in [4.2.2] b).

c) Additional tests
   - Test at lowest engine speed according to the nominal propeller curve.
   - Starting tests for non-reversible engines, or starting and reversing tests for reversible engines.
   - Governor tests.
   - Testing of the safety system, particularly for overspeed and low lubricating oil pressure.

   For engines intended to be used for emergency services, supplementary tests may be required to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C.

4.2.4 Evaluation of test results

The results of the tests and checks required by [4.2.3] will be evaluated by the attending Surveyor. Normally the main operating data to be recorded during the tests are those listed in [4.3.4].

In particular, the maximum combustion pressure measured with the engine running at the maximum continuous power P is not to exceed the value taken for the purpose of checking the scantlings of the engine crankshaft, according to the applicable requirements of Chapter 1, Appendix 1.

The values of temperatures and pressures of media, such as cooling water, lubricating oil, charge air, exhaust gases, etc., are to be within limits which, in the opinion of the Surveyor, are appropriate for the characteristics of the engine tested.

4.2.5 Stage C - Inspection of main engine components

Immediately after the test run as per [4.2.3], the components of one cylinder for in-line engines, and two cylinders for V-type engines, are to be presented for inspection to the Surveyor.

The following main engine components are to be inspected:

- piston removed and dismantled
- crosshead bearing, dismantled
- crank bearing and main bearing, dismantled
- cylinder liner in the installed condition
- cylinder head and valves, disassembled
- control gear, camshaft and crankcase with opened covers.

Where deemed necessary by the Surveyor, further dismantling of the engine may be required.

4.3 Type tests of engines admitted to an alternative inspection scheme

4.3.1 General

Engines for which the Manufacturer is admitted to testing and inspections according to an alternative inspection scheme (see NR216 Materials and Welding, Ch 1, Sec 1, [3.2]) and which have a cylinder bore not exceeding 300 mm are to be type tested in the presence of a Surveyor in accordance with the requirements of the present [4.3].

The selection of the engine to be tested from the production line is to be agreed upon with the Surveyor.

4.3.2 Type test

The programme of the type test is to be in general as specified below, P being the maximum continuous power and n the corresponding speed. The maximum continuous power is that stated by the engine Manufacturer and accepted by the Society, as defined in [1.3.2].

a) 80 hours at power P and speed n
b) 8 hours at overload power (110% of power P)
c) 10 hours at partial loads (25%, 50%, 75% and 90% of power P)
d) 2 hours at intermittent loads
e) starting tests
f) reverse running for direct reversing engines
g) testing of speed governor, overspeed device and lubricating oil system failure alarm device
h) testing of the engine with one turbocharger out of action, when applicable
i) testing of the minimum speed along the nominal (theoretical) propeller curve, for main propulsion engines driving fixed pitch propellers, and of the minimum speed with no brake load, for main propulsion engines driving controllable pitch propellers or for auxiliary engines.

The tests at the above-mentioned outputs are to be combined together in working cycles which are to be repeated in succession for the entire duration within the limits indicated.

In particular, the overload test, to be carried out at the end of each cycle, is to be of one hour’s duration and is to be carried out alternately:

- at 110% of the power P and 103% of the speed n
- at 110% of the power P and 100% of the speed n.

The partial load tests specified in item c) are to be carried out:

- along the nominal (theoretical) propeller curve and at constant speed, for propulsion engines
- at constant speed, for engines intended for generating sets.

For engines intended to be used for emergency services, supplementary tests may be required, to the satisfaction of the Society. In particular, for engines intended to drive emergency generating sets, additional tests and/or documents may be required to prove that the engine is capable of being readily started at a temperature of 0°C, as required in [3.1.3].

In the case of prototype engines, the duration and programme of the type test will be not lower than the one specified in this paragraph.

4.3.3 In cases of engines for which the Manufacturer submits documentary evidence proving successful service experience or results of previous bench tests, the Society, at its discretion, may allow a type test to be carried out in the presence of the Surveyor according to a programme to be agreed upon in each instance.

In the case of engines which are to be type approved for different purposes and performances, the programme and duration of the type test will be decided by the Society in each case to cover the whole range of engine performances for which approval is requested, taking into account the most severe values.

4.3.4 During the type test, at least the following particulars are to be recorded:

a) ambient air temperature, pressure and atmospheric humidity in the test room

b) cooling raw water temperature at the inlet of heat exchangers

c) characteristics of fuel and lubricating oil used during the test

d) engine speed

e) brake power

f) brake torque

g) maximum combustion pressure

h) indicated pressure diagrams, where practicable

i) exhaust smoke (with a smoke meter deemed suitable by the Surveyor)

j) lubricating oil pressure and temperature

k) cooling water pressure and temperature

l) exhaust gas temperature in the exhaust manifold and, where facilities are available, from each cylinder

m) minimum starting air pressure necessary to start the engine in cold condition.

In addition to the above, for supercharged engines the following data are also to be measured and recorded:

- turbocharger speed
- air temperature and pressure before and after turbocharger and charge air coolers
- exhaust gas temperatures and pressures before and after turbochargers and cooling water temperature at the inlet of charge air coolers.

4.3.5 Inspection of main engine components and evaluation of test results

The provisions of [4.2.4] and [4.2.5] are to be complied with, as far as applicable.

4.4 Material and non-destructive tests

4.4.1 Material tests

Engine components are to be tested in accordance with Tab 6 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 6 and are to be effected in positions mutually agreed upon by the Manufacturer and the Society Surveyor, where experience shows defects are most likely to occur.

The magnetic particle test of tie rods/stay bolts is to be carried out at each end, for a portion which is at least twice the length of the thread.

For important structural parts of engines, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any engine component, non-destructive tests using approved detecting methods may be required.

Engines of a cylinder diameter not exceeding 300 mm may be tested according to an alternative survey scheme.

4.4.2 Hydrostatic tests

Parts of engines under pressure are to be hydrostatically tested at the test pressure specified for each part in Tab 7.

The following parts of auxiliaries which are necessary for operation of engines as per [1.1.1] a), b) and c):

- cylinders, cylinder covers, coolers and receivers of independent air compressors
- water, oil and air coolers (tube bundles or coils, shells and heads) not fitted on the engine and filters
- independently driven lubricating oil, fuel oil and water pumps
- pressure pipes (water, lubricating oil, fuel oil, and compressed air pipes), valves and other fittings

are to be subjected to hydrostatic tests at 1,5 times the maximum working pressure, but not less than 0,4 MPa.

4.5 Workshop inspections and testing

4.5.1 General

In addition to the type test, diesel engines are to be subjected to works trials, which are to be witnessed by the Surveyor also when an Alternative Inspection Scheme has been granted.

For all stages at which the engine is to be tested, the relevant operating values are to be measured and recorded by the engine Manufacturer.

In each case all measurements conducted at the various load points are to be carried out at steady operating conditions.

The readings for 100% of the rated power P at the corresponding speed n are to be taken twice at an interval of at least 30 minutes.

At the discretion of the Surveyor, the programme of trials given in [4.5.2], [4.5.3] or [4.5.4] may be expanded depending on the engine application.

4.5.2 Main propulsion engines driving propellers

Main propulsion engines are to be subjected to trials to be performed as follows:

a) at least 60 min, after having reached steady conditions, at rated power P and rated speed n

b) 30 min, after having reached steady conditions, at 110% of rated power P and at a speed equal to 1,032 of rated speed

c) tests at 90% (or normal continuous cruise power), 75%, 50% and 25% of rated power P, carried out:
   - at the speed corresponding to the nominal (theoretical) propeller curve, for engines driving fixed pitch propellers
   - at constant speed, for engines driving controllable pitch propellers

d) idle run

e) starting and reversing tests (when applicable)

f) testing of the speed governor and of the independent overspeed protective device

g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system is to be so adjusted that the engine cannot deliver more than 100% of the rated power at the corresponding speed (overload power cannot be obtained in service).

4.5.3 Engines driving electric generators used for main propulsion purposes

Engines driving electric generators are to be subjected to trials to be performed with a constant governor setting, as follows:

a) at least 60 min, after having reached steady conditions, at 100% of rated power P and rated speed n

b) 45 min, after having reached steady conditions, at 110% of rated power and rated speed

c) 75%, 50% and 25% of rated power P, carried out at constant rated speed n

d) idle run

e) starting tests

f) testing of the speed governor ([2.10.5]) and of the independent overspeed protective device (when applicable)

g) testing of alarm and/or shutdown devices.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be maintained at all times.

4.5.4 Engines driving auxiliary machinery

Engines driving auxiliary machinery are to be subjected to the tests stated in [4.5.2] or [4.5.3] for variable speed and constant speed drives, respectively.

Note 1: After running on the test bed, the fuel delivery system of diesel engines driving electric generators is to be adjusted such that overload (110%) power can be produced but not exceeded in service after installation on board, so that the governing characteristics, including the activation of generator protective devices, can be fulfilled at all times.

4.5.5 Inspection of engine components

Random checks of components to be presented for inspection after works trials are left to the discretion of the Surveyor.

4.5.6 Parameters to be measured

The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for engine operation. The crankshaft deflection is to be verified when this check is required by the Manufacturer during the operating life of the engine.

4.5.7 Testing report

In the testing report for each engine the results of the tests carried out are to be compiled and the reference number and date of issue of the Type Approval Certificate (see [4.6]), relevant to the engine type, are always to be stated; the testing report is to be issued by the Manufacturer and enclosed with the testing certificate as per [4.6].

4.6 Certification

4.6.1 Type Approval Certificate and its validity

After the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the engine manufacturer a "Type Approval Certificate" valid for all engines of the same type.

The Society reserves the right to consider the test carried out on one engine type valid also for engines having a different cylinder arrangement, following examination of suitable, detailed documentation submitted by the Manufacturer and including bench test results.

Table 6 : Material and non-destructive tests

Engine component	Material tests **(1)** (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Crankshaft	all	all	all
2) Crankshaft coupling flange (non-integral) for main power transmissions	if bore > 400 mm	–	–
3) Coupling bolts for crankshaft	if bore > 400 mm	–	–
4) Steel piston crowns **(2)**	if bore > 400 mm	if bore > 400 mm	all
5) Piston rods	if bore > 400 mm	if bore > 400 mm	if bore > 400 mm
6) Connecting rods, together with connecting rod bearing caps	all	all	if bore > 400 mm
7) Crossheads	if bore > 400 mm	–	–
8) Cylinder liners	if bore > 300 mm	–	–
9) Steel cylinder covers **(2)**	if bore > 300 mm	if bore > 400 mm	all
10) Bedplates of welded construction; plates and transverse bearing girders made of forged or cast steel **(2)(3)**	all	all	all
11) Frames and crankcases of welded construction **(3)**	all	–	–
12) Entablatures of welded construction **(3)**	all	–	–
13) Tie rods	all	if bore > 400 mm	–
14) Shafts and rotors, including blades, for turbochargers **(4)**	(see Ch 1, Sec 15)	–	–
15) Bolts and studs for cylinder covers, crossheads, main bearings and connecting rod bearings; nuts for tie rods	if bore > 300 mm	if bore > 400 mm	–
16) Steel gear wheels for camshaft drives	if bore > 400 mm	if bore > 400 mm	–

(1) In addition, material tests may also be required, at the Society's discretion, for piping and valves for starting air lines and any other pressure piping fitted on the engines.
(2) For items 4), 9) and 10), it is implicit that as well as for steel parts, material tests are also required for parts made of other materials which are comparable to steel on account of their mechanical properties in general and their ductility in particular: e.g. aluminium and its alloys, ductile and spheroidal or nodular graphite cast iron.
(3) Material tests for bedplates, frames, crankcases and entablatures are required even if these parts are not welded and for any material except grey cast iron.
(4) Turbocharger is understood as turbocharger itself and engine driven compressor (incl. "root blowers", but not auxiliary blowers).

4.6.2 Testing certification

a) Engines admitted to an alternative inspection scheme

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 6 and Tab 7.

b) Engines not admitted to an alternative inspection scheme

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in Tab 6 and for works trials as per [4.5].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for non-destructive and hydrostatic tests of components in Tab 6 and Tab 7.

In both cases a) and b), the Manufacturer is to supply:

a) the following information:
- engine type
- rated power
- rated speed
- driven equipment
- operating conditions
- list of auxiliaries fitted on the engine

b) a statement certifying that the engine is in compliance with that type tested, except for modifications already notified to the Society. The reference number and date of the Type Approval Certificate are also to be indicated in the statement.

Table 7 : Test pressure of engine parts

Parts under pressure		Test pressure (MPa) **(1) (2)**
1	Cylinder cover, cooling space **(3)**	0,7
2	Cylinder liner, over the whole length of cooling space	0,7
3	Cylinder jacket, cooling space	0,4 (but not less than 1,5 p)
4	Exhaust valve, cooling space	0,4 (but not less than 1,5 p)
5	Piston crown, cooling space **(3) (4)**	0,7
6	Fuel injection system a) Fuel injection pump body, pressure side b) Fuel injection valve c) Fuel injection pipes	 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser) 1,5 p (or p + 30, if lesser)
7	Hydraulic system • Piping, pumps, actuators etc. for hydraulic drive of valves	 1,5 p
8	Scavenge pump cylinder	0,4
9	Turbocharger, cooling space	0,4 (but not less than 1,5p)
10	Exhaust pipe, cooling space	0,4 (but not less than 1,5 p)
11	Engine driven air compressor (cylinders, covers, intercoolers and aftercoolers) a) Air side b) Water side	 1,5 p 0,4 (but not less than 1,5 p)
12	Coolers, each side **(5)**	0,4 (but not less than 1,5 p)
13	Engine driven pumps (oil, water, fuel, bilge)	0,4 (but not less than 1,5 p)

(1) In general, parts are to be tested at the hydraulic pressure indicated in the Table. Where design or testing features may call for modification of these testing requirements, special consideration will be given by the Society.
(2) p is the maximum working pressure, in MPa, in the part concerned.
(3) For forged steel cylinder covers and forged steel piston crowns, test methods other than hydrostatic testing may be accepted, e.g. suitable non-destructive tests and documented dimensional tests.
(4) Where the cooling space is sealed by the piston rod, or by the piston rod and the shell, the pressure test is to be carried out after assembly.
(5) Turbocharger air coolers need to be tested on the water side only.

Section 3 Pressure Equipment

1 General

1.1 Principles

1.1.1 Scope of the Rules

The boilers and other pressure vessels, associated piping systems and fittings are to be of a design and construction adequate for the service for which they are intended and is to be so installed and protected as to reduce to a minimum any danger to persons on board, due regard being paid to moving parts, hot surfaces and other hazards. The design is to have regard to materials used in construction, the purpose for which the equipment is intended, the working conditions to which it will be subjected and the environmental conditions on board.

So these Rules apply to “pressure equipment” for the following requirements:

- be safe in sight of pressure risk
- be safe in sight of other risks, moving parts, hot surfaces
- ensure capability of propulsion and other essential services.

“Pressure equipment” means pressure vessels, piping (Ch 1, Sec 10), safety accessories and pressure accessories.

1.1.2 Overpressure risk

Where main or auxiliary boilers and other pressure vessels or any parts thereof may be subject to dangerous overpressure, means are to be provided where practicable to protect against such excessive pressure.

1.1.3 Propulsion capability

Means are to be provided whereby normal operation of main boilers can be sustained or restored even through one of the essential auxiliaries become inoperative. Special consideration is to be given to the malfunctioning of:

- the source of steam supply
- the boiler feed water systems
- the fuel oil supply system for boilers
- the mechanical air supply for boilers.

However the Society, having regard to overall safety considerations, may accept a partial reduction in propulsion capability from normal operation.

1.1.4 Tests

All boilers and other pressure vessels including their associated fittings which are under internal pressure are to be subjected to appropriate tests including a pressure test before being put into service for the first time (see also Article [7]).

1.2 Application

1.2.1 Pressure vessels covered by the Rules

The requirements of this Section apply to:

- all fired or unfired pressures vessels of metallic construction, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2]
- all boilers and other steam generators, including the associated fittings and mountings with maximum allowable pressure greater than 0,5 bar above atmospheric pressure with the exception of those indicated in [1.2.2].

1.2.2 Pressure vessels not covered by the Rules

Among others the following boilers and pressure vessels are not covered by the Rules and are to be considered on a case by case basis:

a) boilers with design pressure p > 10 MPa

b) pressure vessel intended for radioactive material

c) equipment comprising casings or machinery where the dimensioning, choice of material and manufacturing rules are based primarily on requirements for sufficient strength, rigidity and stability to meet the static and dynamic operational effects or other operational characteristics and for which pressure is not a significant design factor. Such equipment may include:
   - engines including turbines and internal combustion engines
   - steam engines, gas/steam turbines, turbo-generators, compressors, pumps and actuating devices

d) small pressure vessels included in self-contained domestic equipment.

1.3 Definitions

1.3.1 Pressure vessel

"Pressure vessel" means a housing designed and built to contain fluids under pressure including its direct attachments up to the coupling point connecting it to other equipment. A vessel may be composed of more than one chamber.

1.3.2 Fired pressure vessel

Fired pressure vessel is a pressure vessel which is completely or partially exposed to fire from burners or combustion gases or otherwise heated pressure vessel with a risk of overheating.

a) Boiler

Boiler is one or more fired pressure vessels and associated piping systems used for generating steam or hot water at a temperature above 120°C.

Any equipment directly connected to the boiler, such as economisers, superheaters and safety valves, is considered as part of the boiler, if it is not separated from the steam generator by means of any isolating valve. Piping connected to the boiler is considered as part of the boiler upstream of the isolating valve and as part of the associated piping system downstream of the isolating valve.

b) Thermal oil heater

Thermal oil heater is one or more fired pressure vessels and associated piping systems in which organic liquids (thermal oils) are heated. When heated by electricity thermal oil heater is considered as an unfired pressure vessel.

1.3.3 Unfired pressure vessel

Any pressure vessel which is not a fired pressure vessel is an unfired pressure vessel.

a) Heat exchanger

A heat exchanger is an unfired pressure vessel used to heat or cool a fluid with an another fluid. In general heat exchangers are composed of a number of adjacent chambers, the two fluids flowing separately in adjacent chambers. One or more chambers may consist of bundles of tubes.

b) Steam generator

A steam generator is a heat exchanger and associated piping used for generating steam. In general in these Rules, the requirements for boilers are also applicable for steam generators, unless otherwise indicated.

1.3.4 Safety accessories

"Safety accessories" means devices designed to protect pressure equipment against the allowable limits being exceeded. Such devices include:

- devices for direct pressure limitation, such as safety valves, bursting disc safety devices, buckling rods, controlled safety pressure relief systems, and
- limiting devices, which either activate the means for correction or provide for shutdown or shutdown and lockout, such as pressure switches or temperature switches or fluid level switches and safety related measurement control and regulation devices.

1.3.5 Design pressure

The design pressure is the pressure used by the manufacturer to determine the scantlings of the vessel. This pressure cannot be taken less than the maximum working pressure and is to be limited by the set pressure of the safety valve, as prescribed by the applicable Rules. Pressure is indicated as gauge pressure above atmospheric pressure, vacuum is indicated as negative pressure.

1.3.6 Design temperature

a) Design temperature is the actual metal temperature of the applicable part under the expected operating conditions, as modified in Tab 1. This temperature is to be stated by the manufacturer and is to take in account of the effect of any temperature fluctuations which may occur during the service.

b) The design temperature is not to be less than the temperatures stated in Tab 1, unless specially agreed between the manufacturer and the Society on a case by case basis.

1.3.7 Volume

Volume V means the internal volume of a chamber, including the volume of nozzles to the first connection or weld and excluding the volume of permanent internal parts.

1.3.8 Boiler heating surface

Heating surface is the area of the part of the boiler through which the heat is supplied to the medium, on the side exposed to fire or hot gases.

1.3.9 Maximum steam output

Maximum steam output is the maximum quantity of steam than can be produced continuously by the boiler or steam generator operating under the design steam conditions.

Table 1 : Minimum design temperature

Type of vessel	Minimum design temperature
Pressure parts of pressure vessels and boilers not heated by hot gases or adequately protected by insulation	Maximum temperature of the internal fluid
Pressure vessel heated by hot gases	25°C in excess of the temperature of the internal fluid
Water tubes of boilers mainly subjected to convection heat	25°C in excess of the temperature of the saturated steam
Water tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to convection heat	35°C in excess of the temperature of the saturated steam
Superheater tubes of boilers mainly subjected to radiant heat	50°C in excess of the temperature of the saturated steam
Economiser tubes	35°C in excess of the temperature of the internal fluid
For combustion chambers of the type used in wet-back boilers	50°C in excess of the temperature of the internal fluid
For furnaces, fire-boxes, rear tube plates of dry-back boilers and other pressure parts subjected to similar rate of heat transfer	90°C in excess of the temperature of the internal fluid

1.3.10 Toxic and corrosive substances

Toxic and corrosive substances are those which are listed in the IMO “International Maritime Dangerous Goods Code (IMDG Code)”, as amended.

1.3.11 Liquid and gaseous substances

a) liquid substances are liquids having a vapour pressure at the maximum allowable temperature of not more than 0,5 bar above normal atmospheric pressure

b) gaseous substances are gases, liquefied gases, gases dissolved under pressure, vapours and also those liquids whose vapour pressure at the maximum allowable temperature is greater than 0,5 bar above normal atmospheric pressure.

1.3.12 Ductile material

For the purpose of this Section, ductile material is a material having an elongation over 12%.

1.3.13 Incinerator

Incinerator is a shipboard facility for incinerating solid garbage approximating in composition to household garbage and liquid garbage deriving from the operation of the ship (e.g. domestic garbage, cargo-associated garbage, maintenance garbage, operational garbage, cargo residue, and fishing gear), as well as for burning sludge with a flash point above 60°C.

These facilities may be designed to use the heat energy produced.

Incinerators are not generally pressure vessels, however when their fittings are of the same type than those of boilers the requirements for these fittings apply.

1.4 Classes

1.4.1 Significant parameters

Pressure vessels are classed in three class in consideration of the:

- type of equipment: pressure vessel or steam generator
- state (gaseous or liquid) of the intended fluid contents
- substances listed or not in the IMDG Code
- design pressure p, in MPa
- design temperature T, in °C
- actual thickness of the vessel t_A, in mm
- volume V, in litres.

1.4.2 Pressure vessel classification

Pressure vessels are classed as indicated in Tab 2.

1.4.3 Implication of class

The class of a pressure vessel has, among others, implication in:

- design
- material allowance
- welding design
- efficiency of joints
- examination and non-destructive tests
- thermal stress relieving.

See Tab 24.

Table 2 : Pressure vessel classification

Equipment	Class 1	Class 2	Class 3
Steam generators or boilers	$p > 3{,}2$ and $V > 2$ or $p\,V > 20$ and $V > 2$	if not class 1 or class 3	$p\,V \leq 5$ or $V \leq 2$
Pressure vessels for toxic substances	all	–	–
Pressure vessels for corrosive substances	$p > 20$ or $p\,V > 20$ or $T > 350$	if not in class 1	–
Pressure vessels for gaseous substances	$p > 100$ or $p\,V > 300$	$V > 1$ and $p\,V > 100$ and not in class 1	all pressure vessels which are not class 1 or class 2
Pressure vessels for liquid substances	$V > 10$ and $p\,V > 1000$ and $p > 50$	$V \leq 10$ and $p > 100$ or $1 < p \leq 50$ and $p\,V > 1000$	all pressure vessels and heat exchangers which are not class 1 or class 2
Pressure vessels for thermal oil	$p > 1{,}6$ or $T > 300$	if not class 1 or class 3	$p \leq 0{,}7$ and $T \leq 150$
Pressure vessels for fuel oil, lubricating oil or flammable hydraulic oil	$p > 1{,}6$ or $T > 150$	if not class 1 or class 3	$p \leq 0{,}7$ and $T \leq 60$
Whatever type of equipment	$t_A > 40$	$15 < t_A \leq 40$	–
Note 1: Whenever the class is defined by more than one characteristic, the equipment is to be considered belonging to the highest class of its characteristics, independently of the values of the other characteristics.			

1.5 Applicable Rules

1.5.1 Alternative standards

a) Boilers and pressure vessels are to be designed, constructed, installed and tested in accordance with the applicable requirements of this Section.

b) The acceptance of national and international standards as an alternative to the requirements of this Section may be considered by the Society on a case by case basis.

c) In particular composite wrapped cylinders are to be designed, constructed, installed and tested in accordance with a Standard to be accepted by the Society on a case by case basis.

1.6 Documentation to be submitted

1.6.1 General

Documents mentioned in the present sub-article are to be submitted for class 1 and class 2 and not for class 3, unless the equipment is considered as critical.

1.6.2 Boilers and steam generators

The plans listed in Tab 3 are to be submitted.

The drawings listed in Tab 3 are to contain:

- the constructional details of all pressure parts, such as shells, headers, tubes, tube plates, nozzles
- strengthening members, such as stays, brackets, opening reinforcements and covers
- installation arrangements, such as saddles and anchoring system,

as well as the information and data indicated in Tab 4.

1.6.3 Pressure vessels

The plans listed in Tab 5 are to be submitted.

The drawings listedin Tab 5 are to contain the constructional details of:

- pressure parts, such as shells, headers, tubes, tube plates, nozzles, opening reinforcements and covers
- strengthening members, such as stays, brackets and reinforcements.

1.6.4 Incinerators

Incinerators are to be considered on a case by case basis, based on their actual arrangement, using the applicable requirements for boilers and pressure vessels.

Table 3 : Drawings to be submitted for boilers and steam generators

No	A/I	Item
1	I	General arrangement plan, including valves and fittings
2	A	Material specifications
3	A	Sectional assembly
4	A	Evaporating parts
5	A	Superheater
6	A	De-superheater
7	A	Economiser
8	A	Air heater
9	A	Tubes and tube plates
10	A	Nozzles and fittings
11	A	Safety valves and their arrangement
12	A	Boiler seating
13	I	Fuel oil burning arrangement
14	I	Forced draft system
15	I	Refractor or insulation arrangement
16	A	Boiler instrumentation, monitoring and control system
17	A	Type of safety valves and their lift, discharge rate and setting
18	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatment
Note 1: A = to be submitted for approval; I = to be submitted for information.		

Table 4 : Information and data to be submitted for boilers and steam generators

No.	Item
1	Design pressure and temperature
2	Pressure and temperature of the superheated steam
3	Pressure and temperature of the saturated steam
4	Maximum steam production per hour
5	Evaporating surface of the tube bundles and water-walls
6	Heating surface of the economiser, superheater and air-heater
7	Surface of the furnace
8	Volume of the combustion chamber
9	Temperature and pressure of the feed water
10	Type of fuel to be used and fuel consumption at full steam production
11	Number and capacity of burners

Table 5 : Drawings, information and data to be submitted for pressure vessels and heat exchangers

No	A/I	Item
1	I	General arrangement plan, including nozzles and fittings
2	A	Sectional assembly
3	A	Safety valves (if any) and their arrangement
4	A	Material specifications
5	A	Welding details, including at least: • typical weld joint design • welding procedure specifications • post-weld heat treatments
6	I	Design data, including at least design pressure and design temperatures (as applicable)
7	A	For seamless (extruded) pressure vessels, the manufacturing process, including: • a description of the manufacturing process with indication of the production controls normally carried out in the manufacturer's works • details of the materials to be used (specification, yield point, tensile strength, impact strength, heat treatment) • details of the stamped marking to be applied.
8	I	Type of fluid or fluids contained
Note 1: A = to be submitted for approval ; I = to be submitted for information.		

2 Design and construction - Scantlings of pressure parts

2.1 General

2.1.1 Application

a) In general, the formulae in the present Article do not take into account additional stresses imposed by effects other than pressure, such as stresses deriving from the static and dynamic weight of the pressure vessel and its content, external loads from connecting equipment and foundations, etc. For the purpose of the Rules these additional loads may be neglected, provided it can reasonably be presumed that the actual average stresses of the vessel, considering all these additional loads, would not increase more than 10% with respect to the stresses calculated by the formulae in this Article.

b) Where it is necessary to take into account additional stresses, such as dynamic loads, the Society reserves the right to ask for additional requirements on a case by case basis.

2.1.2 Alternative requirements

When pressure parts are of an irregular shape, such as to make it impossible to check the scantlings by applying the formulae of this Article, the approval is to be based on other means, such as burst and/or deformation tests on a prototype or by another method agreed upon between the manufacturer and the Society.

2.2 Materials

2.2.1 Materials for high temperatures

a) Materials for pressure parts having a design temperature exceeding the ambient temperature are to be selected by the Manufacturer and to have mechanical and metallurgical properties adequate for the design temperature. Their allowable stress limits are to be determined as a function of the temperature, as per [2.3.2].

b) When the design temperature of pressure parts exceeds 400°C, alloy steels are to be used. Other materials are subject of special consideration by the Society.

2.2.2 Materials for low temperatures

Materials for pressure parts having a design temperature below the ambient temperature are to have notch toughness properties suitable for the design temperature.

2.2.3 Cast iron

Cast iron is not to be used for:

a) class 1 and class 2 pressure vessels

b) class 3 pressure vessels with design pressure $p > 0,7$ MPa or product $p \cdot V > 1000$, where V is the internal volume of the pressure vessel in litres

c) Bolted covers and closures of pressure vessels having a design pressure $p > 1$ MPa, except for covers intended for boiler shells, for which [3.2.4] applies.

2.2.4 Valves and fittings for boilers

a) Ductile materials are to be used for valves and fittings intended to be mounted on boilers. The material is to have mechanical and metallurgical characteristics suitable for the design temperature and for the thermal and other loads imposed during the operation.

b) Grey cast iron is not to be used for valves and fittings which are subject to dynamic loads, such as safety valves and blow-down valves, and in general for fittings and accessories having design pressure p exceeding 0,3 MPa and design temperature T exceeding 220°C.

c) Spheroidal cast iron is not to be used for parts having a design temperature T exceeding 350°C.

d) Bronze is not to be used for parts having design temperature T exceeding 220°C for normal bronzes and 260°C for bronzes suitable for high temperatures. Copper and aluminium brass are not to be used for fittings with design temperature T above 200°C and copper-nickel fittings with design temperature T exceeding 300°C.

2.2.5 Alternative materials

In the case of boilers or pressure vessels constructed in accordance with one of the standards considered acceptable by the Society as per [1.5], the material specifications are to be in compliance with the requirements of the standard used.

2.3 Permissible stresses

2.3.1 The permissible stresses K, in N/mm², for steels, to be used in the formulae of this Article, may be determined from Tab 6, Tab 7, Tab 8 and Tab 9, where R_m is the ultimate strength of the material, in N/mm². For intermediate values of the temperature, the value of K is to be obtained by linear interpolation.

Table 6 : Permissible stresses K for carbon steels intended for boilers and thermal oil heaters

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	109	107	105	94	77	73	72
	15 mm < t ≤ 40 mm	128	106	105	101	90	77	73	72
	40 mm < t ≤ 60 mm	122	101	99	95	88	77	73	72
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	127	116	103	79	79	72	69
	15 mm < t ≤ 40 mm	133	122	114	102	79	79	72	69
	40 mm < t ≤ 60 mm	133	112	107	99	79	79	72	69
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	132	130	126	112	94	89	86
	15 mm < t ≤ 40 mm	147	131	124	119	107	94	89	86
	40 mm < t ≤ 60 mm	141	120	117	113	105	94	89	86
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	147	135	121	107	95	88	84
	15 mm < t ≤ 40 mm	152	142	133	120	107	95	88	84
	40 mm < t ≤ 60 mm	152	134	127	117	107	95	88	84
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	164	154	139	124	111	104	99
	15 mm < t ≤ 40 mm	169	162	151	137	124	111	104	99
	40 mm < t ≤ 60 mm	162	157	147	136	124	111	104	99
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	170	170	169	159	147	134	125	112

Table 7 : Permissible stresses K for carbon steels intended for other pressure vessels

Carbon steel	T (°C)	≤ 50	100	150	200	250	300	350	400
R_m = 360 N/mm² Grade HA	t ≤ 15 mm	133	117	115	112	100	83	78	77
	15 mm < t ≤ 40 mm	133	114	113	108	96	83	78	77
	40 mm < t ≤ 60 mm	130	108	105	101	94	83	78	77
R_m = 360 N/mm² Grades HB, HD	t ≤ 15 mm	133	133	123	110	97	85	77	73
	15 mm < t ≤ 40 mm	133	131	122	109	97	85	77	73
	40 mm < t ≤ 60 mm	133	119	115	106	97	85	77	73
R_m = 410 N/mm² Grade HA	t ≤ 15 mm	152	141	139	134	120	100	95	92
	15 mm < t ≤40 mm	152	134	132	127	114	100	95	92
	40 mm < t ≤ 60 mm	150	128	121	112	112	100	95	92
R_m = 410 N/mm² Grades HB, HD	t ≤ 15 mm	152	152	144	129	114	101	94	89
	15 mm < t ≤ 40 mm	152	152	142	128	114	101	94	89
	40 mm < t ≤ 60 mm	152	143	139	125	114	101	94	89
R_m = 460 N/mm² Grades HB, HD	t ≤ 15 mm	170	170	165	149	132	118	111	105
	15 mm < t ≤ 40 mm	170	170	161	147	132	118	111	105
	40 mm < t ≤ 60 mm	170	167	157	145	132	118	111	105
R_m = 510 N/mm² Grades HB, HD	t ≤ 60 mm	189	189	180	170	157	143	133	120

Table 8 : Permissible stresses K for alloy steels intended for boilers and thermal oil heaters

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	153	143	134	125	106	100	94	91	89	87	36			
1Cr 0,5Mo	t ≤ 60 mm	167	167	157	144	137	128	119	112	106	104	103	55	31	19	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	170	167	157	147	144	137	131	125	119	115	112	61	41	30	22
2,25Cr 1Mo **(2)**	t ≤ 60 mm	170	167	164	161	159	147	141	130	128	125	122	61	41	30	22

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

Table 9 : Permissible stresses K for alloy steels intended for other pressure vessels

Alloy steel	T(°C)	≤ 50	100	150	200	250	300	350	400	450	475	500	525	550	575	600
0,3Mo	t ≤ 60 mm	159	159	153	143	133	113	107	100	97	95	93	38			
1Cr 0,5Mo	t ≤ 60 mm	167	167	167	154	146	137	127	119	113	111	110	59	33	20	
2,25Cr 1Mo **(1)**	t ≤ 60 mm	183	174	167	157	154	146	140	133	127	123	119	65	44	32	23
2,25Cr 1Mo **(2)**	t ≤ 60 mm	174	174	174	172	170	157	150	139	137	133	130	65	44	32	23

(1) Normalised and tempered
(2) Normalised and tempered or quenched and tempered

2.3.2 Direct determination of permissible stress

The permissible stresses K, where not otherwise specified, may be taken as indicated below.

a) Steel:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{2,7}$$

$$K = \frac{R_{S,MIN,T}}{A}$$

$$K = \frac{S_A}{A}$$

where:

$R_{m,20}$: Minimum tensile strength at ambient temperature (20°C), in N/mm^2

$R_{S,MIN,T}$: Minimum between R_{eH} and $R_{p\ 0,2}$ at the design temperature T, in N/mm^2

S_A : Average stress to produce creep rupture in 100000 hours, in N/mm^2, at the design temperature T

A : Safety factor taken as follows, when reliability of $R_{S,MIN,T}$ and S_A values are proved to the Society's satisfaction:

- 1,6 for boilers and other steam generators
- 1,5 for other pressure vessels
- specially considered by the Society if average stress to produce creep rupture in more than 100000 hours is used instead of S_A.

In the case of steel castings, the permissible stress K, calculated as above, is to be decreased by 20%. Where steel castings are subjected to non-destructive tests, a smaller reduction up to 10% may be taken into consideration by the Society.

b) Spheroidal cast iron:

The permissible stress is be to the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,20}}{4,8}$$

$$K = \frac{R_{S,MIN,T}}{3}$$

c) Grey cast iron:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,20}}{10}$$

d) Copper alloys:

The permissible stress is obtained by the following formula:

$$K = \frac{R_{m,T}}{4}$$

where:

$R_{m,T}$: Minimum tensile strength at the design temperature T, in N/mm^2

e) Aluminium and aluminium alloys:

The permissible stress is to be the minimum of the values obtained by the following formulae:

$$K = \frac{R_{m,T}}{4}$$

$$K = \frac{R_{e,H}}{1,5}$$

where:

$R_{e,H}$: Minimum yield stress, in N/mm^2

f) Additional conditions:
- In special cases the Society reserves the right to apply values of permissible stress K lower than those specified above.
- In the case of boilers or other steam generators, the permissible stress K is not to exceed 170 N/mm^2.
- For materials other than those listed above the permissible stress is to be agreed with the Society on a case by case basis.

2.4 Cylindrical, spherical and conical shells with circular cross-sections subject to internal pressure

2.4.1 Cylindrical shell thickness

a) The minimum thickness of cylindrical, spherical and conical shells with circular cross-sections is not to be less than the value t, in mm, calculated by one of the following formulae, as appropriate. Cylindrical tube plates pierced by a great number of tube holes are to have thickness calculated by the applicable formulae in [2.4.3], [2.4.4], [2.4.5] and [2.9.2].

b) The thicknesses obtained by the formulae in [2.4.3], [2.4.4] and [2.4.5] are "net" thicknesses, as they do not include any corrosion allowance. The thickness obtained by the above formulae is to be increased by 0,75 mm. See also [2.4.7].

2.4.2 Efficiency

The values of efficiency e to be used in the formulae in [2.4.3], [2.4.4] and [2.4.5] are indicated in Tab 10.

Table 10 : Efficiency of unpierced shells

Case	e
Seamless shells	1
Shells of class 1 vessels **(1)**	1
Shells of class 2 vessels (with partial radiographic examination of butt-joints)	0,85
Shells of class 2 vessels with actual thickness ≤ 15mm (without radiographic examination of butt-joints)	0,75
(1) In special cases the Society reserves the right to take a factor e < 1, depending on the welding procedure adopted for the welded joint.	

2.4.3 Cylindrical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of cylindrical shells is given by the following formula:

$$t = \frac{pD}{(2K - p)e}$$

where:

p : Design pressure, in MPa

D : Inside diameter of vessel, in mm

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

e : Efficiency of welded joint, the value of which is given in [2.4.2].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.4 Spherical shells

a) When the ratio external diameter/inside diameter is equal to or less than 1,5, the minimum thickness of spherical shells is given by the following formula:

$$t = \frac{pD}{(4K - p)e}$$

For the meaning of the symbols, see [2.4.3].

b) The minimum thickness of shells having ratio external diameter/inside diameter exceeding 1,5 is subject of special consideration.

2.4.5 Conical shells

a) The following formula applies to conical shells of thickness not exceeding 1/6 of the external diameter in way of the large end of the cone:

$$t = \frac{pD}{(2K - p)e \cdot \cos\varphi}$$

For the meaning of the symbols, see [2.4.3].

D is measured in way of the large end of the cone and φ is the angle of slope of the conical section of the shell to the pressure vessel axis (see Fig 1). When φ exceeds 75°, the shell thickness is to be taken as required for flat heads, see [2.7].

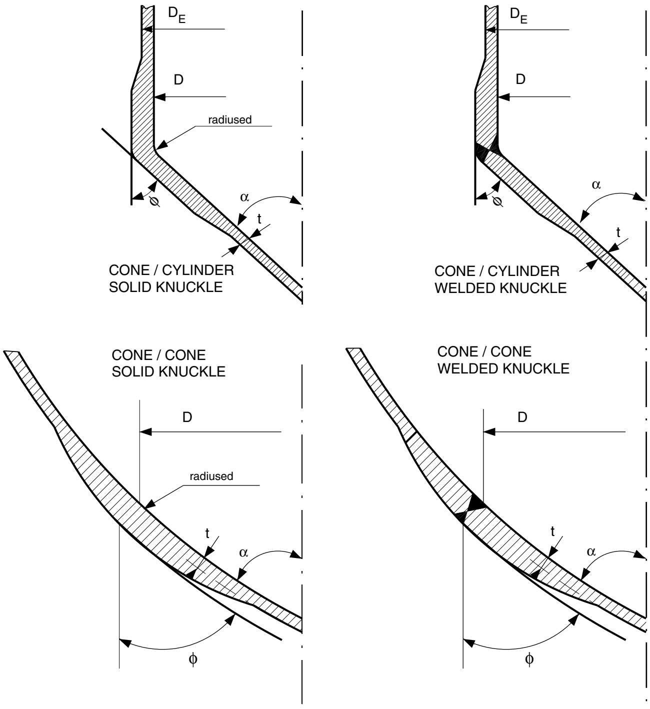
b) The minimum thickness of shells having thickness exceeding 1/6 of the external diameter in way of the large end of the cone is subject of special consideration.

c) Conical shells may be made of several ring sections of decreasing thickness. The minimum thickness of each section is to be obtained by the formula in a) using for D the maximum diameter of the considered section.

d) In general, the junction with a sharp angle between the conical shell and the cylindrical or other conical shell, having different angle of slope, is not allowed if the angle of the generating line of the shells to be assembled exceeds 30°.

e) The shell thickness in way of knuckles is subject of special consideration by the Society.

Figure 1 : Conic shells



2.4.6 Minimum thickness of shells

Irrespective of the value calculated by the formulae in [2.4.3], [2.4.4] or [2.4.5], the thickness t of shells is not to be less than one of the following values, as applicable:

- for pressure vessels: $t = 3 + D/1500$ mm
- for unpierced plates of boilers: $t = 6,0$ mm
- for boiler cylindrical tube plates: $t = 9,5$ mm.

No corrosion allowance needs to be added to the above values.

2.4.7 Corrosion allowance

The Society reserves the right to increase the corrosion allowance value in the case of vessels exposed to particular accelerating corrosion conditions. The Society may also consider the reduction of this factor where particular measures are taken to effectively reduce the corrosion rate of the vessel.

2.5 Dished heads subject to pressure on the concave (internal) side

2.5.1 Dished head for boiler headers

Dished heads for boiler headers are to be seamless.

2.5.2 Dished head profile

The following requirements are to be complied with for the determination of the profile of dished heads (see Fig 2 (a) and (b)).

a) Ellipsoidal heads:

$H \geq 0,2\ D$

where:

H : External depth of head, in mm, measured from the start of curvature at the base.

b) Torispherical heads:

$R_{IN} \leq D$

$r_{IN} \geq 0,1\ D$

$r_{IN} \geq 3\ t$

$H \geq 0,18\ D$

where:

R_{IN} : Internal radius of the spherical part, in mm

r_{IN} : Internal knuckle radius, in mm

H : External depth of head calculated by the following formula (see Fig 2 (b)):

$H = R_E - [(R_E - 0,5\ D) \cdot (R_E + 0,5\ D - 2\ r_E)]^{0,5}$

where:

R_E : External radius of the spherical part, in mm

r_E : External knuckle radius, in mm.

2.5.3 Required thickness of solid dished heads

a) The minimum thickness of solid (not pierced) hemispherical, torispherical, or ellipsoidal unstayed dished heads, subject to pressure on the concave (internal) side, is to be not less than the value t, in mm, calculated by the following formula:

$$t = \frac{pDC}{2Ke}$$

where:

C : Shape factor, obtained from the graph in Fig 3, as a function of H/D and t/D.

For other symbols, see [2.4.3].

b) The thickness obtained by the formula in item a) is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,75 mm. See also [2.4.7].

2.5.4 Composed torispherical heads

a) Torispherical heads may be constructed with welded elements of different thicknesses (see Fig 4).

b) Where a torispherical head is built in two sections, the thickness of the torispherical part is to be obtained by the formula in [2.5.3], while the thickness of the spherical part may be obtained by the formula in [2.4.4].

c) The spherical part may commence at a distance from the knuckle not less than:

$0,5 \cdot (R_{IN} \cdot t)^{0,5}$

where:

R_{IN} : Internal radius of the spherical part, in mm

t : Knuckle thickness, in mm.

2.5.5 Minimum thickness of dished heads

Irrespective of the values calculated in [2.5.2] and [2.5.3], the thickness t of dished heads is not to be less than:

- $3 + D_E / 1500$ mm for normal pressure vessels
- 6 mm for boiler pressure vessels.

No corrosion allowance needs to be added to the above values.

2.5.6 Connection of heads to cylindrical shells

The heads are to be provided, at their base, with a cylindrical skirt not less than 2t in length and with a thickness in no case less than the Rule thickness of a cylindrical shell of the same diameter and the same material, calculated by the formula given in [2.4.3] using the same efficiency factor e adopted for calculation of the head thickness. Fig 5 and Fig 6 show typical admissible attachments of dished ends to cylindrical shells.

In particular, hemispherical heads not provided with the above skirt are to be connected to the cylindrical shell if the latter is thicker than the head, as shown in Fig 5.

Other types of connections are subject to special consideration by the Society.

Figure 2 : Dished head profiles

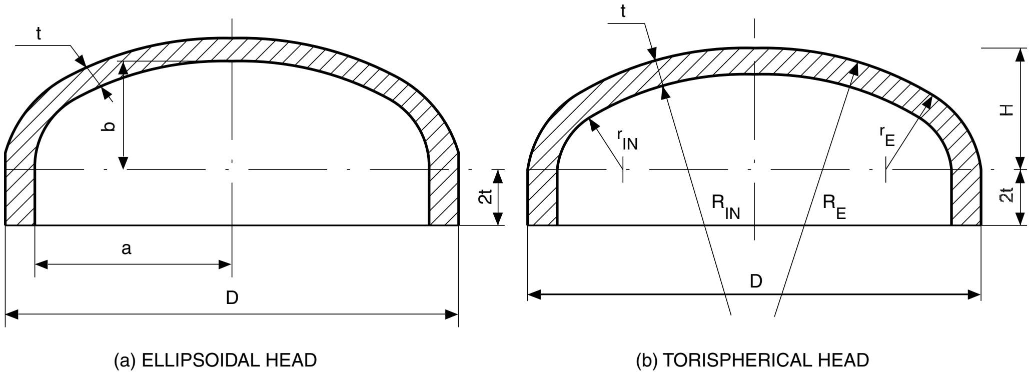


Figure 3 : Shape factor for dished heads

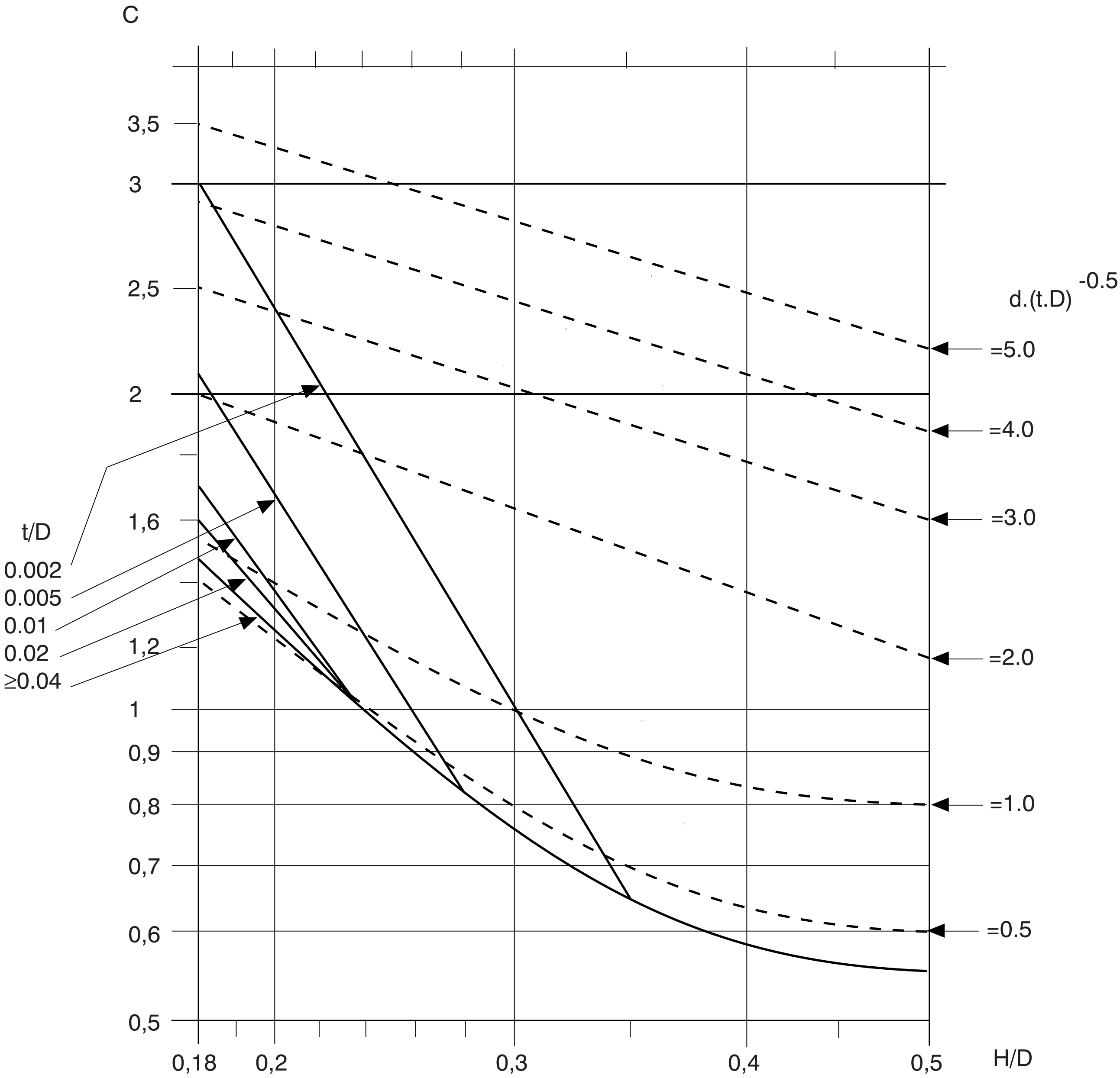


Figure 4 : Composed torispherical head

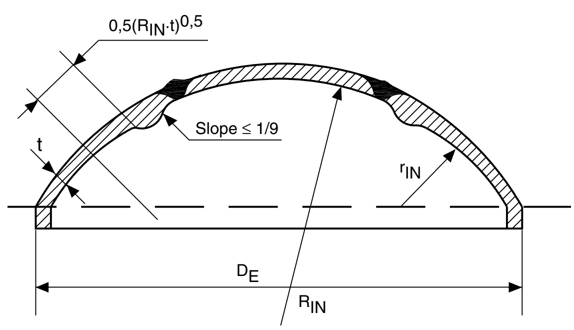
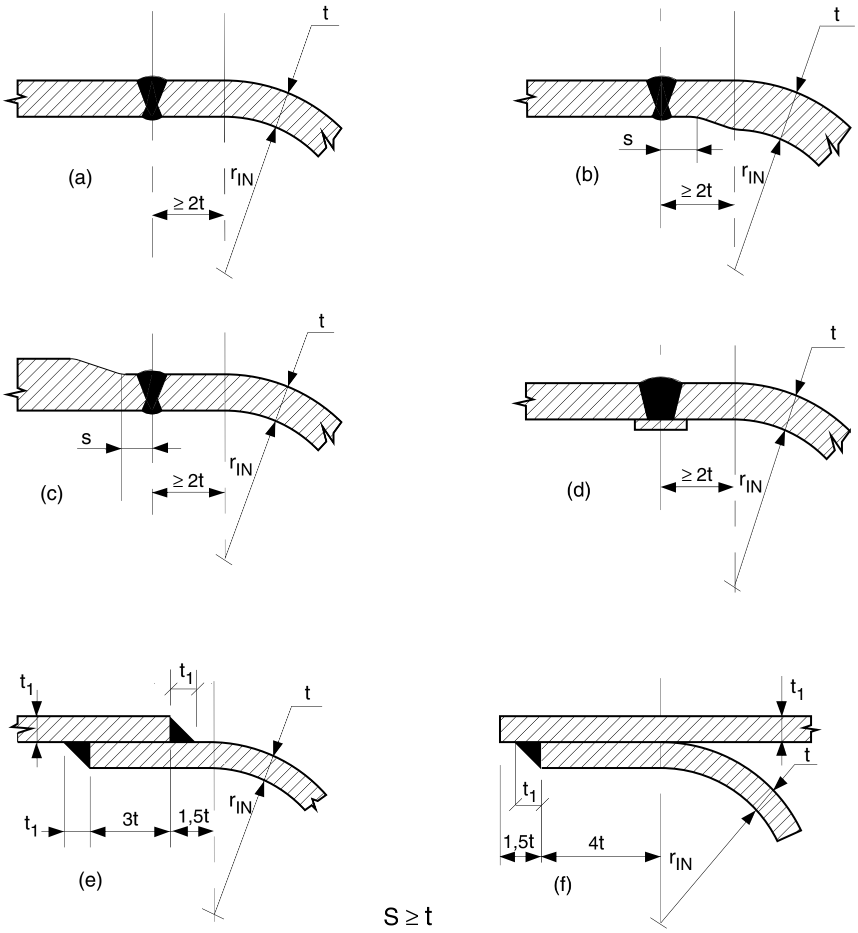
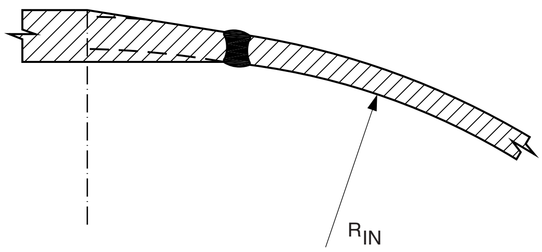


Figure 5 : Typical attachment of dished heads to cylindrical shells



Types shown in (a), (b) and (c) are acceptable for all pressure vessels.
Type shown in (d) is acceptable for class 2 and class 3 pressure vessels.
Types shown in (e) and (f) are acceptable for class 3 pressure vessels only.

Figure 6 : Connection of hemispherical head to the cylindrical shell



2.6 Dished heads subject to pressure on the convex (external) side

2.6.1 The calculation of the minimum thickness is to be performed according to a standard accepted by the Society.

In addition, the thickness of torispherical or ellipsoidal heads under external pressure is no to be less than 1,2 times the thickness required for a head of the same shape subject to internal pressure.

2.7 Flat heads

2.7.1 Unstayed flat head minimum thickness

a) The minimum thickness of unstayed flat heads is not to be less than the value t, in mm, calculated by the following formula:

$$t = D\left(\frac{100p}{CK}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm^2, obtained as specified in [2.3]

D : Diameter of the head, in mm. For circular section heads, the diameter D is to be measured as shown in Fig 7 and Fig 8 for various types of heads. For rectangular section heads, the equivalent value for D may be obtained from the following formula:

$$D = a\left[3,4 - 2,4\left(\frac{a}{b}\right)\right]^{0,5}$$

a and b being the smaller and larger side of the rectangle, respectively, in mm

C : The values given below, depending on the various types of heads shown in Fig 7 and Fig 8:

Fig 7(a) : C = 400 for circular heads

Fig 7(b) : C = 330 for circular heads

Fig 7(c) : C = 350 for circular heads

Fig 7(d) : C = 400 for circular heads and C = 250 for rectangular heads

Fig 7(e) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 7(f) : C = 350 for circular heads

Fig 7(g) : C = 300 for circular heads

Fig 7(h) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(i) : C = 350 for circular heads and C = 200 for rectangular heads

Fig 8(j) : C = 200 for circular heads

Fig 8(k) : C = 330 for circular heads

Fig 8(l) : C = 300 for circular heads

Fig 8(m) : C = 300 for circular heads

Fig 8(n) : C = 400 for circular heads

Fig 8(o) : C = value obtained from the following formula, for circular heads:

$$C = \frac{100}{0,3 + \dfrac{1,9Fh}{pD^3}}$$

where:

h : Radial distance, in mm, from the pitch centre diameter of bolts to the circumference of diameter D, as shown in Fig 8(o)

F : Total bolt load, in N, to be taken as the greater of the following values F_1 and F_2:

$F_1 = 0,785\ D\ p\ (D + m\ b)$

$F_2 = 9,81\ y\ D\ b$

with:

b : Effective half contact width of the gasket, in mm, calculated as follows:

$b = 0,5\ N$ for $N \le 13$ mm, and

$b = 1,8\ N^{0,5}$ for $N > 13$ mm

where N is the geometric contact width of the gasket, in mm, as indicated in Fig 8(o)

m, y : Adimensional coefficients whose values are given in Tab 11, depending on the type of gasket.

The adoption of one of the above-mentioned heads is subject to the Society's approval depending upon its use. Types of heads not shown in Fig 7 and Fig 8 are to be the subject of special consideration by the Society.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.7.2 Stayed flat head minimum thickness

For the minimum thickness of stayed flat heads, see [2.12.3].

Table 11 : Coefficients m and y

Type of gasket	m	y
Self-sealing, metal or rubber (e.g. O-ring)	0	0
Rubber with cotton fabric	10	0,88
Rubber with reinforcing fabric with or without metal wire:		
- 3 layers	18	4,85
- 2 layers	20	6,4
- 1 layers	22	8,2
Synthetic fibre with suitable binders:		
- 3,0 mm thick	16	3,5
- 1,5 mm thick	22	8,2
Organic fibre	14	2,4
Metal spiral lined with synthetic fibre:		
- carbon steel	20	6,4
- stainless steel	24	9,9
Synthetic fibre with plain metal lining:		
- copper	28	14,0
- iron	30	16,8
- stainless steel	30	20,0
Solid metal:		
- copper	38	28,7
- iron	44	39,8
- stainless steel	52	57,5

Figure 7 : Types of unstayed flat heads (1)

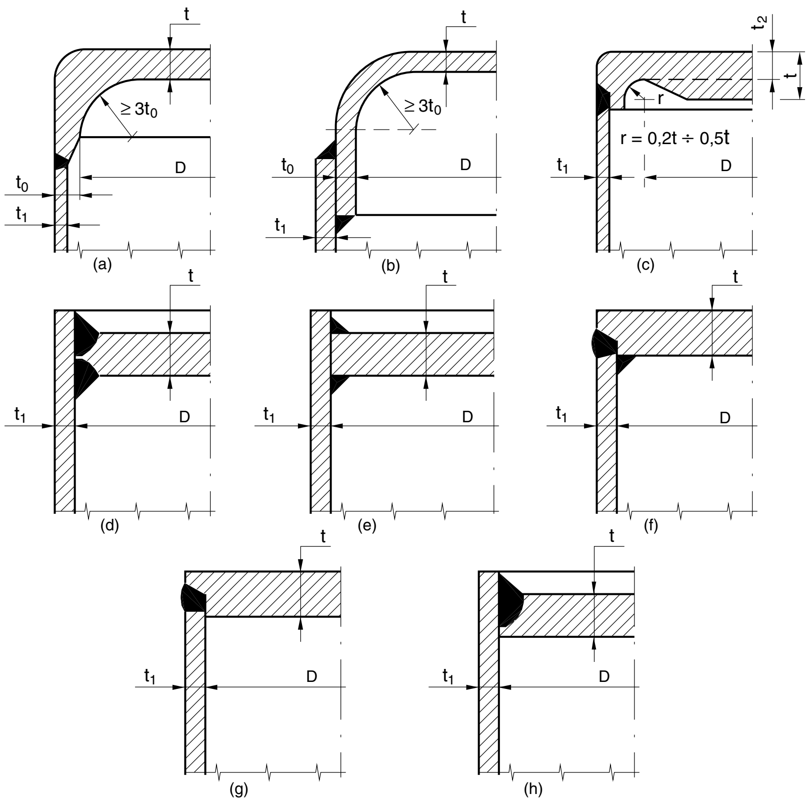
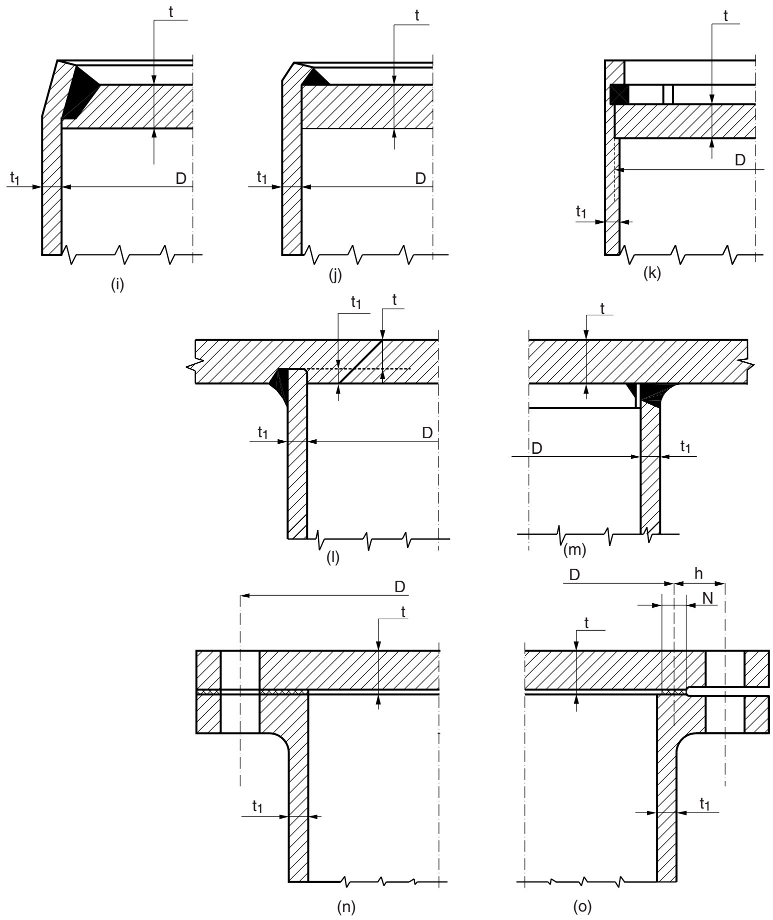


Figure 8 : Types of unstayed flat heads (2)



2.8 Openings and branches (nozzles)

2.8.1 Nozzles thickness

a) The thickness e_b , in mm, of nozzles attached to shells and headers of boilers is not to be less than:

$$e_b = \frac{d_E}{25} + 2,5$$

where d_E is the outside diameter of nozzle, in mm.

The thickness of the nozzle is, however, to be not less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not to be greater than the thickness of the shell to which it is connected.

b) The thickness of the nozzle attached to shells and headers of other pressure vessels is not to be less than the thickness required for the piping system attached to the vessel shell calculated at the vessel design pressure, and need not be greater than the thickness of the shell to which it is connected.

c) Where a branch is connected by screwing, the thickness of the nozzle is to be measured at the root of the thread.

2.8.2 Nozzle connection to vessel shell

a) In general, the axis of the nozzle is not to form an angle greater than 15° with the normal to the shell.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show some typical acceptable connections of nozzles to shells. Other types of connections are to be considered by the Society on a case by case basis.

2.8.3 Openings in shells

a) In general, the largest dimensions of the openings in shells are not to exceed:

- for shells up to 1500 mm in diameter D_E:

  1/2 D_E , but not more than 500 mm

- for shells over 1500 mm in diameter D_E:

  1/3 D_E, but not more than 1000 mm,

where D_E is the vessel external diameter, in mm.

Greater values may be considered by the Society on a case by case basis.

b) In general, in oval or elliptical openings the ratio major diameter/minor diameter is not to exceed 2.

2.8.4 Openings compensation in cylindrical shells

a) Compensation methods

For cylindrical shells with openings, the efficiency of the main body is to be satisfied by one of the following methods:

- by increasing the wall thickness of main body compared with that of the cylindrical shell without opening: see Fig 9
- by branches which have been provided with a wall thickness of that required on account of the internal pressure: see Fig 10 and Fig 11
- by reinforcing pads or rings analogous to increasing the wall thickness: see Fig 12 and Fig 13
- by a combination of previous reinforcement.

b) Definitions

Effective lengths ℓ_{rs} required for calculation of efficiency and of compensations is to be taken as:

$$\ell_{rs} = \min(\sqrt{Dt_a}, \ell_{s1})$$

where:

D : Outside diameter, in mm

t_a : Available thickness, in mm

ℓ_{s1} : Transition length, in mm, according to Fig 9 and Fig 10

c) Basic calculation

The required wall thickness without allowance of a cylindrical shell is determined with the following formula (see [2.4.3]):

$$t = \frac{pD}{(2K - p)e}$$

With the available thickness t_a, we obtain the available efficiency e_a and the maximum diameter d_{obmax} of an unreinforced opening when the average stress of the main body is equal to the permissible stress K:

$$e_a = \frac{pD_i}{(2K - p)t_a}$$

$$d_{obmax} = 2\left[\frac{\ell_{rs}}{e_a} - \ell_{rs}\right]$$

where:

D_i : Internal diameter of the main body, in mm

d) Isolated opening reinforcement

The reinforcement of isolated openings as indicated in Fig 9 to Fig 13 are to be in respect with:

$$\frac{A_p}{A_f} \le \frac{K}{p} - 0{,}5$$

where:

K : Permissible stress in the shell, in N/mm^2

A_f : Total area of cross section (wall and branch and pad)

A_p : Total area under pressure p.

In Fig 9 to Fig 13, ℓ_{rs}, ℓ_{rb} and ℓ_{rbi} are effective lengths for calculation of efficiencies and compensation, equal to:

- for shell:

  $$\ell_{rs} = \min(\sqrt{(D + e_{rs})e_{rs}}, \ell_{s1})$$

- for external branch projection:

  $$\ell_{rb} = \min(\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b1})$$

- for internal branch projection:

  $$\ell_{rbi} = \min(0,5\sqrt{(d_{ib} + e_{rb})e_{rb}}, \ell_{b2})$$

Figure 9 : Reinforcement by increasing the wall thickness of the main body with opening

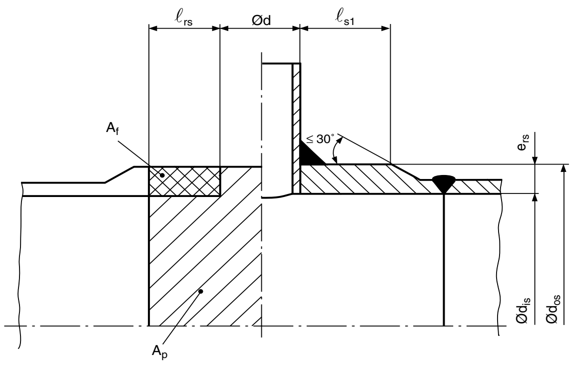


Figure 10 : Reinforcement by set-through and full penetration welded branch

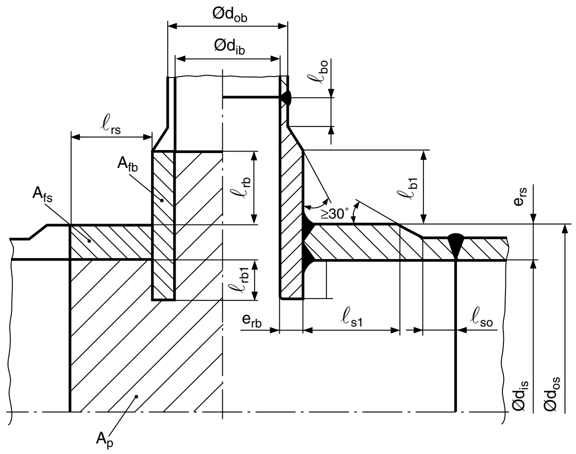


Figure 11 : Reinforcement by welded on branch

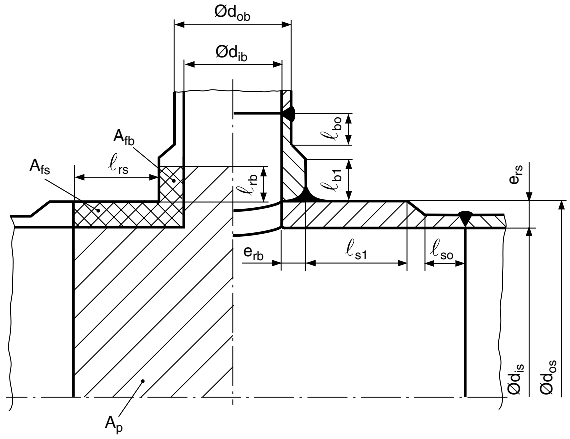
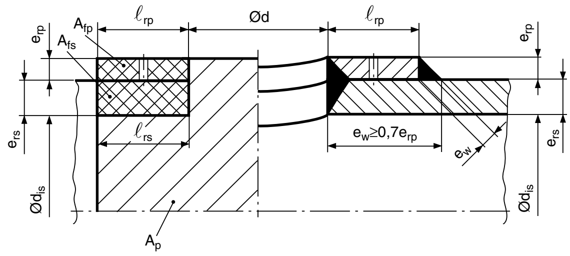


Figure 12 : Opening with reinforcing pad



e) Condition of isolated openings

- Full case

  Adjacent openings are to be treated as isolated openings if the centre distance P_ϕ, in accordance with Fig 16, is not less than:

  $$\frac{\left(\frac{d_{ib1}}{2}+e_{rb1}\right)}{\cos\Psi_1}+\frac{\left(\frac{d_{ib2}}{2}+e_{rb2}\right)}{\cos\Psi_2}+2\sqrt{(d_{is}+e_{rs})e_{rs}}$$

  For variable definition see Fig 14 and Fig 15.

- Simplification

  - For openings without branch:

    $e_{rb} = 0$ and $\Psi = 0$

  - For openings with nozzles perpendicular to shell:

    The openings are to be treated as isolated openings if the centre distance P_ϕ in accordance with Fig 16 is not less than:

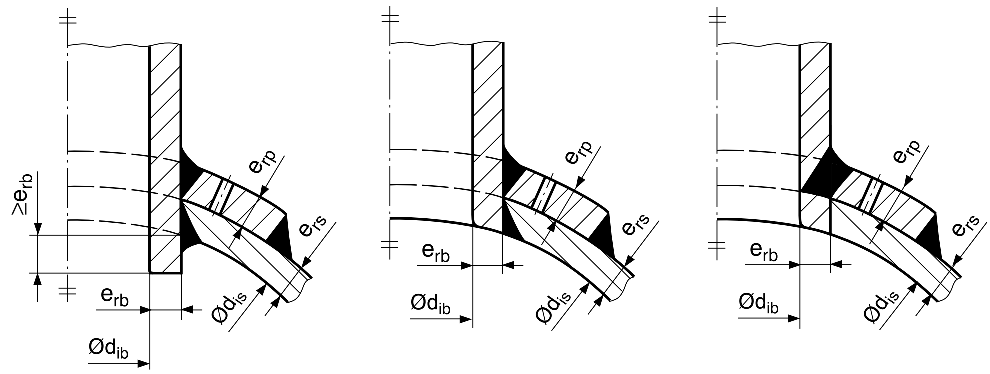
    $$\left(\frac{d_{ib1}}{2}+e_{rb1}\right)+\left(\frac{d_{ib2}}{2}+e_{rb2}\right)+2\sqrt{(d_{is}+e_{rs})e_{rs}}$$

f) Adjacent openings

Where the condition of isolated openings is not fulfilled, the compensation is to be calculated, using Fig 16, as per the following formula:

$$\frac{A_p}{A_f}\le\frac{K}{p}-0,5$$

Figure 13 : Opening with reinforcing pad and full penetration branch



a) set through welded branch b) set in welded branch c) set on welded branch

Figure 14 : Angle definition for cylindrical shell with oblique branch

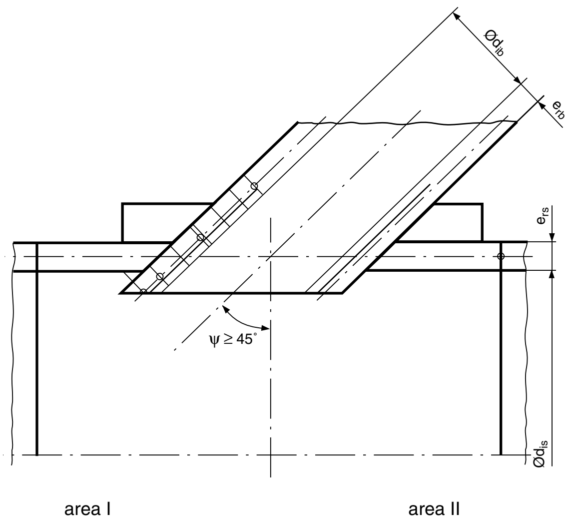


Figure 15 : Angle definition for cylindrical shell with non-radial branch

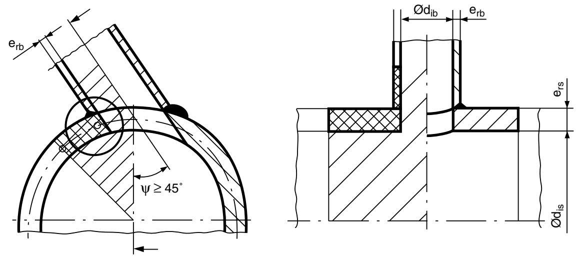
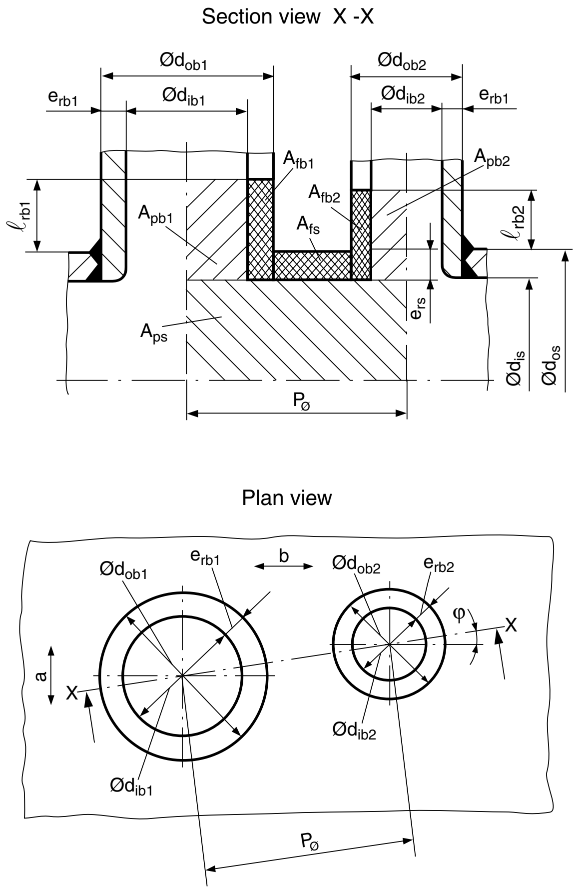


Figure 16 : Load diagram for cylindrical shell with adjacent branches



a : Circumferential direction

b : Longitudinal direction.

2.8.5 Openings in dished heads

a) The openings in dished heads may be circular, elliptical or oval.

b) The largest diameter of the non-compensated opening is not to exceed one half of the external diameter of the head.

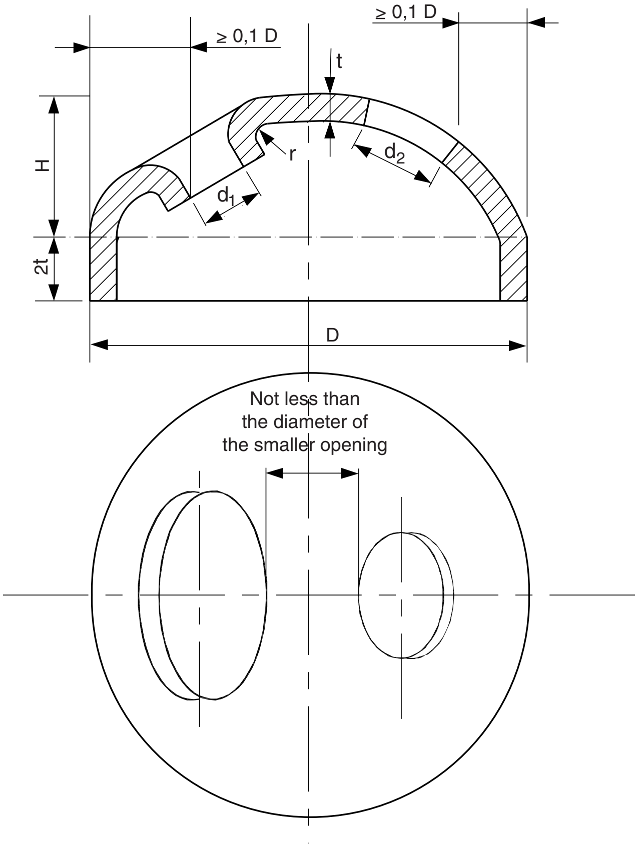
c) The opening is to be so situated that its projection, or its reinforcement projection in the case of compensated openings, is completely contained inside a circle having its centre at the centre of the head and a diameter of 0,8 D, D being the external diameter of the head (see Fig 17). However, a small reinforced opening for drainage may be accepted outside the indicated area.

d) In the case of non-compensated openings (for this purpose, flanged openings are also to be considered as non-compensated), the head thickness is not to be less than that calculated by the formula in [2.5.3] using the greatest of the shape factors C obtained from the graph in Fig 3 as a function of:

H/D and t/D or H/D and $d \cdot (t \cdot D)^{-0,5}$,

where d is the diameter of the largest non-compensated opening in the head, in mm. For oval and elliptical openings, d is the width of the opening in way of its major axis.

Figure 17 : Openings on dished heads



e) In all cases the diameter D of the head base, the head thickness t and the diameter d of the largest non-compensated opening are to be such as to meet the following requirements:
- the position of non-compensated openings in the heads is to be as shown in Fig 17
- for flanged openings, the radius r of the flanging (see Fig 17) is not to be less than 25 mm
- the thickness of the flanged part may be less than the Rule thickness.

2.8.6 Opening compensation in dished heads

a) Where openings are cut in dished heads and the proposed thickness of the head is less than that calculated by the formula in [2.5.3], the openings are to be compensated.

b) Fig 30, Fig 31, Fig 32 and Fig 33 show typical connections of nozzles and compensating rings.

c) The opening is considered sufficiently compensated when the head thickness t is not less than that calculated in accordance with [2.5.3] and using the shape-factor C obtained from the graph in Fig 3 using the value:

$$\left(d - \frac{A}{t}\right) \cdot (t \cdot D)^{-0,5}$$

instead of:

$$d \cdot (t \cdot D)^{-0,5}$$

where:

A : Area, in mm², of the total transverse section of the compensating parts

t : Actual thickness of the head, in mm, in the zone of the opening under consideration.

d) When A/t > d, the coefficient C is to be determined using the curve corresponding to the value:

$$d \cdot (t \cdot D)^{-0,5} = 0$$

e) If necessary, calculations are to be repeated.

2.8.7 Compensation criteria

In the evaluation of the area A, the following is also to be taken into consideration:

a) The material that may be considered for compensating an opening is that located around the opening up to a distance l from the edge of the opening. The distance l, in mm, is the lesser obtained from the following formulae:

$$l = 0,5\ d$$

$$l = (2 \cdot R_{IN} \cdot t)^{0,5}$$

where:

d : Diameter of the opening, in mm

R_{IN} : Internal radius of the spherical part, in mm, in the case of hemispherical or torispherical heads

In the case of ellipsoidal heads, R_{IN} is to be calculated by the following formula (see Fig 2 (a):

$$R_{IN} = \frac{[a^4 - x^2(a^2 - b^2)]^{3/2}}{a^4 b}$$

where;

a : Half the major axis of the elliptical meridian section of the head, in mm

b : Half the minor axis of the above section, in mm

x : Distance between the centre of the hole and the rotation axis of the shell, in mm.

b) In the case of nozzles or pads welded in the hole, the section corresponding to the thickness in excess of that required is to be considered for the part which is subject to pressure and for a depth h, in mm, both on the external and internal sides of the head, not greater than:

$(d_B \cdot t_B)^{0,5}$

where d_B and t_B are the diameter of the opening and the thickness of the pad or nozzle, in mm, respectively.

c) The area of the welding connecting nozzle and pad reinforcements may be considered as a compensating section.

d) If the material of reinforcement pads, nozzles and collars has a permissible stress lower than that of the head material, the area A, to be taken for calculation of the coefficient C, is to be reduced proportionally.

2.8.8 Openings in flat end plates

The maximum diameter of an unreinforced opening in a flat end plate is to be determined from the equation:

$$d_{max} = 8 e_{rh}\left[1,5\frac{e_{rh}^2}{e_{ch}^2} - 1\right]$$

where:

e_{rh} : Actual thickness of the flat end, in mm

e_{ch} : Required calculated thickness of the flat end, in mm.

2.8.9 Opening compensation in flat end plate

Reinforcement of branch openings is to be achieved by taking account of locally disposed material, including the attachment welds, in excess of the minimum requirements for end plate and branch thickness as shown in Fig 18. The branch thickness is to be increased where required. Compensation is to be considered adequate when the compensating area Y is equal to or greater than the area X requiring compensation.

Area X is to be obtained by multiplying 25% of the inside radius of the branch by the thickness of the flat end plate, calculated for the part of the end plate under consideration.

Area Y is to be measured in a plane through the axis of the branch parallel to the surface of the flat end plate, and is to be calculated as follows:

a) For that part of the branch which projects outside the boiler, calculate the full sectional area of the branch up to a distance ℓ_b from the actual outer surface of the flat end plate and deduct from it the sectional area that the branch would have within the same distance if its thickness were calculated in accordance with equation given in [2.4.3]

Note 1: The compensating plate is required only in cases where area Y would otherwise be less than area X.

b) Add to it the full sectional area of that part of the branch that projects inside the boiler (if any) up to a distance ℓ_b from the inside surface of the flat end plate

c) Add to it the sectional area of the fillet welds

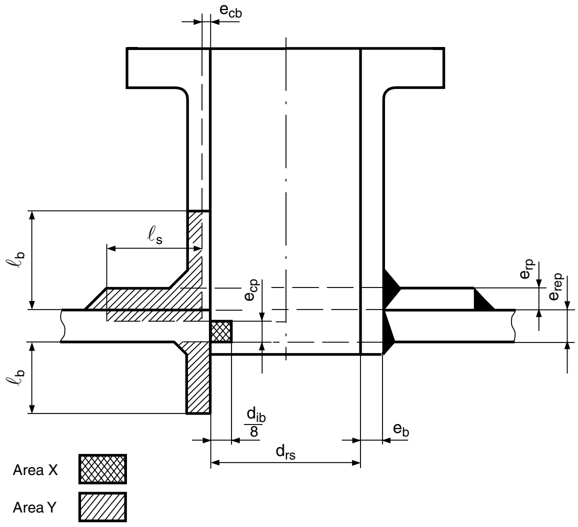
d) Add to it the area obtained by multiplying the difference between the actual flat end plate thickness and its thickness calculated for the part of the end plate under consideration by the length ℓ_s

e) Add to it the area of the compensating plate (if any) within the limits of reinforcement shown in Fig 18.

Where material having a lower allowable stress than that of the flat end plate is taken as compensation, its effective area is to be reduced in the ratio of the allowable stresses at the calculation temperature. No credit is to be taken for the additional strength of material having a higher allowable stress than that of the flat end plate

Welds attaching branches and compensating plates are to be capable of transmitting the full strength of the reinforcing area and all other loadings to which they may be subjected.

Figure 18 : Compensation for branch in flat end plate



e_{cp} : Thickness calculated in accordance with equation in [2.8.1] for the part under consideration

e_{cb} : Thickness calculated taking efficiency = 1

ℓ_b : The smaller of the two values:
$2,5\ e_{rep}$ and $(2,5\ e_b + e_{rp})$

ℓ_s : The greater of the two values:
$(e_{rep} + 75)$ and $(d_{ib} / 4)$

Area Y is not to be less than area X.

2.8.10 Covers

a) Circular, oval and elliptical inspection openings are to be provided with steel covers. Inspection openings with a diameter not exceeding 150 mm may be closed by blind flanges.

b) The thickness of the opening covers is not to be less than the value t, in mm, given by the following formula:

$$t = 1{,}22 \cdot a \cdot \left(\frac{pC}{K}\right)^{0,5}$$

where:

a : The minor axis of the oval or elliptical opening, measured at half width of gasket, in mm

b : The major axis of the oval or elliptical opening, measured at half width of the gasket, in mm

C : Coefficient in Tab 12 as a function of the ratio b/a of the axes of the oval or elliptical opening, as defined above. For intermediate values of the ratio b/a, the value of C is to be obtained by linear interpolation.

For circular openings the diameter d, in mm, is to be used in the above formula instead of a.

c) The thickness obtained by the formula in item a) is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm for classification purpose. See also [2.4.7].

2.9 Regular pattern openings - Tube holes

2.9.1 Definition

Openings may be considered as regular pattern openings when not less than three non isolated openings are disposed in regularly staggered rows in longitudinal or circular direction of a shell.

In such a case, instead of a direct calculation of the compensation of openings, the thickness of the shell could be calculated by application of applicable formulae given in [2.4], [2.5] with a reduced efficiency e as indicated in [2.9.2] and [2.9.3].

This requirement apply for pressure vessels and for boiler.

2.9.2 Efficiency factor of tube holes in cylindrical tube plates

The efficiency factor e of pipe holes in cylindrical shells pierced by tube holes is to be determined by direct calculation or by another suitable method accepted by the Society. In the case of cylindrical holes of constant diameter and radial axis, the efficiency factor e may be determined by the following formula (see Fig 19):

$$e = \frac{1}{\frac{s}{s-d} \cdot (1 - (0{,}5 \cdot \sin^2\alpha)) + m \cdot \sin 2\alpha}$$

where:

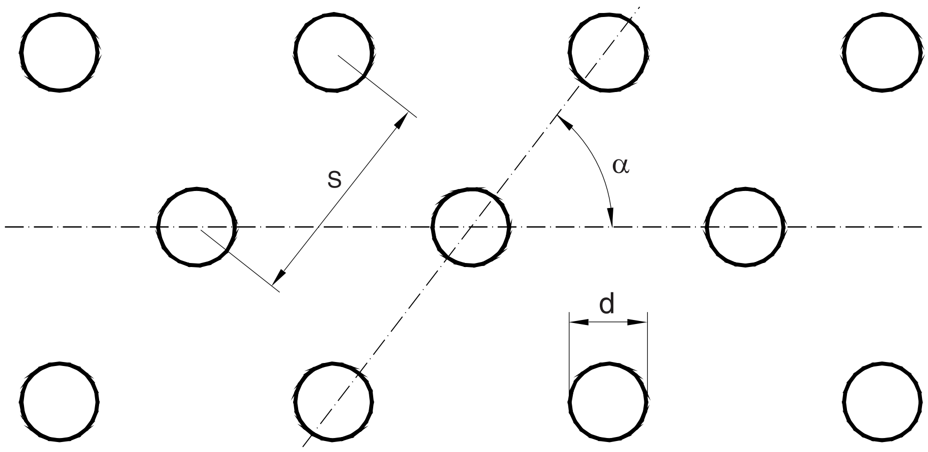
Table 12 : Coefficient C for oval or elliptical covers

b/a	1,00	1,05	1,10	1,15	1,20	1,25	1,30	1,40	1,50	1,60
C	0,206	0,220	0,235	0,247	0,259	0,271	0,282	0,302	0,321	0,333
b/a	1,70	1,80	1,90	2,00	2,50	3,00	3,50	4,00	4,50	5,00
C	0,344	0,356	0,368	0,379	0,406	0,433	0,449	0,465	0,473	0,480

Table 13 : Coefficient m

d/s	0,30	0,35	0,40	0,45	0,50	0,55	0,60	0,65	0,70	0,75	0,80
m	0,137	0,175	0,220	0,274	0,342	0,438	0,560	0,740	1,010	1,420	2,060

Figure 19 : Hole pattern in cylindrical shells



s : Pitch of the hole row considered, in mm

d : Diameter of holes, in mm. The hole diameter d may be reduced by the amount Y/e_{cp} where Y is the compensating area, in mm², of nozzle and welds and e_{cp} the calculated unpierced shell thickness, see [2.8.9] and Fig 18

α : Angle between the axis of hole row considered and the axis of the cylinder (α = 0° if the hole row is parallel to the cylinder generating line; α = 90° for circumferential hole row)

m : Coefficient depending upon the ratio d/s, as obtained from Tab 13. For intermediate values of d/s, the value of m is to be obtained by linear interpolation.

The value of e actually used is to be the smallest calculated value for either longitudinal, diagonal or circumferential rows of holes.

2.9.3 Welded shells with tube holes and efficiency factor of different hole patterns

Where shells have welding butts and/or different groups of hole patterns, the value to be assumed for the efficiency e in the formulae is the minimum of the values calculated separately for each type of welding (as per [2.4.2]) and for each configuration of holes (as per [2.9.1]).

2.9.4 Rectangular section headers

a) For seamless type headers of rectangular section design, the wall thickness t, in mm, in way of corner fillets and the thickness t_1, in mm, of any drilled wall is not to be less than those given by the following formulae, as appropriate (see Fig 20):

$$t = \left(\frac{100pM_1}{K}\right)^{0,5}$$

$$t_1 = \left(\frac{100pM_2}{eK}\right)^{0,5}$$

where (see also Fig 20):

t : Wall thickness at the corners, in mm

t_1 : Thickness of drilled wall, in mm

p : Design pressure, in MPa

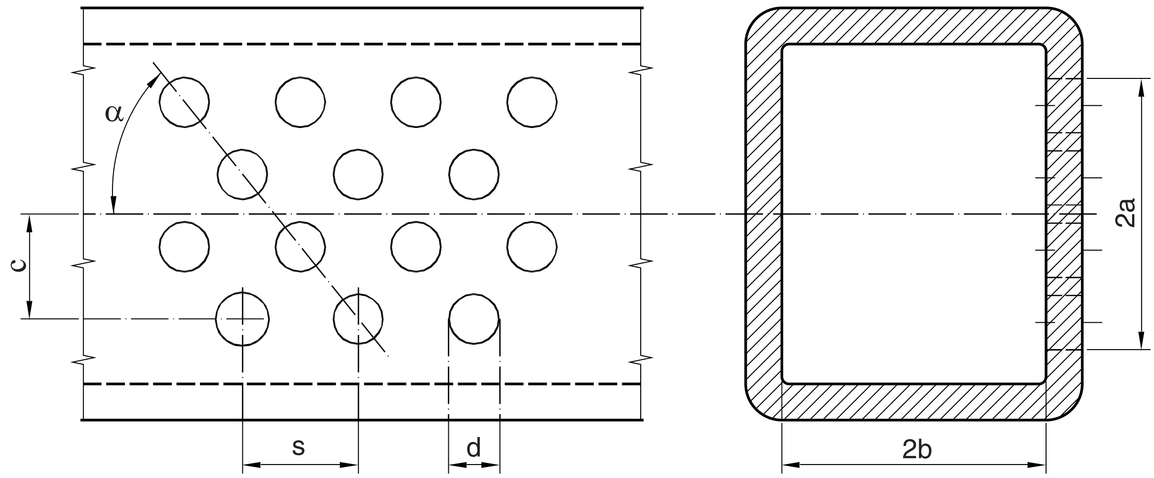
K : Permissible stress, in N/mm², obtained as specified in [2.3]

a : Internal half width of the header, in a direction parallel to the wall under consideration, in mm

b : Internal half width of the header, in a direction normal to the wall under consideration, in mm

c : Distance between the axis of the hole row considered and the centreline of the header wall, in mm

Figure 20 : Rectangular section headers



e : Efficiency factor of holes in the wall, determined by the following formulae:

$$e = \frac{s-d}{s} \quad \text{for } d < a$$

$$e = \frac{s-0,67d}{s} \quad \text{for } a \le d < 1,3a$$

$$e = \frac{s-0,33d}{s} \quad \text{for } d \ge 1,3a$$

where:

s : Pitch of the holes, in mm, of the longitudinal or diagonal row under consideration. For a staggered pattern of holes the pitch of the diagonal row is to be considered

d : Diameter of the holes, in mm

M_1 : Coefficient to be calculated by the following formula:

$$M_1 = \frac{a^2 + b^2 - ab}{50}$$

M_2 : Coefficient (to be taken always positive) to be calculated by one of the following formulae, as appropriate:

- For a non-staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab + \frac{3}{2}c^2}{50}$$

- For a staggered pattern of holes:

$$M_2 = \frac{b^2 - \frac{1}{2}a^2 - ab}{50}\cos\alpha$$

where α is the angle between the axis of the diagonal row of the holes under consideration and the axis of the header, in the case of a staggered pattern of holes.

b) The thickness obtained by the formulae in a) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1,5 mm. See also [2.4.7].

2.10 Water tubes, superheaters and economiser tubes of boilers

2.10.1

a) The thickness of tubes of evaporating parts, economisers and superheaters exposed to gases which are subject to internal pressure is not to be less than the value t given by the following formula:

$$t = \frac{pd}{2K + p} + 0,3$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

d : Outside diameter of tube, in mm.

However, irrespective of the value calculated by the formulae in item a), the thickness t of tubes is not to be less than the values given in Tab 14.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in item a) is to be increased by 12,5% to take into account the manufacturing tolerance. For bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the formula.

c) Whenever abnormal corrosion and erosion may occur during service, the corrosion constant of 0,3 in the formula may be increased to the satisfaction of the Society.

d) The thickness of tubes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes (see Ch 1, Sec 10, [14]).

2.11 Additional requirements for fired pressure vessels

2.11.1 Insulation for headers and combustion chambers

Those parts of headers and/or combustion chambers which are not protected by tubes and are exposed to radiant heat or to high temperature gases are to be covered by suitable insulating material.

2.11.2 Connections of tubes to drums and tube plates

Tubes are to be adequately secured to drums and/or tube plates by expansion, welding or other appropriate procedure.

a) Where the tubes are secured by expanding or equivalent process, the height of the shoulder bearing the tube, measured parallel to the tube axis, is to be at least 1/5 of the hole diameter, but not less than 9 mm for tubes normal to the tube plate or 13 mm for tubes angled to the tube plate. The tubes ends are not to project over the other face of the tube plate more than 6 mm.

b) The tube ends intended to be expanded are to be partially annealed when the tubes have not been annealed by the manufacturer.

2.12 Additional requirements for vertical boilers and fire tube boilers

2.12.1 General

The scantlings of the shells of vertical boilers and fire tube boilers are to be determined in accordance with [2.4].

2.12.2 Ends of vertical boilers

a) The minimum thickness of the dished ends forming the upper part of vertical boilers and subject to pressure on their concave face is to be determined in accordance with [2.5].

b) When the end is supported in its centre by an uptake, the minimum thickness t, in mm, is to be calculated with the following formula:

$$t = 0,77 \cdot \frac{pR_I}{K}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

R_I : Radius of curvature at the centre of the end measured internally. R_I is not to exceed the external diameter of the shell.

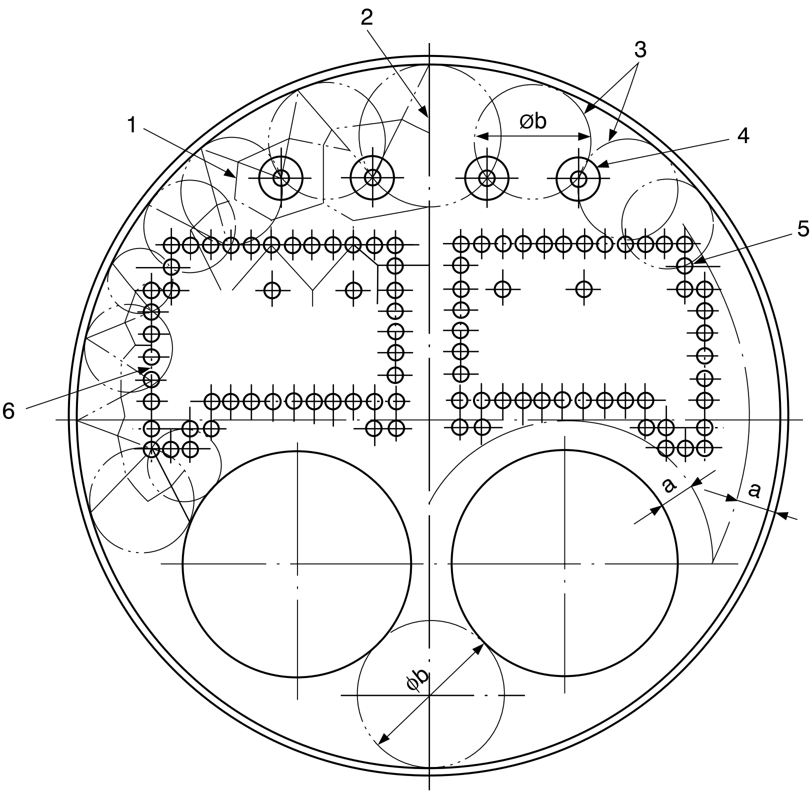
c) The thickness obtained by the formula in item b) is "net" thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 0,7 mm. See also [2.4.7].

d) For ends supported by an uptake at their centre, the corner radius measured internally is not to be less than 4 times the end thickness or 65 mm, whichever is the lesser and the inside radius of curvature on the flange to uptake is not to be less than twice the end thickness or 25 mm, whichever is the lesser.

Table 14 : Minimum thickness of water tubes

Outside diameter, in mm	Minimum thickness in mm of tubes subject to internal pressure of cylindrical boilers and water tube boilers having the feed water system	
	Closed type, if equipped with suitable devices for reducing the oxygen concentration in the water	Open type, not equipped with suitable devices for reducing the oxygen concentration in the water
< 38	1,8	2,9
38 - 48,3	2,0	2,9
51 - 63,5	2,4	2,9
70	2,6	3,2
76,1 - 88,9	2,9	3,2
101,6 - 127	3,6	–

Figure 21 :



Key:

1	:	Boundaries of areas supported by individual stays
2	:	To establish the area supported by bar stays or stay tubes in boundary rows, the boundary of the loaded area is to terminate at the centre of the associated main circle
3	:	Main circles, diameter b
4	:	Bar stays
5	:	Stay tubes
6	:	Termination of boundary areas where stay tubes are situated in the boundary rows only.

2.12.3 Supported flat head

a) Breathing space

- Stays are to give breathing space around the furnace tube connections and tube nests and equally divide the unstayed areas. Breathing space between furnace tube and tube nests are to be a minimum of 50 mm or 5% of the shell outside diameter, whichever is the larger, but need not be more than 100 mm.
- Breathing space between furnace tube and shell depends on the thickness of the plate of the type of end and of the dimensions of the boiler but is to be not less than 50 mm or, for bowling hoop furnaces tubes, not less than 75 mm.

b) The thickness of stayed flat heads, or of heads supported by flanges, is not to be less than the value t, in mm, given by the following formula:

$$t = D\left[\frac{100p}{CC_1K(1+C_2B^2)}\right]^{0,5}$$

where:

B : Ratio of the thickness of the large washer or doubler, where fitted, to the thickness of the plate:
$B = t_1 / t$
The value of B is to be taken between 0,67 and 1

K : Permissible stress, in N/mm², obtained as specified in [2.3]

C : C = 1 when the plate is not exposed to flame
C = 0,88 when the plate is exposed to flame

C_1 : C_1 = 462 when the plate is supported by welded stays
C_1 = 704 for plates supported by flanges or equivalent

C_2 : C_2 = 0 when no doublers are fitted
C_2 = 0,85 when a complete doubling plate is fitted, adequately joined to the base plate.

The value of D is to be in accordance with the following provisions:

- In the parts of the flat heads between the stays:

  D is the diameter, in mm, of the largest circle which can be drawn through the centre of at least three stays without enclosing any other stay, where the stays are not evenly spaced (see Fig 21), or

  $D = (a^2 + b^2)^{0,5}$ where the stays are evenly spaced, considering the most unfavourable condition

  where:

  a : Distance between two adjacent rows of stays, in mm

  b : Pitch of stays in the same row, in mm.

- In the parts of the flat heads between the stays and the boundaries, where flat heads are generally supported by flanges or shapes, or connected to other parts of the boiler:

  D is the diameter, in mm, of the largest circle which can be drawn through not less than three points of support (stay centres or points of tangency of the circle with the contour line). To this end, the contour of the part under consideration is to be drawn at the beginning of the flanging or connection curve if its inside radius does not exceed 2,5 times the thickness of the plate, or, where such radius is greater, at the above-mentioned distance (of 2,5 times the thickness of the plate) from the ideal intersection with other surfaces (see Fig 21).

c) When applying the formulae for calculation of thickness of heads covered by this sub-article, the position of plates in the most unfavourable condition is to be considered.

d) Where various types of supports are provided, the value of C_1 should be the arithmetic mean of the values of C_1 appropriate to each type of support.

e) The thickness obtained by the formulae in a), is “net” thickness, as it does not include any corrosion allowance. The thickness obtained by the above formula is to be increased by 1 mm. See also [2.4.7].

2.12.4 Flat tube plates

a) Flat tube plates in tube bundles

The thickness of the parts of flat tube plates contained in the tube bundle and supported by stay tubes is not to be less than the value t, in mm, given by the following formula:

$$t = s\left(\frac{p}{2,8K}\right)^{0,5}$$

where:

p : Design pressure, in MPa

K : Permissible stress, in N/mm², obtained as specified in [2.3]

s : Pitch of stay tubes, taken as the greatest mean pitch of the stay tubes supporting a quadrilateral portion of the plate, in mm.

Moreover the spacing of tube holes (diameter d) is to be such that the minimum width, in mm, of any ligament between the tube holes is to be not less than:

- for expanded tubes:

  (0,125 d + 12,5) mm

- for welded tubes:
  - for gas entry temperatures greater than 800°C:

    (0,125 d + 9) mm, but need not exceed 15 mm
  - for gas entry temperatures less than or equal to 800°C:

    (0,125 d + 7) mm, but need not exceed 15 mm.

Moreover the calculated thickness of tube plates is to be not less than the following:

- 12 mm where the tubes are expanded into the tube plate when the diameter of the tube hole does not exceed 50 mm, or 14 mm when the diameter of the tube hole is greater than 50 mm, or
- 6 mm where the tubes are attached to the tube plate by welding only.

b) Flat tube plates of combustion chamber in vertical boilers

Where tube plates contained in the tube bundle are simultaneously subject to compression due to the pressure in the combustion chamber, their thickness, as well as complying with the requirements in item a) is not to be less than the value t, in mm, given by the following formula:

$$t = \frac{pls_1}{1,78(s_1 - d)K}$$

where:

l : Depth of the combustion chamber, in mm

s_1 : Horizontal pitch of tubes, in mm

d : Inside diameter of plain tubes, in mm.

For the meaning of other symbols, see item a).

c) Tube plates outside tube bundles

For those parts of tube plates which are outside the tube bundle, the formula in [2.13.3] is to be applied, using the following coefficients C_1 and C_2:

$C_1 = 390$

$C_2 = 0,55$

Doublers are only permitted where the tube plate does not form part of a combustion chamber.

d) Tube plates not supported by stays

Flat tube plates which are not supported by stay tubes (e.g. in heat exchangers), are subject of special consideration by the Society (see also [2.14]).

e) Stay and stay tube scantling

- The diameter of solid stays of circular cross-section is not to be less than the value d calculated by the following formula:

$$d = \left(\frac{pA}{K}\right)^{0,5}$$

where:

d : Minimum diameter, in mm, of the stay throughout its length

A : Area supported by the stay, in mm^2

K : $K = R_m / 7$

R_m : Minimum ultimate tensile strength of the stay material, in N/mm^2.

The cross section of tube stays is to be equivalent to that of a solid stay supporting the same area, whose diameter is calculated by the above formula.

Stays which are not perpendicular to the supported surface are to be of an adequately increased diameter depending on the component of the force normal to the plate.

- Where articulated stays are used, articulation details are to be designed assuming a safety factor for articulated elements not less than 5 with respect to the value of R_m and a wear allowance of 2 mm.

The articulation is to be of the fork type and the clearance of the pin in respect of the holes is not to exceed 1,5 mm. The pin is to bear against the jaws of the fork and its cross-sectional area is not to be less than 80% of the cross-sectional area of the stay. The width of material around the holes is not to be less than 13 mm.

- Where stays are flanged for joining to the plate, the thickness of the flange is not to be less than one half the diameter of the stay.
- For welded connections of stays to tube plates, see Fig 37.

f) Stay and stay tubes construction

- In general, doublers are not to be fitted in plates exposed to flame.
- As far as possible, stays are to be fitted perpendicularly to the supported surface.
- Long stays in double front boilers and, in general, stays exceeding 5 m in length, are to be supported at mid-length.
- Where the ends of stay tubes are of increased thickness, the excess material is to be obtained by forging and not by depositing material by means of welding.
- After forging, the ends of stay tubes are to be stress relieved.

g) Gusset stays

Tube plate may be supported by gussets stays with full penetration welds to plate and shell.

The general shape and the scantling are to be in accordance with a standard accepted by the Society.

h) Girders

Where tops of combustion chambers, or similar structures, are supported by girders of rectangular section associated with stays, the thickness of the single girder or the aggregate thickness of all girders, at mid-length, is not to be less than the value t determined by the appropriate formula below, depending upon the number of stays.

- In case of an odd number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+1}{n}$$

- In case of an even number of stays:

$$t = \frac{pL(L-s)l}{0,25R_m a^2} \cdot \frac{n+2}{n+1}$$

where:

p : Design pressure, in MPa

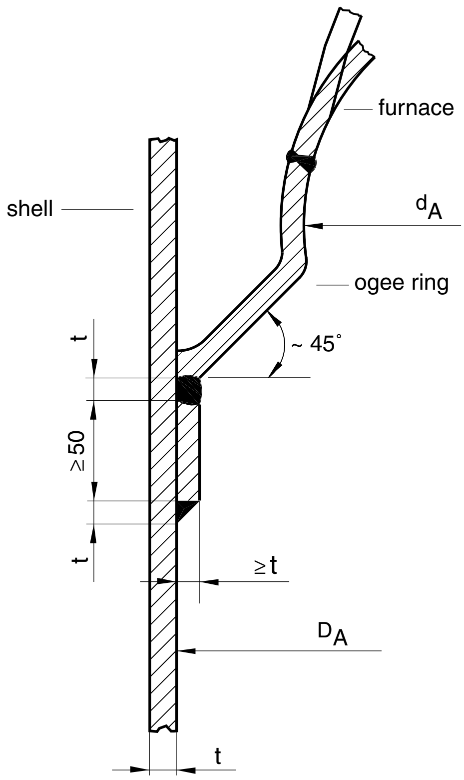
a : Depth of the girder plate at mid-length, in mm

L : Length of girder between supports, in mm

s : Pitch of stays, in mm

n : Number of stays on the girder

Figure 22 : Ogee ring



l : Distance between centres of girders, in mm

R_m : Minimum ultimate tensile strength of the material used for the plates, in N/mm².

The above formulae refer to the normal arrangement where:

- The stays are regularly distributed over the length L.
- The distance from the supports of the outer stays does not exceed the uniform pitch s.
- When the tops of the combustion chambers are connected to the sides with curved parts with an external radius less than 0,5 l, the distance of end girders from the inner part of the side surface does not exceed l.
- When the curvature radius mentioned under item just above exceeds 0,5 l, the distance of the end girders from the beginning of the connection does not exceed 0,5 l.

In other cases a direct calculation is to be made using a safety factor not less than 5, with respect to the minimum value of the tensile strength R_m.

i) Ogee rings

The thickness of ogee rings connecting the furnaces to the shell in vertical auxiliary boilers (see Fig 22), where the latter support the weight of the water above the furnace, is not to be less than the value t, in mm, given by the following formula:

$$t = [1{,}02 \cdot 10^{-3} \cdot pD_A \cdot (D_A - d_A)]^{0,5} + 1$$

where:

p : Design pressure, in MPa

D_A : Inside diameter of boiler shell, in mm

d_A : Inside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

2.12.5 Fire tubes

a) The thickness of fire tubes subject to external pressure in cylindrical boilers is not to be less than the value t, in mm, calculated by the following formula:

$$t = \frac{pd}{0{,}15 R_m} + 1{,}8$$

where:

p : Design pressure, in MPa

d : Outside diameter of tube, in mm

R_m : Minimum ultimate tensile strength of the tube material, in N/mm^2.

The minimum acceptable thickness is given in Tab 15.

b) The values of t determined by the above-mentioned formula are to be considered as theoretical values for straight tubes, not taking account of the manufacturing tolerance. Where the tubes are not sized precision tubes, the thickness calculated by the formula in a) is to be increased by 12,5% to take into account the manufacturing tolerance. In the case of bent tubes, the thickness of the thinner part in way of the bend is not to be less than that given by the above formula.

c) Whenever abnormal corrosion and erosion may occur during service the corrosion constant of 1,8 in the formula may be increased to the satisfaction of the Society.

Table 15 : Minimum thickness of fire tubes

Nominal outside diameter	Lowest nominal thickness t
$d \le 88,9$	3,00
$88,9 < d \le 114,3$	3,15
$114,3 < d \le 139,7$	3,50
$139,7 < d \le 168,3$	3,99

2.12.6 Furnaces general points

a) Thermal design of furnace tubes.

The heat input for a given furnace tube inside diameter is not to exceed a value compatible with the chosen design temperature. Burners with a fixed firing rate are not to be used for heat inputs exceeding 1 MW per furnace tube.

b) The minimum thickness of furnaces is to be calculated for elastic buckling and plastic deformation in accordance with the requirements of a Standard for pressure vessels subject to external pressure accepted by the Society.

c) However, the minimum thicknesses of furnaces and cylindrical ends of combustion chambers of fire tube boilers are to be not less than the value t given by the appropriate formulae in [2.12.7], [2.12.8] and [2.12.9].

d) The thickness of furnaces is not to be less than 8 mm for plain furnace and 10 mm for corrugated furnace and the stays are to be spaced such that the thickness does not exceed 22 mm.

e) All the thicknesses obtained for furnaces by the formulae in [2.12.7], [2.12.8], [2.12.9] and [2.12.4] are "net" thicknesses, as they do not include any corrosion allowance. The thicknesses obtained by the above formulae are to be increased by 1 mm. See also [2.4.7].

2.12.7 Plain furnace tubes

a) Plain furnace tube

The minimum thickness t of plain cylindrical furnaces is to be not less than the greater value, in mm, obtained from the following formulae:

$$t = \frac{B}{2}\left[1 + \sqrt{1 + \frac{0,12D \cdot u}{(1+5D/L)B}}\right]$$

$$t = D^{0,6}[(LS_2p)/(2,6E)]^{0,4}$$

where:

$$B = \frac{pDS_1}{2R_{S,MIN,T}(1+5D/L)}$$

S_1 : Safety factor, equal to 2,5

L : Unstayed length of furnace, in mm

u : Departure from circularity, in %, equal to:

$$u = \frac{2(D_{max} - D_{min})}{D_{max} + D_{min}} \times 100$$

u is to be taken as 1,5% for plain furnace tubes

S_2 : Safety factor for buckling, equal to:

- 3 for $u \le 1,5\%$
- 4 for $1,5\% < u \le 2\%$

E : Elastic modulus, in MPa, at design temperature T, in °C, and equal to:

$E = 208800 - 93,4 \cdot T$

b) Stiffeners

Stiffeners welded to furnaces tubes according to a standard accepted by the Society may be considered as providing effective stiffening (reduction of L in upper formulae).

2.12.8 Corrugated furnace tubes

The minimum thickness of corrugated furnace tubes, in mm, is to be determined by:

$$t = \frac{pD_E}{0,26R_m}$$

where:

D_E : External diameter of the furnace, in mm, measured at the bottom of the corrugation.

This formula apply for Fox and Morisson type furnaces tubes. The scantling of furnaces of other types and the use of stiffeners are to be especially considered by the Society.

2.12.9 Hemispherical furnaces

The minimum thickness t, in mm, of hemispherical furnaces is not to be less than the value given by the following equation:

$$t = \frac{pD_E}{120}$$

2.13 Bottles containing pressurised gases

2.13.1 General

a) The following requirements apply to bottles intended to contain pressurised and/or liquefied gases at ambient temperature, made by seamless manufacturing processes.

b) In general, such bottles are to have an outside diameter not exceeding 420 mm, a length not exceeding 2000 mm and capacity not exceeding 150 litres (see also [3.4.1]).

c) For bottles exceeding the above capacity and dimensions, the following requirements may be applied at the discretion of the Society.

2.13.2 Cylindrical shell

The wall thickness of the cylindrical shell is not to be less than the value t, in mm, determined by the following formula:

$$t = \frac{p_H D_E}{2K + p_H}$$

where:

p_H : Hydrostatic test pressure, in MPa. This pressure is to be taken as 1,5 times the setting pressure of the safety valves with the following exceptions:

- 25 MPa for CO_2 bottles
- for refrigerants, the value of hydrostatic test pressure is given in Pt E, Ch 11, Sec 3

D_E : Outside diameter of tube, in mm

$K = R_{S,MIN} / 1,3$

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), at the ambient temperature, in N/mm². In no case is the value $R_{S,MIN}$ to exceed:

- 0,75 R_m for normalised steels
- 0,90 R_m for quenched and tempered steels.

2.13.3 Dished heads

Dished ends are to comply with the following requirements:

a) Hemispherical ends: the thickness of the ends is to be not less than the thickness calculated for spherical shells in accordance with [2.4.4]

b) Convex ends: see Fig 23

c) Concave base ends: see Fig 24

d) Ends with openings: see Fig 25

e) Other types of ends are to be specially considered by the Society.

Figure 23 : Dished convex ends

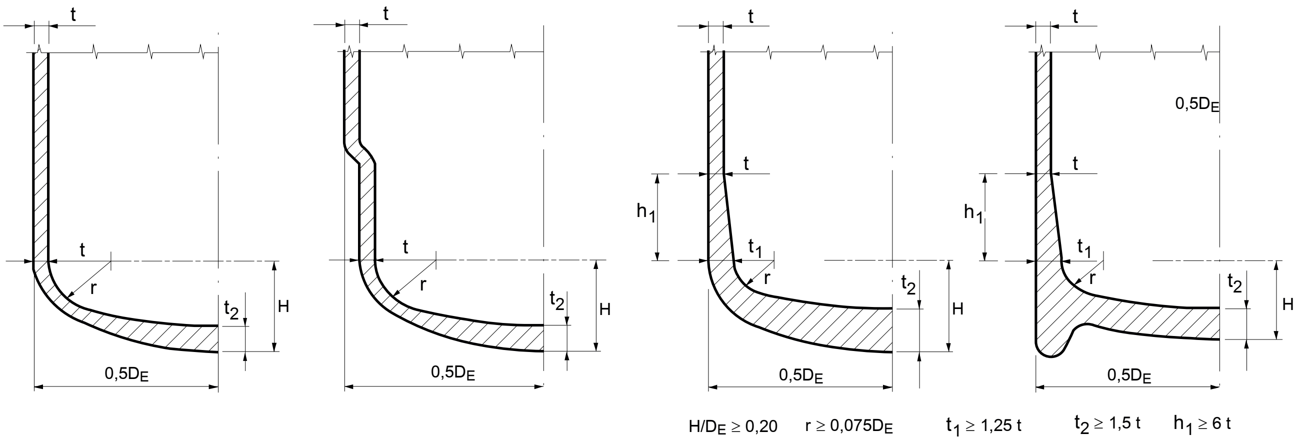


Figure 24 : Dished concave ends

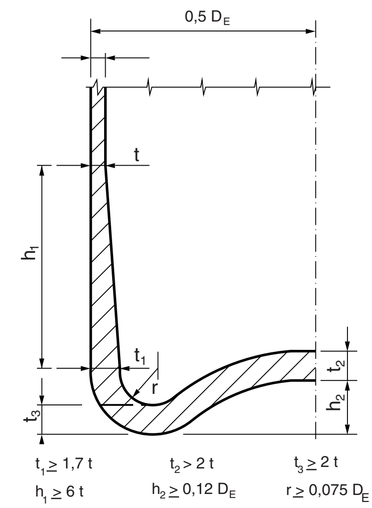
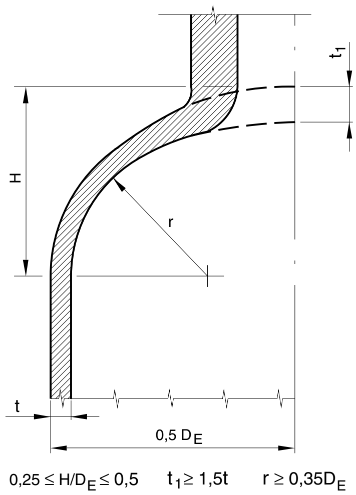


Figure 25 : Heads with openings



2.14 Heat exchangers

2.14.1 Scantlings

a) Vessels are to be designed in accordance with the applicable requirements stated in [2.4] and [2.5].

b) Tubes are to be designed in accordance with [2.10.1].

c) Tube plates are to be designed in accordance with a standard accepted by the Society.

2.14.2 Thermal oil heat exchangers

The provisions of [2.14.1] apply also to thermal oil heat exchangers. However, irrespective of the thickness obtained by the formula in [2.10.1], the tube thickness of oil fired and exhaust fired thermal oil heaters is to be not less than the values indicated in Tab 16.

Table 16 : Minimum thickness of thermal oil heat exchanger tubes

Outside diameter, in mm	Minimum thickness, in mm, of tubes subject to internal pressure of oil fired and exhaust fired thermal oil heaters
< 63,5	2,4
70 - 89	2,9
> 89	3,6

3 Design and construction - Equipment

3.1 All pressure vessels

3.1.1 Drainage

a) Each air pressure vessel is to be fitted with a drainage device allowing the evacuation of any oil or water accumulated in the vessel.

b) Drainage devices are also to be fitted on other vessels, in particular steam vessels, in which condensation water is likely to accumulate.

3.2 Boilers and steam generators

3.2.1 Safety valve arrangement

a) Every steam boiler and every steam generator with a total heating surface of 50 m^2 and above is to be provided with not less than two spring loaded safety valves of adequate capacity. For steam boilers and steam generators having heating surface less than 50 m^2, only one safety valve need be fitted.

b) Where a superheater is an integral part of the boiler, at least one safety valve is to be located on the steam drum and at least one at the superheater outlet. The valves fitted at the superheater outlet may be considered as part of the boiler safety valves required in item a), provided that their capacity does not account for more than 25% of the total capacity required in [3.2.2], unless specially considered by the Society.

c) Where fitted, superheaters which may be shut-off from the boiler are to be provided with at least one safety valve; such valve(s) cannot be considered as part of the boiler safety valves required in item a).

d) In the case of boilers fitted with a separate steam accumulator, safety valves may be fitted on the accumulator if no shut-off is provided between it and the boiler and if the connecting pipe is of a size sufficient to allow the whole steam production to pass through, without increasing the boiler pressure more than 10% above the design pressure.

3.2.2 Relieving capacity of safety valves

a) The relieving capacity of each safety valve Q, in kg/h, is to be determined by the appropriate formula below in order that:

$Q \geq W$

- saturated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1,05)}{100}$$

- superheated steam:

$$Q = \frac{C \cdot A \cdot (10 \cdot P + 1,05)}{100} \times \sqrt{\frac{V}{V_S}}$$

where:

W : Maximum steam production, in kg/h, as defined by the maximum power of the heating equipment; otherwise the value of W is to be based on evaporating capacities (referring to evaporating surfaces of the boiler concerned) less than the following:

- 14 kg/(m^2·h) for exhaust gas heated boilers
- 29 kg/(m^2·h) for oil fired boilers
- 60 kg/(m^2·h) for water walls of oil fired boilers

A : Aggregate area, in mm^2, of the orifices in way of the seat of the valve, deducting the obstructions corresponding to the guides and the conformation of the valve in full lift position

p : Maximum working pressure of the boiler or other steam generator, in MPa. For superheated steam safety valves, P is to be the pressure at the superheater outlet

C : Coefficient with the following values:

- C = 4,8 for ordinary safety valves, i.e. where the valve lift is at least 1/24 of the internal diameter of the seat
- C = 10 for high lift safety valves, i.e. where the valve lift is at least 1/12 of the internal diameter of the seat
- C = 20 for full lift safety valves, i.e. where the valve lift is at least 1/4 of the internal diameter of the valve

Higher values of coefficient C may be admitted for safety valves of approved type and having undergone, in the presence of the Surveyor or according to a procedure considered as equivalent by the Society, capacity tests with conditions of pressure and temperature comparable to those of the plant considered. In such a case, coefficient C is to be, as a rule, taken as 90% of the resulting value from the capacity test

v : Specific volume of saturated steam at the pressure corresponding to the superheater outlet

v_S : Specific volume of superheated steam at the temperature corresponding to the superheater outlet.

b) When the safety valves are fitted at the superheater outlet. Their relieving capacity is to be such that, during the discharge of safety valves, a sufficient quantity of steam is circulated through the superheater to avoid damage.

c) The orifice diameter in way of the safety valves seat is not to be less than 40 mm. Where only one safety valve need be fitted, the orifice minimum diameter is not to be less than 50 mm. Valves of large relieving capacity with 15 mm minimum diameter may be accepted for boilers with steam production not exceeding 2000 kg/h.

d) Independently of the above requirements, the aggregate capacity of the safety valves is to be such as to discharge all the steam that can be generated without causing a transient pressure rise of more than 10% over the design pressure.

3.2.3 Miscellaneous safety valve requirements

a) Safety valves operated by pilot valves

The arrangement on the superheater of large relieving capacity safety valves, operated by pilot valves fitted in the saturated steam drum, is to be specially considered by the Society.

b) Safety valve setting

- safety valves are to be set under steam in the presence of the Surveyor to a pressure not higher than 1,03 times the design pressure
- safety valves are to be so constructed that their setting may not be increased in service and their spring may not be expelled in the event of failure. In addition, safety valves are to be provided with simple means of lifting the plug from its seat from a safe position in the boiler or engine room
- where safety valves are provided with means for regulating their relieving capacity, they are to be so fitted that their setting cannot be modified when the valves are removed for surveys.

c) Safety valve fitting on boiler

- the safety valves of a boiler are to be directly connected to the boiler and separated from other valve bodies
- where it is not possible to fit the safety valves directly on the superheater headers, they are to be mounted on a strong nozzle fitted as close as practicable to the superheater outlet. The cross-sectional area for passage of steam through restricted orifices of the nozzles is not to be less than 1/2 the aggregate area of the valves, calculated with the formulae of [2.3.2] when $C \leq 10$, and not less than the aggregate area of the valves when $C > 10$
- safety valve bodies are to be fitted with drain pipes of a diameter not less than 20 mm for double valves, and not less than 12 mm for single valves, leading to the bilge or to the hot well. Valves or cocks are not to be fitted on drain pipes.

d) Exhaust pipes

- the minimum cross-sectional area of the exhaust pipes of safety valves which have not been experimentally tested is not to be less than C times the aggregate area A
- the cross-sectional area of the exhaust manifold of safety valves is to be not less than the sum of the areas of the individual exhaust pipes connected to it
- silencers fitted on exhaust manifolds are to have a free passage area not less than that of the manifolds
- the strength of exhaust manifolds and pipes and associated silencers is to be such that they can withstand the maximum pressure to which they may be subjected, which is to be assumed not less than 1/4 of the safety valve setting pressure
- in the case that the discharges from two or more valves are led to the same exhaust manifold, provision is to be made to avoid the back pressure from the valve which is discharging influencing the other valves
- exhaust manifolds are to be led to the open and are to be adequately supported and fitted with suitable expansion joints or other means so that their weight does not place an unacceptable load on the safety valve bodies.

e) Steam generator heated by steam

Steam heated steam generators are also to be protected against possible damage resulting from failure of the heating coils. In this case, the area of safety valves calculated as stated in [3.2.2] may need to be increased to the satisfaction of the Society, unless suitable devices limiting the flow of steam in the heating coils are provided.

3.2.4 Other requirements

Access arrangement

a) Boilers are to be provided with openings in sufficient number and size to permit internal examination, cleaning and maintenance operations. In general, all pressure vessels which are part of a boiler with inside diameter exceeding 1200 mm, and those with inside diameter exceeding 800 mm and length exceeding 2000 mm, are to be provided with access manholes.

b) Manholes are to be provided in suitable locations in the shells, headers, domes, and steam and water drums, as applicable. The “net” (actual hole) dimension of elliptical or similar manholes is to be not less than 300mm x 400mm. The “net” diameter of circular manholes (actual hole) cannot be less than 400 mm. The edges of manholes are to be adequately strengthened to provide compensation for vessel openings in accordance with [2.8.4], [2.8.6] and [2.8.9], as applicable.

c) In pressure vessels which are part of a boiler and are not covered by the requirement in item a) above, or where an access manhole cannot be fitted, at least the following openings are to be provided, as far as practicable:
   - head holes: minimum dimensions: 220mm x 320mm (320 mm diameter if circular)
   - handholes: minimum dimensions: 87mm x 103mm
   - sight holes: minimum diameter: 50 mm.

d) Sight holes may only be provided when the arrangement of manholes, head holes, or handholes is impracticable.

e) Covers for manholes and other openings are to be made of ductile steel, dished or welded steel plates or other approved design. Grey cast iron may be used only for small openings, such as handholes and sight holes, provided the design pressure p does not exceed 1 MPa and the design temperature T does not exceed 220°C.

f) Covers are to be of self-closing internal type. Small opening covers of other type may be accepted by the Society on a case by case basis.

g) Covers of the internal type are to have a spigot passing through the opening. The clearance between the spigot and the edge of the opening is to be uniform for the whole periphery of the opening and is not to exceed 1,5 mm.

h) Closing devices of internal type covers, having dimensions not exceeding 180mm x 230mm, may be fitted with a single fastening bolt or stud. Larger closing devices are to be fitted with at least two bolts or studs.

i) Covers are to be designed so as to prevent the dislocation of the required gasket by the internal pressure. Only continuous ring gaskets may be used for packing.

Fittings

a) In general, cocks and valves are to be designed in accordance with the requirements in Ch 1, Sec 10, [2.7.2].

b) Cocks, valves and other fittings are to be connected directly or as close as possible to the boiler shell.

c) Cocks and valves for boilers are to be arranged in such a way that it can be easily seen when they are open or closed and so that their closing is obtained by a clockwise rotation of the actuating mechanism.

Boiler burners

Burners are to be arranged so that they cannot be withdrawn unless the fuel supply to the burners is cut off.

Allowable water levels

a) In general, for water tube boilers the lowest permissible water level is just above the top row of tubes when the water is cold. Where the boiler is designed not to have fully submerged tubes, when the water is cold, the lowest allowable level indicated by the manufacturer is to be indicated on the drawings and submitted to the Society for consideration.

b) For fire tube boilers with combustion chamber integral with the boiler, the minimum allowable level is to be at least 50 mm above the highest part of the combustion chamber.

c) For vertical fire tube boilers the minimum allowable level is 1/2 of the length of the tubes above the lower tube sheet.

Steam outlets

a) Each boiler steam outlet, if not serving safety valves, integral superheaters and other appliances which are to have permanent steam supply during boiler operation, is to be fitted with an isolating valve secured either directly to the boiler shell or to a standpipe of substantial thickness, as short as possible, and secured directly to the boiler shell.

b) The number of auxiliary steam outlets is to be reduced to a minimum for each boiler.

c) Where several boilers supply steam to common mains, the arrangement of valves is to be such that it is possible to positively isolate each boiler for inspection and maintenance. In addition, for water tube boilers, non-return devices are to be fitted on the steam outlets of each boiler.

d) Where steam is used for essential auxiliaries (such as whistles, steam operated steering gears, steam operated electric generators, etc.) and when several boilers are fitted on board, it is to be possible to supply steam to these auxiliaries with any one of these boilers out of operation.

e) Each steam stop valve exceeding 150 mm nominal diameter is to be fitted with a bypass valve.

Feed check valves

a) Each fired boiler supplying steam to essential services is to be fitted with at least two feed check valves connected to two separate feed lines. For unfired steam generators a single feed check valve may be allowed.

b) Feed check valves are to be secured directly to the boiler or to an integral economiser. Water inlets are to be separated. Where, however, feed check valves are secured to an economiser, a single water inlet may be allowed provided that each feed line can be isolated without stopping the supply of feed water to the boiler.

c) Where the economisers may be bypassed and cut off from the boiler, they are to be fitted with pressure-limiting type valves, unless the arrangement is such that excessive pressure cannot occur in the economiser when cut off.

d) Feed check valves are to be fitted with control devices operable from the stokehold floor or from another appropriate location. In addition, for water tube boilers, at least one of the feed check valves is to be arranged so as to permit automatic control of the water level in the boiler.

e) Provision is to be made to prevent the feed water from getting in direct contact with the heated surfaces inside the boiler and to reduce, as far as possible and necessary, the thermal stresses in the walls.

Drains

Each superheater, whether or not integral with the boiler, is to be fitted with cocks or valves so arranged that it is possible to drain it completely.

Water sample

a) Every boiler is to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

b) For this purpose, boilers are to be fitted with at least one water sample cock or valve. This device is not to be connected to the water level standpipes.

c) Suitable inlets for water additives are to be provided in each boiler.

Marking of boilers

a) Each boiler is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
   - the design pressure
   - the design temperature
   - the test pressure and the date of the test.

b) Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.

c) For lagged vessels, these markings are also to appear on a similar plate fitted above the lagging.

3.3 Thermal oil heaters and thermal oil installation

3.3.1 General

a) The following requirements apply to thermal oil heaters in which organic liquids (thermal oils) are heated by oil fired burners, exhaust gases or electricity to temperatures below their initial boiling point at atmospheric pressure.

b) Thermal oils are only to be used within the limits set by the manufacturer.

c) Means are to be provided for manual operation. During manual operation, the automated functioning of at least the temperature control device on the thermal oil side as well as the flow monitoring is to be maintained.

d) Means are to be provided to take samples of thermal oil.

3.3.2 Thermal oil heater design

a) Heaters are to be so constructed that neither the surfaces nor the thermal oil becomes excessively heated at any point. The flow of the thermal oil is to be ensured by forced circulation.

b) The surfaces which come into contact with the thermal oil are to be designed for the design pressure, subject to the minimum pressure of 1 MPa.

c) Copper and copper alloys are not permitted.

d) Heaters heated by exhaust gas are to be provided with inspection openings at the exhaust gas intake and outlet.

e) Oil fired heaters are to be provided with inspection openings for examination of the combustion chamber. The opening for the burner may be considered as an inspection opening, provided its size is sufficient for this purpose.

f) Heaters are to be fitted with means enabling them to be completely drained.

g) Thermal oil heaters heated by exhaust gas are to be fitted with a permanent system for extinguishing and cooling in the event of fire, for instance a pressure water spraying system.

3.3.3 Safety valves of thermal oil heaters

Each heater is to be equipped with at least one safety valve having a discharge capacity at least equal to the increase in volume of the thermal oil at the maximum heating power. During discharge the pressure may not increase above 10% over the design pressure.

3.3.4 Pressure vessels of thermal oil heaters

The design pressure of all vessels which are part of a thermal oil system, including those open to the atmosphere, is to be taken not less than 0,2 MPa.

3.3.5 Equipment of the expansion, storage and drain tanks

For the equipment to be installed on expansion, storage and drain tanks, see Ch 1, Sec 10, [13].

3.3.6 Marking

Each thermal oil heater and other pressure vessels which are part of a thermal oil installation are to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):

- Heaters
  - maximum allowable heating power
  - design pressure
  - maximum allowable discharge temperature
  - minimum flow rate
  - liquid capacity
- Vessels
  - design pressure
  - design temperature
  - capacity.

3.4 Special types of pressure vessels

3.4.1 Seamless pressure vessels (bottles)

Each bottle is to be marked with the following information:

- name or trade name of the manufacturer
- serial number
- type of gas
- capacity
- test pressure
- empty weight
- test stamp.

3.4.2 Steam condensers

a) The water chambers and steam spaces are to be fitted with doors for inspection and cleaning.

b) Where necessary, suitable diaphragms are to be fitted for supporting tubes.

c) Condenser tubes are to be removable.

d) High speed steam flow, where present, is to be prevented from directly striking the tubes by means of suitable baffles.

e) Suitable precautions are to be taken in order to avoid corrosion on the circulating water side and to provide an efficient grounding.

3.5 Other pressure vessels

3.5.1 Safety valves arrangement

a) General
  - Pressure vessels which are part of a system are to be provided with safety valves, or equivalent devices, if they are liable to be isolated from the system safety devices. This provision is also to be made in all cases in which the vessel pressure can rise, for any reason, above the design pressure.
  - In particular, air pressure vessels which can be isolated from the safety valves ensuring their protection in normal service are to be fitted with another safety device, such as a rupture disc or a fusible plug, in order to ensure their discharge in case of fire. This device is to discharge to the open.
  - Safety devices ensuring protection of pressure vessels in normal service are to be rated to operate before the pressure exceeds the maximum working pressure by more than 5%
  - where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

b) Heat exchangers

Special attention is to be paid to the protection against overpressure of vessels, such as heat exchangers, which have parts that are designed for a pressure which is below that to which they might be subjected in the case of rupture of the tubular bundles or coils contained therein and that have been designed for a higher pressure.

3.5.2 Other requirements

a) Access arrangement

The access requirements for boilers stated in [3.2.4] are also applicable for other pressure vessels.

b) Corrosion protection

Vessels and equipment containing media that might lead to accelerated corrosion are to be suitably protected.

c) Marking

- Each pressure vessel is to be fitted with a permanently attached plate made of non-corrosive metal, with indication of the following information, in addition to the identification marks (name of manufacturer, year and serial number):
  - the design pressure
  - the design temperature
  - the test pressure and the date of the test.
- Markings may be directly stamped on the vessel if this does not produce notches having an adverse influence on its behaviour in service.
- For smaller pressure vessels the indication of the design pressure only may be sufficient.

4 Design and construction - Fabrication and welding

4.1 General

4.1.1 Base materials

a) These requirements apply to boilers and pressure vessels made of steel of weldable quality.

b) Fabrication and welding of vessels made of other materials are to be the subject of special consideration.

4.1.2 Welding

a) Weldings are to be performed in accordance with welding procedures approved by the Society.

b) Manual and semi-automatic welding is to be performed by welders qualified by the Society.

c) The conditions under which the welding procedures, welding equipment and welders operate are to correspond to those specified in the relevant approvals or qualifications.

d) Both ordinary and special electric arc welding processes are covered in the following requirements.

4.1.3 Cutting of plates

a) Plates are to be cut by flame cutting, mechanical machining or a combination of both processes. For plates having a thickness less than 25 mm, cold shearing is admitted provided that the sheared edge is removed by machining or grinding for a distance of at least one quarter of the plate thickness with a minimum of 3 mm.

b) For flame cutting of alloy steel plates, preheating is to be carried out if necessary.

c) The edges of cut plates are to be examined for laminations, cracks or any other defect detrimental to their use.

4.1.4 Forming of plates

a) The forming processes are to be such as not to impair the quality of the material. The Society reserves the right to require the execution of tests to demonstrate the suitability of the processes adopted. Forming by hammering is not allowed.

b) Unless otherwise justified, cold formed shells are to undergo an appropriate heat treatment if the ratio of internal diameter after forming to plate thickness is less than 20. This heat treatment may be carried out after welding.

c) Before or after welding, hot formed plates are to be normalised or subjected to another treatment suitable for their steel grade, if hot forming has not been carried out within an adequate temperature range.

d) Plates which have been previously butt-welded may be formed under the following conditions:

- Hot forming

  After forming, the welded joints are to be subjected to X-ray examination or equivalent. In addition, mechanical tests of a sample weld subjected to the same heat treatment are to be carried out.

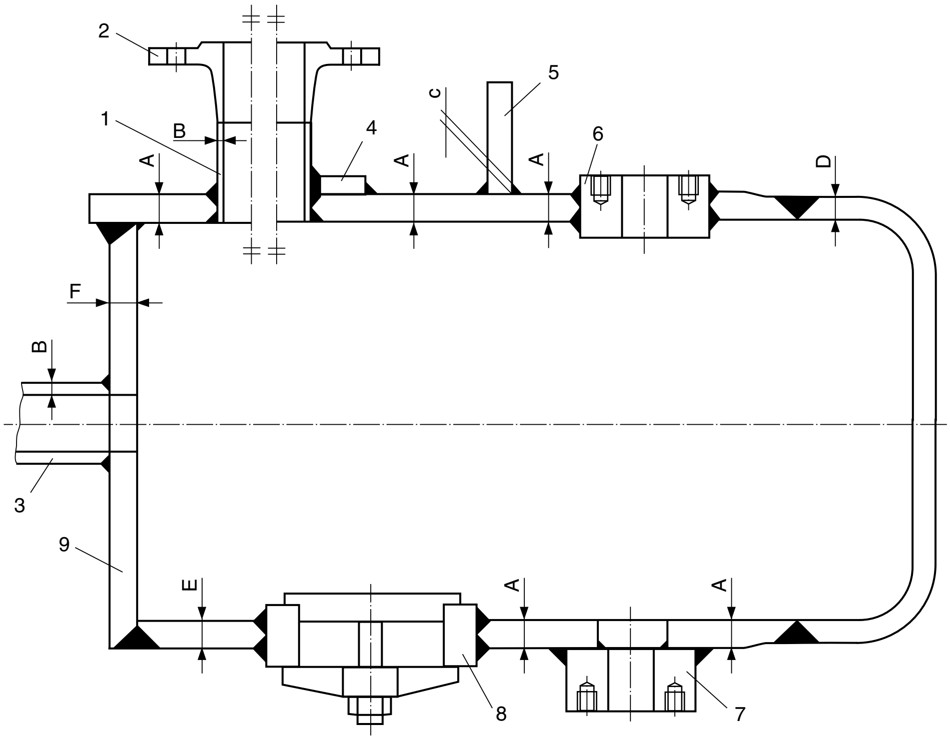
- Cold forming

  Cold forming is only allowed for plates having a thickness not exceeding:

  - 20 mm for steels having minimum ultimate tensile strength R_m between 360 N/mm^2 and 410 N/mm^2
  - 15 mm for steels having R_m between 460 N/mm^2 and 510 N/mm^2 as well as for steels 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.

  Cold forming is not allowed for steels 1Cr0,5Mo and 2,25Cr1Mo.
- Weld reinforcements are to be carefully ground smooth prior to forming.
- A proper heat treatment is to be carried out after forming, if the ratio of internal diameter to thickness is less than 36, for steels: 460 N/mm^2, 510 N/mm^2, 0,3Mo, 1Mn0,5Mo, 1Mn0,5MoV and 0,5Cr0,5Mo.
- After forming, the joints are to be subjected to X-ray examination or equivalent and to a magnetic particle or liquid penetrant test.
- Refer to Fig 26 for definition of thickness to be taken in account.

Figure 26 : Example of acceptable joints and thickness to be considered for forming and post-weld heat treatment



Key

1 : Nozzle (set in); **2** : Flange; **3** : Nozzle (set on); **4** : Reinforcing plate; **5** : Non-pressure part;

6 : Pad (set in); **7** : Pad (set on); **8** : Manhole frame; **9** : Flat plate.

4.2 Welding design

4.2.1 Main welded joints

a) All joints of class 1 and 2 pressure parts of boilers and pressure vessels are to be butt-welded, with the exception of welding connecting flat heads or tube sheets to shells, for which partial penetration welds or fillet welds may be accepted.

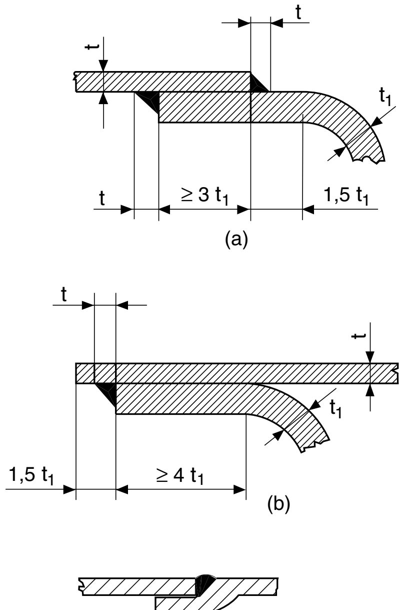
Fig 26 show examples of acceptable welding for class 1 and 2 pressure vessels.

b) Joints of class 3 pressure vessels are also subject to the requirement in a), however connection of dished heads to shells by lap welds may be accepted. Fig 27 shows some acceptable details of circumferential lap welds for class 3 pressure vessels.

4.2.2 Shell longitudinal and circumferential welds

Longitudinal and circumferential joints are to be welded from both sides of the plate. Welding from one side may be allowed only when there is evidence that the welding process permits a complete penetration and a sound weld root. If a backing strip is used, it is to be removed after welding and prior to any non-destructive examination. However, the backing strip may be retained in circumferential joints of class 2 vessels, having a thickness not exceeding 15 mm, and of class 3 vessels, provided that the material of the backing strip is such as not to adversely affect the weld.

Figure 27 : Example of acceptable lap-joints



Details (b) and (c) may be used only for pressure vessels having internal diameter less than 600mm.

4.2.3 Plates of unequal thickness

a) If plates of unequal thickness are butt-welded and the difference between thicknesses is more than 3 mm, the thicker plate is to be smoothly tapered for a length equal to at least four times the offset, including the width of the weld. For longitudinal joints the tapering is to be made symmetrically on both sides of the plate in order to obtain alignment of middle lines.

b) If the joint is to undergo radiographic examination, the thickness of the thicker plate is to be reduced to that of the thinner plate next to the joint and for a length of at least 30 mm.

4.2.4 Dished heads

a) For connection of a hemispherical end with a cylindrical shell, the joint is to be arranged in a plane parallel to that of the largest circle perpendicular to the axis of the shell and at such a distance from this plane that the tapering of the shell made as indicated in [2.5.6] is wholly in the hemisphere.

b) For torispherical ends made of parts assembled by welding, no welded joint is normally admitted along a parallel in the knuckle nor at a distance less than 50 mm from the beginning of the knuckle.

4.2.5 Welding location

The location of main welded joints is to be chosen so that these joints are not submitted to appreciable bending stresses.

4.2.6 Accessories and nozzles

a) Attachment of accessories by welds crossing main welds or located near such welds is to be avoided; where this is impracticable, welds for attachment of accessories are to completely cross the main welds rather than stop abruptly on or near them.

b) Openings crossing main joints or located near main joints are also to be avoided as far as possible.

c) Doubling plates for attachment of accessories such as fixing lugs or supports are to be of sufficient size to ensure an adequate distribution of loads on pressure parts; such doubling plates are to have well rounded corners. Attachment of accessories such as ladders and platforms directly on the walls of vessels such that they restrain their free contraction or expansion is to be avoided.

d) Welded connections of nozzles and other fittings, either with or without local compensation, are to be of a suitable type, size and preparation in accordance with the approved plans.

4.2.7 Connections of stays to tube plates

a) Where stays are welded, the cross-sectional area of the weld is to be at least 1,25 times the cross-section of the stay.

b) The cross-sectional area of the end welding of welded stay tubes is to be not less than 1,25 times the cross-sectional area of the stay tube.

4.2.8 Type of weldings

Fig 28, Fig 29, Fig 30, Fig 31, Fig 32, Fig 33, Fig 34, Fig 35, Fig 36 and Fig 37 indicate the type and size of weldings of typical pressure vessel connections. Any alternative type of welding or size is to be the subject of special consideration by the Society.

Figure 28 : Types of joints for unstayed flat heads (1)

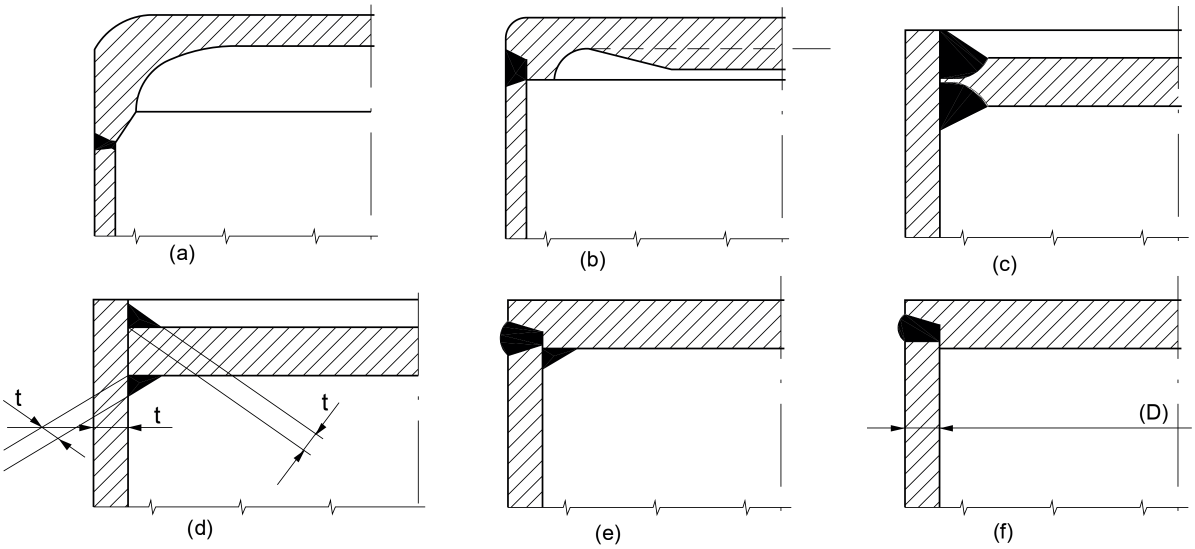


Figure 29 : Types of joints for unstayed flat heads (2)

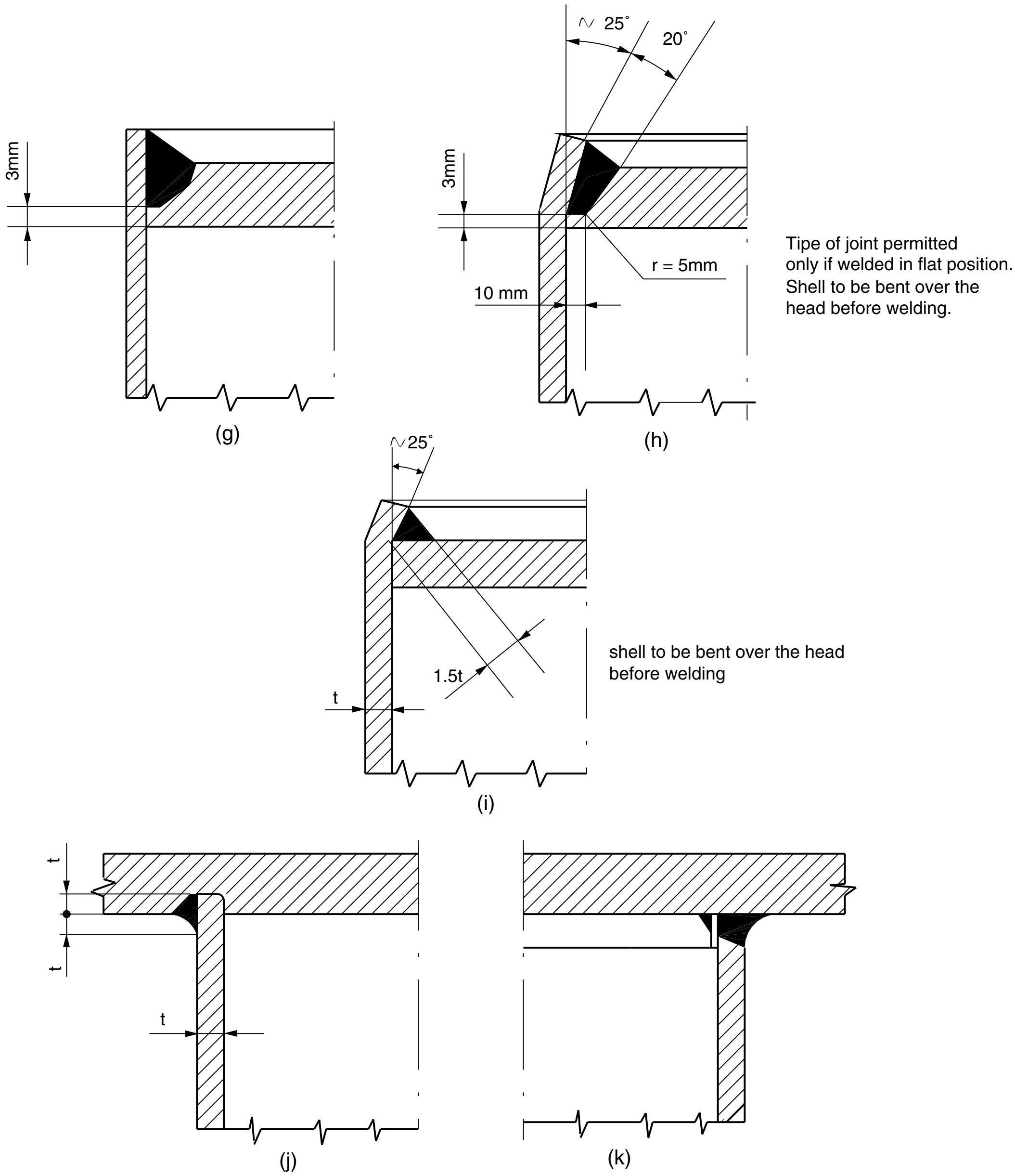


Figure 30 : Types of joints for nozzles and reinforced rings (1)

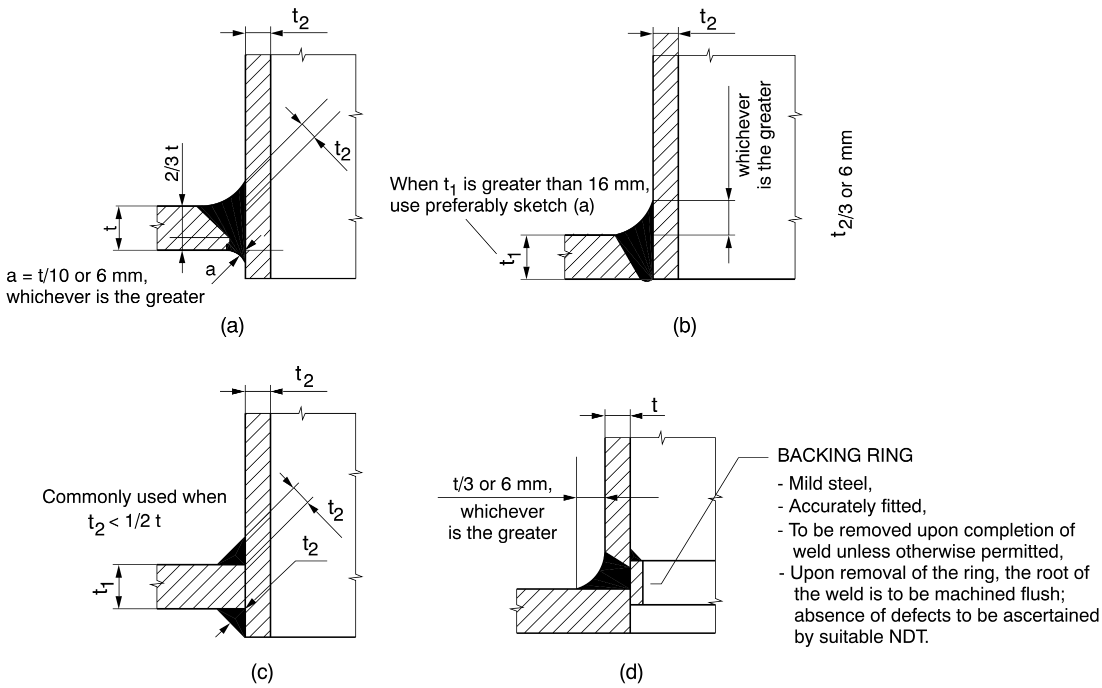


Figure 31 : Types of joints for nozzles and reinforcing rings (2)

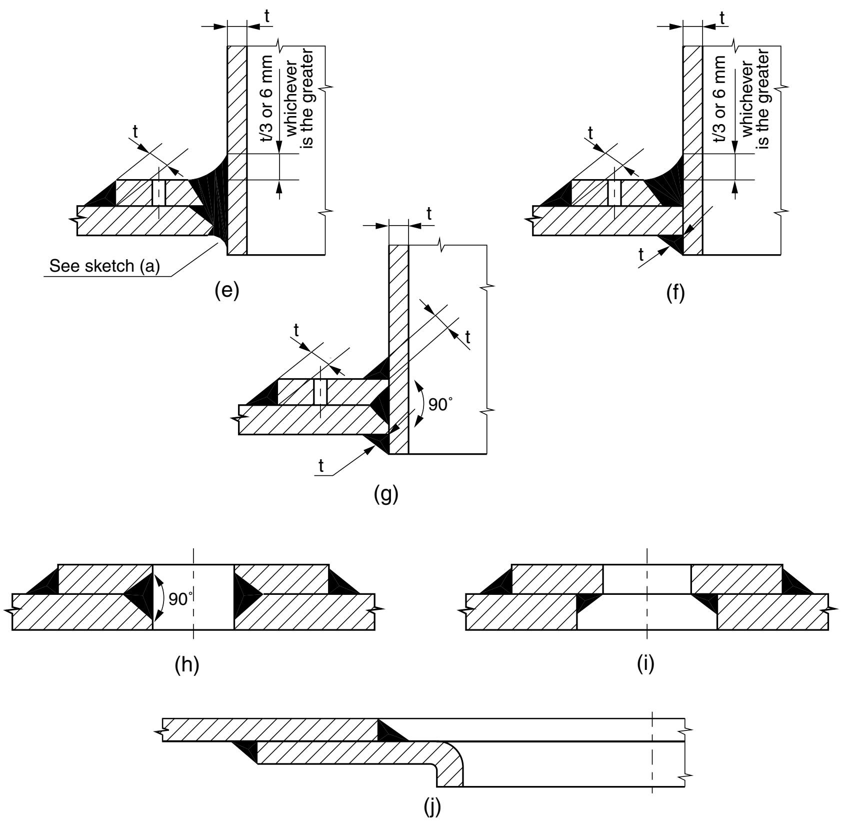


Figure 32 : Types of joints for nozzles and reinforcing rings (3)

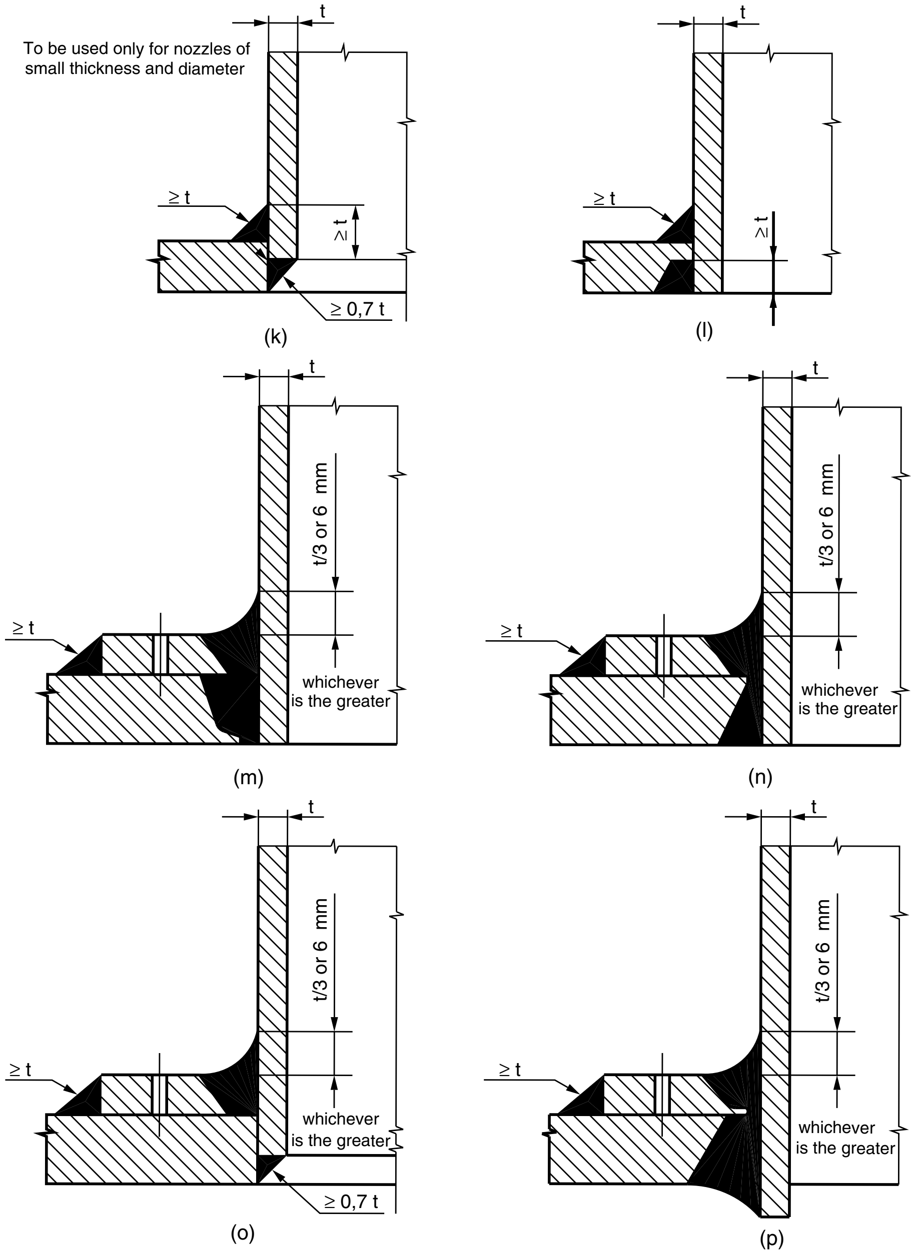
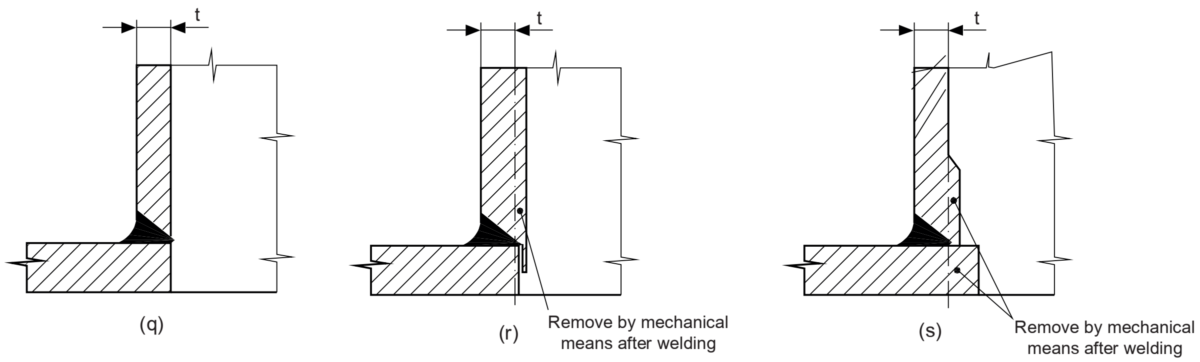


Figure 33 : Types of joints for nozzles (4)



Note: Where preparations of Fig 33 are carried out, the shell is to be carefully inspected to ascertain the absence of lamination.

Figure 34 : Types of joints for flanges to nozzles

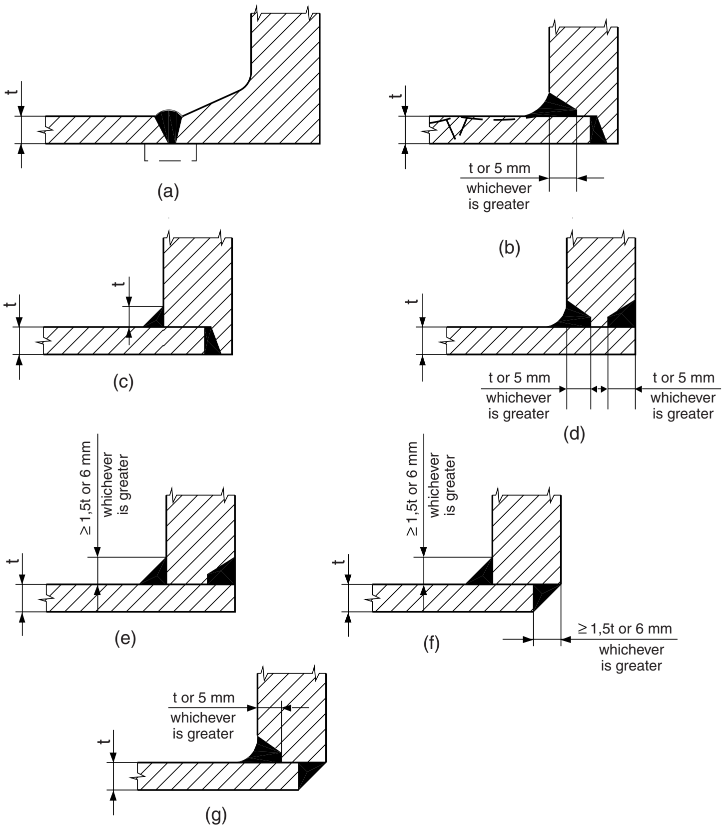


Figure 35 : Types of joints for tubesheets to shell (1)

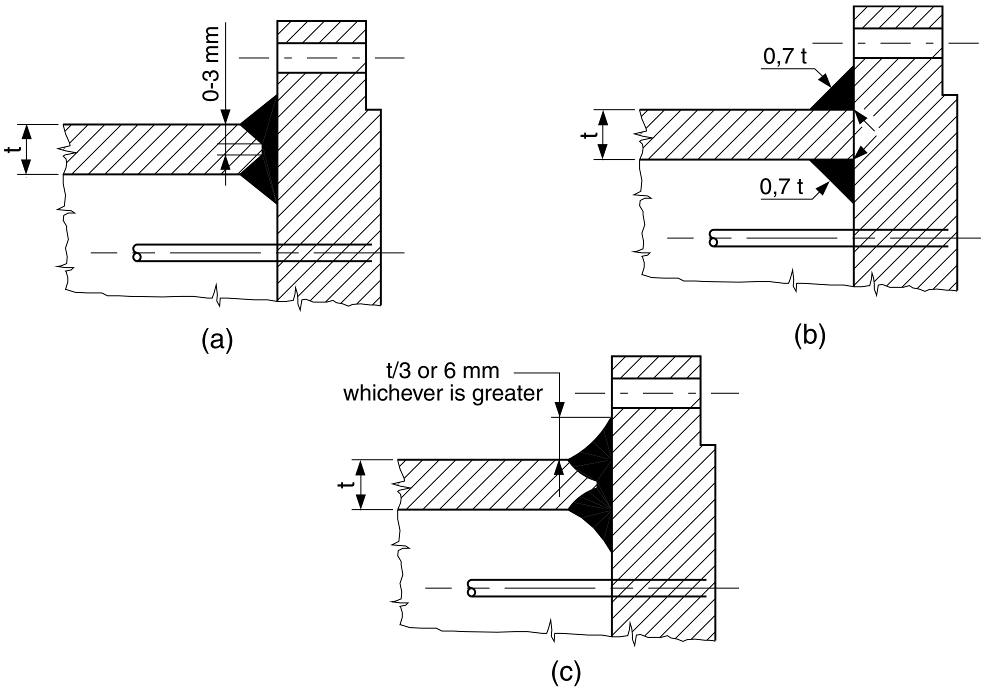


Figure 36 : Types of joints for tubesheets to shells (2)

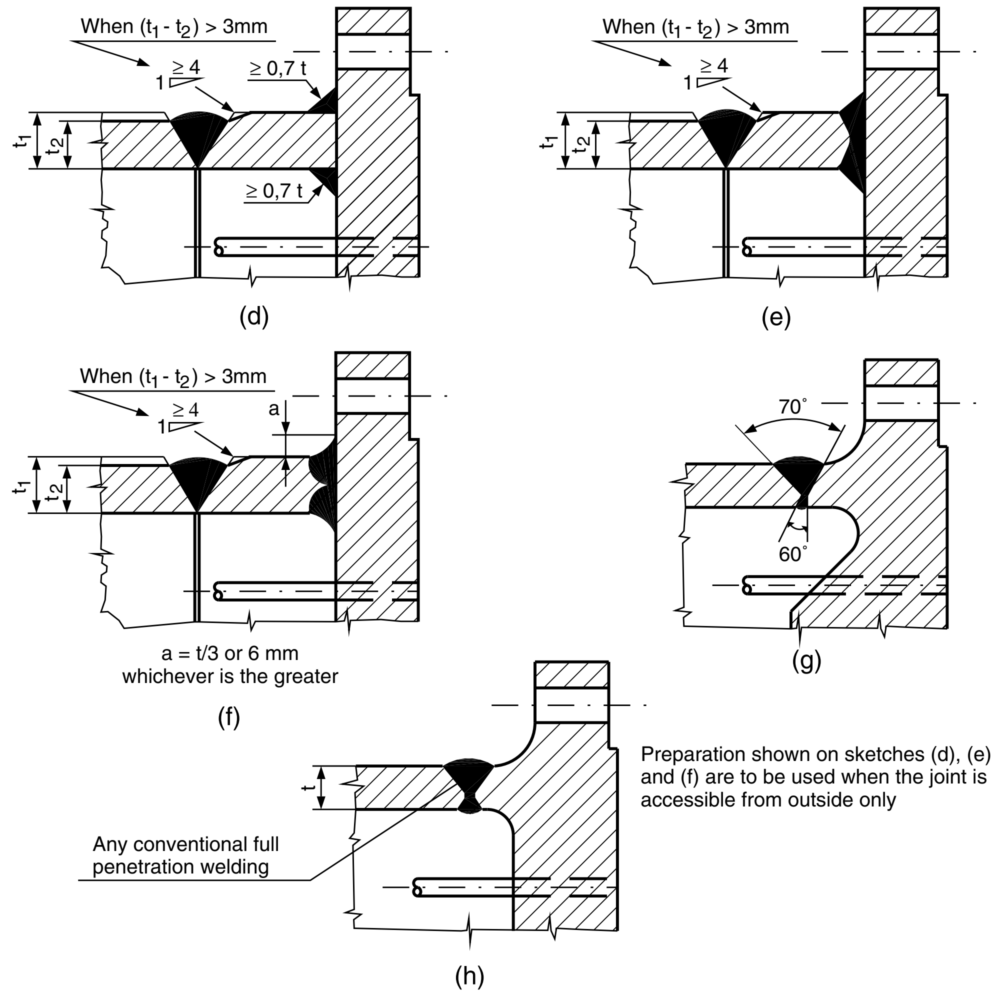
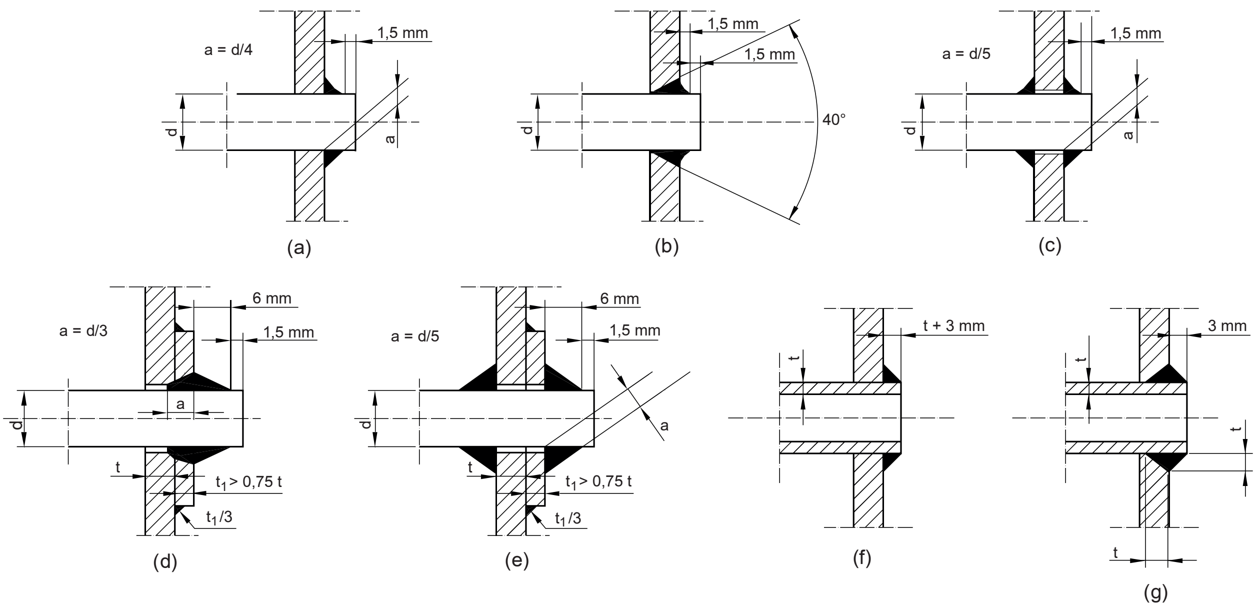


Figure 37 : Type of joints for stays and stay tubes



4.3 Miscellaneous requirements for fabrication and welding

4.3.1 Welding position

a) As far as possible, welding is to be carried out in the downhand horizontal position and arrangements are to be foreseen so that this can be applied in the case of circumferential joints.

b) When welding cannot be performed in this position, tests for qualification of the welding process and the welders are to take account thereof.

4.3.2 Cleaning of parts to be welded

a) Parts to be welded are, for a distance of at least 25 mm from the welding edges, to be carefully cleaned in order to remove any foreign matter such as rust, scale, oil, grease and paint.

b) If the weld metal is to be deposited on a previously welded surface, all slag or oxide is to be removed to prevent inclusions.

4.3.3 Protection against adverse weather conditions

a) Welding of pressure vessels is to be done in a sheltered position free from draughts and protected from cold and rain.

b) Unless special justification is provided, no welding is to be performed if the temperature of the base metal is less than 0°C.

4.3.4 Interruption in welding

If, for any reason, welding is stopped, care is to be taken on restarting to obtain a complete fusion.

4.3.5 Backing weld

When a backing weld is foreseen, it is to be carried out after suitable chiseling or chipping at the root of the first weld, unless the welding process applied does not call for such an operation.

4.3.6 Appearance of welded joints

a) Welded joints are to have a smooth surface without under-thickness; their connection with the plate surface is to be gradual without undercutting or similar defects.

b) The weld reinforcement of butt welds, on each side of the plate, is not to exceed the following thickness:
   - 2,5 mm for plates having a thickness not exceeding 12 mm
   - 3 mm for plates having a thickness greater than 12 mm but less than 25 mm
   - 5 mm for plates having a thickness at least equal to 25 mm.

4.4 Preparation of parts to be welded

4.4.1 Preparation of edges for welding

a) Grooves and other preparations of edges for welding are to be made by machining, chipping or grinding. Flame cutting may also be used provided that the zones damaged by this operation are removed by machining, chipping or grinding. For alloy steel plates, preheating is to be provided, if needed, for flame cutting.

b) Edges prepared are to be carefully examined to check that there are no defects detrimental to welding.

4.4.2 Abutting of parts to be welded

a) Abutting of parts to be welded is to be such that surface misalignment of plates does not exceed:
   - 10% of the thickness of the plate with a maximum of 3 mm for longitudinal joints
   - 10% of the thickness of the plate plus 1 mm with a maximum of 4 mm for circumferential joints.

b) For longitudinal joints, middle lines are to be in alignment within 10% of the thickness of the thinner plate with a maximum of 3 mm.

c) Plates to be welded are to be suitably retained in position in order to limit deformation during welding. The arrangements are to be such as to avoid modification of the relative position of parts to be welded and misalignment, after welding, exceeding the limits indicated above.

d) Temporary welds for abutting are to be carried out so that there is no risk of damage to vessel shells. Such welds are to be carefully removed after welding of the vessel and before any heat treatment. Non-destructive testing of the corresponding zones of the shell may be required by the Surveyor if considered necessary.

e) Accessories such as doubling plates, brackets and stiffeners are to be suitable for the surface to which they are to be attached.

4.5 Tolerances after construction

4.5.1 General

The sizes and shape of vessels are to be checked after welding for compliance with the design taking into account the tolerances given below. The Society reserves the right to stipulate smaller values for these tolerances for vessels subjected to special loads.

Any defect in shape is to be gradual and there is to be no flat area in way of welded joints.

Measurements are to be taken on the surface of the parent plate and not on the weld or other raised part.

4.5.2 Straightness

The straightness of cylindrical shells is to be such that their deviation from the straight line does not exceed 0,6% of their length, with a maximum of 15 mm for each 5 m of length.

4.5.3 Out-of-roundness

a) Out-of-roundness of cylindrical shells is to be measured either when set up on end or when laid flat on their sides; in the second case, measures of diameters are to be repeated after turning the shell through 90° about its axis and out-of-roundness is to be calculated from the average of the two measures of each diameter.

b) For any transverse section, the difference between the maximum and minimum diameters is not to exceed 1% of the nominal diameter D with a maximum of:

   (D + 1250) / 200, D being expressed in mm.

   For large pressure vessels, this limit may be increased by a maximum of 0,2% of the internal diameter of the vessel. Any possible out-of-roundness within the above limit is to be gradual and there are to be no localised deformations in way of the welded joints.

4.5.4 Irregularities

Irregularities in profile of cylindrical shells, checked by a 20° gauge, are not to exceed 5% of the thickness of the plate plus 3 mm. This value may be increased by 25% if the length of the irregularity does not exceed one quarter of the distance between two circumferential seams, with a maximum of 1 mm.

4.6 Preheating

4.6.1

a) Preheating, to be effectively maintained during the welding operation, may be required by the Society when deemed necessary in relation to a number of circumstances, such as the type of steel, thickness of the base material, welding procedure and technique, type of restraint, and heat treatment after welding, if any.

b) The preheating temperature is to be determined accordingly. However, a preheating temperature of approximately 150°C is required for 0,5Mo or 1Cr0,5Mo type steel, and approximately 250°C for 2,25Cr1Mo type steel.

c) These requirements also apply to welding of nozzles, fittings, steam pipes and other pipes subject to severe conditions.

4.7 Post-weld heat treatment

4.7.1 General

a) When post-weld heat treatment of a vessel is to be carried out, such treatment is to consist of:
   - heating the vessel slowly and uniformly up to a temperature suitable for the grade of steel
   - maintaining this temperature for a duration determined in relation to the actual thickness t_A of the vessel and the grade of steel
   - slowly cooling the vessel in the furnace down to a temperature not exceeding 400°C, with subsequent cooling allowed out of the furnace in still air.

b) As far as possible, vessels are to be heat treated in a single operation. However, when the sizes of the vessels are such that heat treatment requires several operations, care is to be taken such that all the parts of the vessels undergo heat treatment in a satisfactory manner. In particular, a cylindrical vessel of great length may be treated in sections in a furnace if the overlap of the heated sections is at least 1500 mm and if parts outside the furnace are lagged to limit the temperature gradient to an acceptable value.

4.7.2 Thermal stress relieving

Upon completion of all welding, including connections of nozzles, doublers and fittings, pressure vessels of classes 1 and 2, boilers and associated parts are to be subjected to an effective stress relieving heat treatment in the following cases:

- pressure vessels of classes 1 and 2 containing fluids at a temperature not less than the ambient temperature, where the thickness exceeds that indicated in Tab 17
- boilers and steam generators for thicknesses higher than 20 mm or, depending upon the type of steel, for lower thicknesses as required for class 1 pressure vessels.

Applications at temperatures less than the ambient temperature and/or steels other than those indicated above are to be the subject of special consideration by the Society.

Stress relieving heat treatment is not to be required when the minimum temperature of the fluid is at least 30°C higher than the KV-notch impact test temperature specified for the steel; this difference in temperature is also to be complied with for welded joints (both in heat-affected zones and in weld metal).

Pressure vessels and pipes of class 3 and associated parts are not required to be stress relieved, except in specific cases.

Table 17 : Thermal stress relieving

Grade	Thickness (mm) above which post-weld heat treatment is required	
	Boilers	Unfired pressure vessels
R_m = 360 N/mm² Grade HA R_m = 410 N/mm² Grade HA	14,5	14,5
R_m = 360 N/mm² Grade HB R_m = 410 N/mm² Grade HB	20	30
R_m = 360 N/mm² Grade HD R_m = 410 N/mm² Grade HD	20	38
R_m = 460 N/mm² Grade HB R_m = 510 N/mm² Grade HB	20	25
R_m = 460 N/mm² Grade HD R_m = 510 N/mm² Grade HD	20	35
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	20	20
1Cr 0,5Mo 2,25Cr 1Mo	ALL	ALL

4.7.3 Heat treatment procedure

The temperature of the furnace at the time of introduction of the vessel is not to exceed 400°C.

a) The heating rate above 400°C is not to exceed:
   - 220°C per hour if the maximum thickness is not more than 25 mm, or
   - (5500 / t_A)°C per hour, with a minimum of 55°C per hour, if the maximum thickness t_A , in mm, is more than 25 mm

b) The cooling rate in the furnace is not to exceed:
   - –280°C per hour if the maximum thickness is not more than 25 mm, or
   - –(7000 / t_A)°C per hour, with a minimum of –55°C per hour, if the maximum thickness t_A , in mm, is more than 25 mm.

Unless specially justified, heat treatment temperatures and duration for maintaining these temperatures are to comply with the values in Tab 18.

Table 18 : Heat treatment procedure

Grade	Temperatures	Time per 25 mm of maximum thickness	Minimum time
Carbon steels	580-620°C	1 hour	1 hour
0,3Mo 1Mn 0,5Mo 1Mn 0,5MoV 0,5Cr 0,5Mo	620-660°C	1 hour	1 hour
1Cr 0,5Mo	620-660°C	1hour	2 hours
2,25Cr 1Mo	600-750°C **(1)**	2 hours	2 hours
(1) The temperature is to be chosen, with a tolerance of ± 20°C, in this temperature range in order to obtain the required mechanical characteristics			

4.7.4 Alternatives

When, for special reasons, heat treatment is carried out in conditions other than those given in [4.7.2], all details regarding the proposed treatment are to be submitted to the Society, which reserves the right to require tests or further investigations in order to verify the efficiency of such treatment.

4.7.5 Execution of heat treatment

Furnaces for heat treatments are to be fitted with adequate means for controlling and recording temperature; temperatures are to be measured on the vessel itself. The atmosphere in the furnaces is to be controlled in order to avoid abnormal oxidation of the vessel.

4.7.6 Treatment of test plates

Test plates are normally to be heated at the same time and in the same furnace as the vessel.

When separate heat treatment of test plates cannot be avoided, all precautions are to be taken such that this treatment is carried out in the same way as for the vessel, specifically with regard to the heating rate, the maximum temperature, the duration for maintaining this temperature and the cooling conditions.

4.7.7 Welding after heat treatment

a) Normally, welding after heat treatment is only allowed if:
   - the throat of welding fillets does not exceed 10 mm
   - the largest dimension of openings in the vessel for the accessories concerned does not exceed 50 mm.

b) Any welding of branches, doubling plates and other accessories on boilers and pressure vessels after heat treatment is to be submitted for special examination by the Society.

4.8 Welding samples

4.8.1 Test plates for welded joints

a) Test plates of sufficient size, made of the same grade of steel as the shell plates, are to be fitted at each end of the longitudinal joints of each vessel so that the weld in the test plates is the continuation of these welded joints. There is to be no gap when passing from the deposited metal of the joint to the deposited metal of the test plate.

b) No test plate is required for circumferential joints if these joints are made with the same process as longitudinal joints. Where this is not the case, or if there are only circumferential joints, at least one test plate is to be welded separately using the same welding process as for the circumferential joints, at the same time and with the same welding materials.

c) Test plates are to be stiffened in order to reduce as far as possible warping during welding. The plates are to be straightened prior to their heat treatment which is to be carried out in the same conditions as for the corresponding vessel (see also [4.7.6]).

d) After radiographic examination, the following test pieces are to be taken from the test plates:
   - one test piece for tensile test on welded joint
   - two test pieces for bend test, one direct and one reverse
   - three test pieces for impact test
   - one test piece for macrographic examination.

4.8.2 Mechanical tests of test plates

a) The tensile strength on welded joint is not to be less than the minimum specified tensile strength of the plate.

b) The bend test pieces are to be bent through an angle of 180° over a former of 4 times the thickness of the test piece. There is to be no crack or defect on the outer surface of the test piece exceeding in length 1,5 mm transversely or 3 mm longitudinally. Premature failure at the edges of the test piece is not to lead to rejection. As an alternative, the test pieces may be bent through an angle of 120° over a former of 3 times the thickness of the test piece.

c) The impact energy measured at 0°C is not to be less than the values given in NR216 Materials and Welding for the steel grade concerned.

d) The test piece for macrographic examination is to permit the examination of a complete transverse section of the weld. This examination is to demonstrate good penetration without lack of fusion, large inclusions and similar defects. In case of doubt, a micrographic examination of the doubtful zone may be required.

4.8.3 Re-tests

a) If one of the test pieces yields unsatisfactory results, two similar test pieces are to be taken from another test plate.

b) If the results for these new test pieces are satisfactory and if it is proved that the previous results were due to local or accidental defects, the results of the re-tests may be accepted.

4.9 Specific requirements for class 1 vessels

4.9.1 General

The following requirements apply to class 1 pressure vessels, as well as to pressure vessels of other classes, whose scantlings have been determined using an efficiency of welded joint e greater than 0,90.

4.9.2 Non-destructive tests

a) All longitudinal and circumferential joints of class 1 vessels are to be subject of 100% radiographic or equivalent examination with the following exceptions:
   - for pressure vessels or parts designed to withstand external pressures only, at the Society’s discretion, the extent may be reduced up to approximately 30% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.
   - for vessels not intended to contain toxic or dangerous matters, made of carbon steels having thickness below 20 mm when the joints are welded by approved automatic processes at the Society’s discretion, the extent may be reduced up to

approximately 10% of the length of the joints. In general, the positions included in the examinations are to include all welding crossings.

- for circumferential joints having an external diameter not exceeding 175 mm, at the Society's discretion, the extent may be reduced up to approximately 10% of the total length of the joints.

b) Fillet welds for parts such as doubling plates, branches or stiffeners are to undergo a spot magnetic particle test for at least 10% of their length. If magnetic particle tests cannot be used, it is to be replaced by liquid penetrant test.

c) Welds for which non destructive tests reveal unacceptable defects, such as cracks or areas of incomplete fusion, are to be rewelded and are then to undergo a new non destructive examination

4.9.3 Number of test samples

a) During production, at least one test plate for each 20 m of length (or fraction) of longitudinal weldings is to be tested as per [4.8.2].

b) During production, at least one test plate for each 30 m of length (or fraction) of circumferential welding is to be tested as per [4.8.2].

c) When several vessels made of plates of the same grade of steel, with thicknesses varying by not more than 5 mm, are welded successively, only one test plate may be accepted per each 20 m of length of longitudinal joints (or fraction) and per each 30 m of circumferential welding (or fraction) provided that the welders and the welding process are the same. The thickness of the test plates is to be the greatest thickness used for these vessels.

4.10 Specific requirements for class 2 vessels

4.10.1 General

For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1].

4.10.2 Non-destructive tests

All longitudinal and circumferential joints of class 2 vessels are to be subjected to radiographic or equivalent examination to an extent of 10% of each weld length. This examination is to cover all the junctions between welds.

This extension may be increased at the Society's discretion depending on the actual thickness of the welded plates.

For actual thickness ≤ 15 mm, this examination can be omitted. In this case, the value of the efficiency should be as indicated in Tab 10.

4.10.3 Number of test samples

In general, the same requirements of [4.9.3] apply also to class 2 pressure vessels. However, test plates are required for each 50 m of longitudinal and circumferential weldings (or fraction).

4.11 Specific requirements for class 3 vessels

4.11.1 For vessels whose scantlings have been determined using an efficiency of welded joint e greater than 0,90, see [4.9.1]. Heat treatment, mechanical tests and non-destructive tests are not required for welded joints of other class 3 vessels.

5 Design and construction - Control and monitoring

5.1 Boiler control and monitoring system

5.1.1 Local control and monitoring

Means to effectively operate, control and monitor the operation of oil fired boilers and their associated auxiliaries are to be provided locally. The functional condition of the fuel, feed water and steam systems and the boiler operational status are to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.1.2 Emergency shut-off

Means are to be provided to shut down boiler forced draft or induced draft fans and fuel oil service pumps from outside the space where they are located, in the event that a fire in that space makes their local shut-off impossible.

5.1.3 Water level indicators

a) Each boiler is to be fitted with at least two separate means for indicating the water level. One of these means is to be a level indicator with transparent element. The other may be either an additional level indicator with transparent element or an equivalent device. Level indicators are to be of an approved type.

b) The transparent element of level indicators is to be made of glass, mica or other appropriate material.

c) Level indicators are to be located so that the water level is readily visible at all times. The lower part of the transparent element is not to be below the safety water level defined by the builder.

d) Level indicators are to be fitted either with normally closed isolating cocks, operable from a position free from any danger in case of rupture of the transparent element or with self-closing valves restricting the steam release in case of rupture of this element.

5.1.4 Water level indicators - Special requirements for water tube boilers

a) For water tube boilers having an athwarships steam drum more than 4 m in length, a level indicator is to be fitted at each end of the drum.

b) Water tube boilers serving turbine propulsion machinery are to be fitted with a high-water-level audible and visual alarm (see also Tab 20).

5.1.5 Water level indicators - Special requirements for fire tube boilers (vertical and cylindrical boilers)

a) For cylindrical boilers, the two water level indicators mentioned in [5.1.3] are to be distributed at each end of the boiler; i.e. double front cylindrical boilers are to have two level indicators on each front.

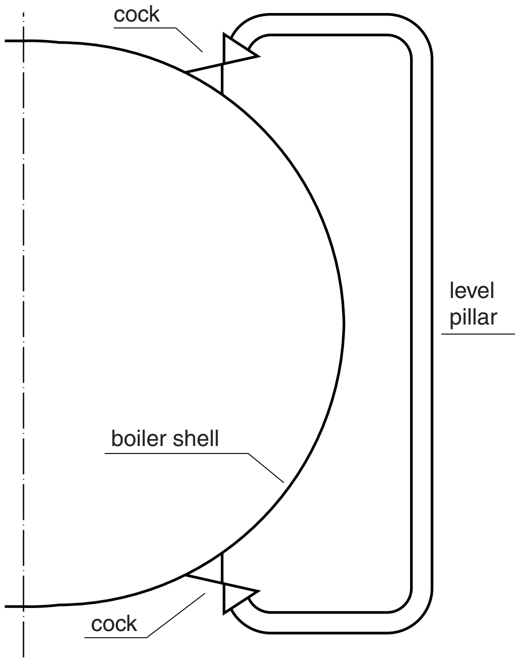
b) A system of at least two suitably located and remote controlled gauge-cocks may be considered as the equivalent device mentioned in [5.1.3] for cylindrical boilers having a design pressure lower than 1 MPa, for cylindrical boilers having a diameter lower than 2 m and for vertical boilers having height lower than 2,3 m. Gauge-cocks are to be fixed directly on the boiler shell.

c) Where level indicators are not fixed directly on the boiler shell, but on level pillars, the internal diameter of such pillars is not to be less than the value d_N given in Tab 19. Level pillars are to be either fixed directly on the boiler shell or connected to the boiler by pipes fitted with cocks secured directly to the boiler shell. The internal diameter of these pipes d_C is not to be less than the values given in Tab 19. The upper part of these pipes is to be arranged so that there is no bend where condense water can accumulate. These pipes are not to pass through smoke boxes or uptakes unless they are located inside metallic ducts having internal diameter exceeding by not less than 100 mm the external diameter of the pipes. Fig 38 shows the sketch of a level pillar arrangement.

Table 19 : Minimum internal diameters d_N and d_C

Internal diameter of the boiler	d_N (mm)	d_C (mm)
D > 3 m	60	38
2,30 m ≤ D ≤ 3 m	50	32
D < 2,30 m	45	26

Figure 38 : Level pillar arrangement



5.1.6 Pressure control devices

a) Each boiler is to be fitted with a steam pressure gauge so arranged that its indications are easily visible from the stokehold floor. A steam pressure gauge is also to be provided for superheaters which can be shut off from the boiler they serve.

b) Pressure gauges are to be graduated in units of effective pressure and are to include a prominent legible mark for the pressure that is not to be exceeded in normal service.

c) Each pressure gauge is to be fitted with an isolating cock.

d) Double front boilers are to have a steam pressure gauge arranged in each front.

5.1.7 Temperature control devices

Each boiler fitted with a superheater is to have an indicator or recorder for the steam temperature at the superheater outlet.

5.1.8 Automatic shut-off of oil fired propulsion and auxiliary boilers

a) Each burner is to be fitted with a flame scanner designed to automatically shut off the fuel supply to the burner in the event of flame failure. In the case of failure of the flame scanner, the fuel to the burner is to be shut off automatically.

b) A low water condition is to automatically shut off the fuel supply to the burners. The shut-off is to operate before the water level reaches a level so low as to affect the safety of the boiler and no longer be visible in the gauge glass. Means are to be provided to minimise the risk of shut-off provoked by the effect of roll and pitch and/or transients. This shut-off system need not be installed in auxiliary boilers which are under local supervision and are not intended for automatic operation.

c) Forced draft failure is to automatically shut off the fuel supply to the burners.

d) Loss of boiler control power is to automatically shut off the fuel supply to the burners.

5.1.9 Alarms

Any actuation of the fuel-oil shut-off listed in [5.1.8] is to operate a visual and audible alarm.

5.1.10 Additional requirements for boilers fitted with automatic control systems

a) The flame scanner required in [5.1.8], item a) is to operate within 6 seconds from the flame failure.

b) A timed boiler purge with all air registers open is to be initiated manually or automatically when boilers are fitted with an automatic ignition system. The purge time is based on a minimum of 4 air changes of the combustion chamber and furnace passes. Forced draft fans are to be operating and air registers and dampers are to be open before the purge time commences.

c) Means are to be provided to bypass the flame scanner control system temporarily during a trial-for-ignition for a period of 15 seconds from the time the fuel reaches the burners. Except for this trial-for-ignition period, no means are to be provided to bypass one or more of the burner flame scanner systems unless the boiler is locally controlled.

d) Where boilers are fitted with an automatic ignition system, and where residual fuel oil is used, means are to be provided for lighting of burners with igniters lighting properly heated residual fuel oil. In the case of flame failure, the burner is to be brought back into automatic service only in the low-firing position.

e) An alarm is to be activated whenever a burner operates outside the limit conditions stated by the manufacturer.

f) Immediately after normal shutdown, an automatic purge of the boiler equal to the volume and duration of the pre-purge is to occur. Following automatic fuel valve shut-off, the air flow to the boiler is not to automatically increase; post-purge in such cases is to be carried out under manual control.

g) Propulsion and auxiliary boilers associated with propulsion machinery intended for centralised, unattended operations are to comply with the requirements of Part C, Chapter 3.

5.2 Pressure vessel instrumentation

5.2.1

a) Pressure vessels are to be fitted with the necessary devices for checking pressure, temperature and level, where it is deemed necessary.

b) In particular, each air pressure vessel is to be fitted with a local manometer.

5.3 Thermal oil heater control and monitoring

5.3.1 Local control and monitoring

Suitable means to effectively operate, control and monitor the operation of oil fired thermal oil heaters and their associated auxiliaries are to be provided locally. The functional condition of the fuel, thermal oil circulation, forced draft and flue gas systems is to be indicated by pressure gauges, temperature indicators, flow-meter, lights or other similar devices.

5.3.2 Flow control and monitoring

a) A flow indicator of the thermal oil is to be provided.

b) The flow detection is to be representative of the flow in each heated element.

c) The flow detection is not to be based on a measurement of the pressure-drop through the heating element.

d) Oil fired or exhaust gas heaters are to be provided with a flow monitor limit-switch. If the flow rate falls below a minimum value the firing system is to be switched off and interlocked.

5.3.3 Manual control

During manual operation, the automated functioning of at least the temperature control device on the thermal oil side as well as the flow monitoring is to be maintained.

5.3.4 Leakage monitoring

Oil tanks are to be equipped with a leakage detector which, when actuated, shuts down and interlocks the thermal oil firing system. If the oil fired heater is on stand-by, the starting of the burner is to be blocked if the leakage detector is actuated.

5.4 Control and monitoring requirements

5.4.1 Tab 20, Tab 21, Tab 22 and Tab 23 summarise the control and monitoring requirements for main propulsion boilers, auxiliary boilers, oil fired thermal oil heaters and exhaust gas thermal oil heaters and incinerators, respectively.

Table 20 : Main propulsion boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil							
• Fuel oil delivery pressure or flow	L						
• Fuel oil temperature after heater or viscosity fault	L+H	local					
• Master fuel oil valve position (open / close)		local					
• Fuel oil input burner valve position (open / close)		local					
Combustion							
• Flame failure of each burner	X						
• Failure of atomizing fluid	X					5	
• Boiler casing and economizer outlet smoke temperature (in order to detect possible fire out-break)	H						
	HH			X			
Air							
• Air register position		local					
General steam							
• Superheated steam pressure	L+H	local					
					X		
• Superheated steam temperature	H	local					
• Lifting of safety valve (or equivalent: high pressure alarm for instance)	X						
• Water level inside the drum of each boiler	L+H	local**(1)**					
	LL			X			
					X		
(1) Duplication of level indicator is required							

Table 21 : Auxiliary boilers

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Boiler			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Water level	L+H	local					
	LL			X			
Circulation stopped (when forced circulation boiler)	X			X			
Fuel oil temperature or viscosity **(2)**	L+H	local					
Flame failure	X			X			
Temperature in boiler casing (Fire)	H						
Steam pressure	H**(1)**	local		X			
(1) When the automatic control does not cover the entire load range from zero load **(2)** Where heavy fuel is used							

Table 22 : Thermal oil system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Thermal fluid temperature heater outlet	H	local		X(**1**)			
Thermal fluid pressure pump discharge	H	local		X			
Thermal fluid flow through heating element	L LL	local		 X(**1**)			
Expansion tank level	L LL	local		 X(**2**)			
Expansion tank temperature	H						
Forced draft fan stopped	X			X			
Heavy fuel oil temperature or viscosity	H+L	local					
Burner flame failure	X			X			
Flue gas temperature heater outlet	H HH			 X(**2**)			

(1) Shut-off of heat input only
(2) Stop of fluid flow and shut-off of heat input

Table 23 : Incinerators

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Incinerator			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Flame failure	X			X			
Furnace temperature	H			X			
Exhaust gas temperature	H						
Fuel oil pressure		local					
Fuel oil temperature or viscosity **(1)**	H+L	local					

(1) Where heavy fuel is used

6 Arrangement and installation

6.1 Foundations

6.1.1 For boilers and pressure vessels bolting down to their foundations, see Ch 1, Sec 1, [3.3.1]. Where necessary, they are also to be secured to the adjacent hull structures by suitable ties.

Where chocks are required to be fitted between the boilers and their foundations, they are to be of cast iron or steel.

6.2 Boilers

6.2.1 Thermal expansion

Means are to be provided to compensate thermal expansion of boilers.

6.2.2 Minimum distance of boilers from vertical bulkheads and fuel tanks

a) The distance between boilers and vertical bulkheads is to be not less than the minimum distance necessary to provide access for inspection and maintenance of the structure adjacent to the boiler.

b) In addition to the requirement in a), the distance of boilers from fuel oil tanks is to be such as to prevent the possibility that the temperature of the tank bulkhead may approach the flash point of the oil.

c) In any event, the distance between a boiler and a vertical bulkhead is not to be less than 450 mm.

6.2.3 Minimum distance of boilers from double bottom

a) Where double bottoms in way of boilers may be used to carry fuel oil, the distance between the top of the double bottom and the lower metal parts of the boilers is not to be less than:
- 600 mm, for cylindrical boilers
- 750 mm, for water tube boilers.

b) The minimum distance of vertical tube boilers from double bottoms not intended to carry oil may be 200 mm.

6.2.4 Minimum distance of boilers from ceilings

a) A space sufficient for adequate heat dissipation is to be provided on the top of boilers.

b) Oil tanks are not permitted to be installed in spaces above boilers.

6.2.5 Installation of boilers on engine room flats

Where boilers are installed on an engine room flat and are not separated from the remaining space by means of a watertight bulkhead, a coaming of at least 200 mm in height is to be provided on the flat. The area surrounded by the coaming may be drained into the bilge.

6.2.6 Drip trays and gutterways

Boilers are to be fitted with drip trays and gutterways in way of burners so arranged as to prevent spilling of oil into the bilge.

6.2.7 Hot surfaces

Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7.1].

6.2.8 Registers fitted in the smoke stacks of oil fired boilers

Where registers are fitted in smoke stacks, they are not to obstruct more than two thirds of the cross-sectional area of gas passage when closed. In addition, they are to be provided with means for locking them in open position when the boiler is in operation and for indicating their position and degree of opening.

6.3 Pressure vessels

6.3.1 Safety devices on multiple pressure vessels

Where two or more pressure vessels are interconnected by a piping system of adequate size so that no branch of piping may be shut off, it is sufficient to provide them with one safety valve and one pressure gauge only.

6.4 Thermal oil heaters

6.4.1 In general, the requirements of [6.2] for boilers are also applicable to thermal oil heaters.

7 Material test, workshop inspection and testing, certification

7.1 Material testing

7.1.1 General

Materials, including welding consumables, for the constructions of boilers and pressure vessels are to be certified by the material manufacturer in accordance with the appropriate material specification.

7.1.2 Boilers, other steam generators, and oil fired and exhaust gas thermal oil heaters

In addition to the requirement in [7.1.1], testing of materials intended for the construction of pressure parts of boilers, other steam generators, oil fired thermal oil heaters and exhaust gas thermal oil heaters is to be witnessed by the Surveyor.

7.1.3 Class 1 pressure vessels and heat exchangers

In addition to the requirement in [7.1.1], testing of materials intended for the construction of class 1 pressure parts of pressure vessels and heat exchangers is to be witnessed by the Surveyor.

This requirement may be waived at the Society’s discretion for mass produced small pressure vessels (such as accumulators for valve controls, gas bottles, etc.).

7.2 Workshop inspections

7.2.1 Boilers and individually produced class 1 and 2 pressure vessels

The construction, fitting and testing of boilers and individually produced class 1 and 2 pressure vessels are to be attended by the Surveyor, at the builder's facility.

7.2.2 Mass produced pressure vessels

Construction of mass produced pressure vessels which are type approved by the Society need not be attended by the Surveyor.

7.3 Hydrostatic tests

7.3.1 General

Hydrostatic tests of all class 1, 2 and 3 pressure vessels are to be witnessed by the Surveyor with the exception of mass produced pressure vessels which are built under the conditions stated in [7.2.2].

7.3.2 Testing pressure

a) Upon completion, pressure parts of boilers and pressure vessels are to be subjected to a hydraulic test under a pressure p_t defined below as a function of the design pressure p:
   - $p_t = 1,5\ p$ where $p \le 4$ MPa
   - $p_t = 1,4\ p + 0,4$ where $4\ \text{MPa} < p \le 25$ Mpa
   - $P_t = p + 10,4$ where $p > 25$ MPa

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

c) If the design temperature exceeds 300°C, the test pressure p_t is to be as determined by the following formula:

$$p_t = 1,5 \cdot \frac{K_{100}}{K} \cdot p$$

where:

p : Design pressure, in MPa

K_{100} : Permissible stress at 100°C, in N/mm^2

K : Permissible stress at the design temperature, in N/mm^2.

d) Consideration is to be given to the reduction of the test pressure below the values stated above where it is necessary to avoid excessive stress. In any event, the general membrane stress is not to exceed 90% of the yield stress at the test temperature.

e) Economisers which cannot be shut off from the boiler in any working condition are to be submitted to a hydraulic test under the same conditions as the boilers.

f) Economisers which can be shut off from the boiler are to be submitted to a hydraulic test at a pressure determined as a function of their actual design pressure p.

7.3.3 Hydraulic test of boiler and pressure vessel accessories

a) Boilers and pressure vessel accessories are to be tested at a pressure p_t which is not less than 1,5 times the design pressure p of the vessels to which they are attached.

b) The test pressure may be determined as a function of a pressure lower than p; however, in such case, the setting and characteristics of the safety valves and other overpressure protective devices are also to be determined and blocked as a function of this lower pressure.

7.3.4 Hydraulic test procedure

a) The hydraulic test specified in [7.3.1] is to be carried out after all openings have been cut out and after execution of all welding work and of the heat treatment, if any. The vessel to be tested is to be presented without lagging, paint or any other lining and the pressure is to be maintained long enough for the Surveyor to proceed with a complete examination.

b) Hydraulic tests of boilers are to be carried out either after installation on board, or at the manufacturer's plant. Where a boiler is hydrotested before installation on board, the Surveyor may, if deemed necessary, request to proceed with a second hydraulic test on board under a pressure at least equal to 1,1 p. For this test, the boiler may be fitted with its lagging. However, the Surveyor may require this lagging to be partially or entirely removed as necessary.

c) For water tube boilers, the hydraulic test may also be carried out separately for different parts of the boiler upon their completion and after heat treatment. For drums and headers, this test may be carried out before drilling the tube holes, but after welding of all appendices and heat treatment. When all parts of the boiler have been separately tested and following assembly the boiler is to undergo a hydraulic test under a pressure of 1,25 p.

7.3.5 Hydraulic tests of condensers

Condensers are to be subjected to a hydrostatic test at the following test pressures:

- Steam space: 0,1 MPa
- Water space: maximum pressure which may be developed by the pump with closed discharge valve increased by 0,07 MPa. However, the test pressure is not to be less than 0,2 MPa. When the characteristics of the pump are not known, the hydrostatic test is to be carried out at a pressure not less than 0,35 MPa.

7.4 Certification

7.4.1 Certification of boilers and individually produced pressure vessels

Boilers and individually produced pressure vessels of classes 1, 2 and 3 are to be certified by the Society in accordance with the procedures stated in Part A.

7.4.2 Mass produced pressure vessels

Small mass produced pressure vessels of classes 1, 2 and 3 may be accepted provided they are type approved by the Society in accordance with the procedures stated in Part A.

Table 24 : Pressure vessel certification

Class	Drawing / Calculation		Material testing		Hydraulic test	
	Manufacturer	The Society	Manufacturer	The Society	Manufacturer	The Society
1	X	review	X	witness + workshop inspection	X	witness
2	X	review	X	review	X	witness
3	X	–	X	review	X	witness
Note 1: Certificates of the Manufacturer and the Society to be issued for all cases for pressure vessels covered by the Rules of the Society.						

Section 4 Steam Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Auxiliary turbines driving generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with those of Part C, Chapter 2.

1.2 Documentation to be submitted

1.2.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans and data listed in Tab 1 are to be submitted.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of the types of materials employed.

Table 1 : Documents to be submitted

No	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Rotors and discs, revolving and stationary blades for each turbine
3	A	Fastening details of revolving and stationary blades
4	A	Casings
5	A	Schematic diagram of control and safety devices
6	I	General specification of the turbine, including an operation and instruction manual
7	I	Maximum power and corresponding maximum rotational speed, and the values of pressure and temperature at each stage
8	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, when the service temperature exceeds 400°C, the fatigue strength, the corrosion resistance and the heat treatments
9	I	Distribution box
10	A	Strength calculations of rotors, discs and blades and blade vibration calculations
11	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding conditions, heat treatments and non-destructive examinations after welding

(1) A = to be submitted for approval
I = to be submitted for information.

2 Design and construction

2.1 Materials

2.1.1 Rotating components

a) Rotors, shafts and discs of turbines are to be of forged steel. In general, the forgings are to have minimum tensile strength R_m within the limits in Tab 2.

b) Rotors of small turbines may be built of special cast steels.

c) Turbine blades are to be built of corrosion-resistant materials.

Table 2 : Limits of R_m

STEEL	R_m limits (N/mm^2)
Carbon and carbon-manganese steel	$400 < R_m < 600$
Alloy steels for rotors	$500 < R_m < 800$
Alloy steels for discs and other forgings	$500 < R_m < 1000$

2.1.2 Static components

The casings and diaphragms of turbines are to be built of forged or cast steels capable of withstanding the pressures and temperatures to which they are subjected. Cast iron may be used for temperatures up to 300°C.

2.2 Design and constructional details

2.2.1 Rotors and stators

a) All components of turbines are to be free from defects and are to be built and installed with tolerances and clearances such as to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Particular care is to be devoted to preventing condensation water from accumulating in the blade spaces of the casings. Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easy to operate.

c) When labyrinth packings are used, the steam supply pipes to the sealing system are to be so arranged that condensed steam may not enter the turbine.

d) Particular attention is to be paid to the connection of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of section of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.2.2 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from adjacent hot parts.

b) Lubricating oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped may also be required, at the discretion of the Society.

2.2.3 Turning gear

a) Main propulsion turbines are to be equipped with turning gear for both directions of rotation. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of turning gear is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the turbine cannot be started up when the turning gear is engaged.

2.2.4 Astern power for main propulsion

a) The main propulsion turbine is to have sufficient power for running astern. The astern power is considered to be sufficient if it is able to attain astern revolutions equivalent to at least 70% of the rated ahead revolutions for a period of at least 30 minutes.

b) For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running is not to cause any overloading of the propulsion machinery.

c) During astern running, the main condenser and the ahead turbines are not to be excessively overheated.

2.2.5 Interlock

The simultaneous admission of steam to the ahead and astern turbines is to be prevented by interlocks. Brief overlapping of the ahead and astern valves during manoeuvring may be permitted.

2.2.6 Turbine exhaust

a) Sentinel valves or other equivalent means are to be provided at the exhaust end of all turbines. The valve discharge outlets are to be clearly visible and suitably guarded, as necessary.

b) Where, in auxiliary steam turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valve are designed, means to relieve the excess pressure are to be provided.

2.2.7 Water accumulation prevention

a) Non-return valves or other approved means are to be fitted in bled steam connections to prevent steam and water returning into the turbines.

b) Bends are to be avoided in steam piping in which water may accumulate.

2.2.8 Steam strainers

Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or alternatively at the inlets to manoeuvring valves.

2.2.9 Emergency arrangements

a) In single screw ships fitted with compound main turbine installations the arrangements are to be such as to enable safe navigation when the steam led to any one of the turbines is cut off. For this purpose the steam may be led direct to the low pressure (L.P.) turbine and either the high pressure (H.P.) or medium pressure (M.P.) turbine can exhaust direct to the condenser.

b) Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam do not exceed those which the turbine and condenser can safely withstand.

c) Ships classed for unrestricted service and fitted with a steam turbine propulsion plant and only one main boiler are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

2.3 Welded fabrication

2.3.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable when the plans are submitted to the Society for approval. Requirements relative to fabrication, welding, heat treatments, examinations, testing and acceptance will be stipulated on a case by case basis.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures and using approved consumables.

2.4 Control, monitoring and shut-off devices

2.4.1 Governors

a) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or electrical transmission systems are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed given in [2.4.2].

b) The speed increase of turbines driving electric generators - except those for electrical propeller drive - resulting from a change from full load to no-load may not exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed.

2.4.2 Overspeed devices

a) Each main and auxiliary turbine is to be provided with an overspeed protective device to prevent the rotational speed from exceeding the maximum rotational by more than 15%. The device is to be actuated by the turbine shaft.

b) Where two or more steam turbines are coupled to the same gear wheel, the Society may accept the fitting of only one overspeed device for all the coupled turbines.

c) For turbines driving electric generators, the overspeed protective device mentioned in a) is also to be fitted with a means for manual tripping.

d) Where exhaust steam from auxiliary systems is led to the main turbine, provision is to be made to cut off the steam automatically when the overspeed protective device is activated.

2.4.3 Rotor axial displacement

A quick-closing valve is to be provided which automatically shuts off the steam supply in the event of axial displacement of the rotor beyond the permissible limits stated by the manufacturer. The device controlling the valve is to be actuated by the turbine shaft.

2.4.4 Bearing lubrication failure

a) Main ahead turbines are to be provided with a quick-closing valve which automatically shuts off the steam supply in the event of a dangerous reduction in oil pressure in the bearing lubricating system.

b) This arrangement is to be such as to ensure the admission of steam to the astern turbine for braking purposes.

2.4.5 Shut-off arrangement

a) Arrangements are to be provided for shutting off the steam to the main turbines by a suitable hand trip device controlling the steam admission valve situated at the control platform and at the turbine itself.

b) Hand tripping for auxiliary turbines is to be arranged in the proximity of the turbine overspeed protective device.

c) The hand trip device is any device which is operated manually irrespective of the way the action is performed, i.e. mechanically or by means of external power.

d) The quick-closing valves are also to be manually operable at the turbine and from the control platform.

e) Re-setting of the quick-closing valve device may be effected only at the turbine or from the control platform with the control valves in the closed position.

f) Where the valves are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, at the Society's discretion, a hand-operated pump may be accepted as a standby pump.

g) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

h) A quick-closing device is to be provided which automatically shuts off the steam supply in the event of an increase in pressure or water level in the condenser beyond the permissible limits.

2.4.6 Summary Tables

Tab 3 and Tab 4 summarise the minimum control and monitoring requirements for main propulsion and auxiliary turbines, respectively.

Table 3 : Main propulsion turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Main turbine speed		local					
	H			X			
					X		
• Main turbine axial displacement	X	local		X			
• Main turbine vibration	H	local					
Lubricating oil							
• Supply pressure		local					
	L			X**(2)**			
• Level of gravity tank	L**(1)**	local					

(1) Sensor to be located near the normal level
(2) This is not to prevent astern operation for braking

Table 4 : Auxiliary turbine

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Overspeed	H	local		X			
Rotor displacement	X	local		X			
Vibration	H	local					
Lubricating oil supply pressure	L			X			
Lubricating oil level in gravity tank	L						

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Jointing of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine casings are to be fitted in such a way as to minimise the thrust loads and moments.

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1 Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet.

3.6 Circulating water system

3.6.1 The circulating water system with vacuum ejectors is to be so arranged that water may not enter the low pressure turbines.

3.7 Gratings

3.7.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.8 Drains

3.8.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.9 Instruments

3.9.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts.

This check is to be performed to the Surveyor’s satisfaction at the time of installation.

4 Material tests, workshop inspection and testing, certification

4.1 Material tests

4.1.1 Parts to be tested

The materials for the construction of the parts listed in Tab 5 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

Table 5 : Material and non-destructive tests

Turbine component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	sample
Stationary parts (castings and plates for casings)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

4.1.2 Special auxiliary turbines

In the case of auxiliary turbines with a steam inlet temperature of up to 250°C, the extent of the tests stated in Tab 5 may be limited to the disc and shaft materials.

4.2 Inspections and testing during construction

4.2.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of the Surveyor during the construction of all turbines which are indicated in [1.1.1].

- material tests, as required (see [4.1])
- welded fabrication (see [4.2.2])
- non-destructive examination of turbine blades (see [4.2.3])
- hydrostatic tests (see [4.2.4])
- safety valves (see [4.2.5])
- thermal stability test of rotor (see [4.2.6])
- rotor balancing and overspeed test (see [4.2.7] and [4.2.8])
- shop trials (see [4.2.9]).

4.2.2 Welded fabrication

Welded fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.2.3 Turbine blades

When turbine blades are calculated using a permissible stress $K > R_m/4$, all turbine rotor blades are to be checked by dye penetrants or other equivalent method.

4.2.4 Hydrostatic tests

a) Turbine and nozzle casings are to be subjected to a hydrostatic test at the greater of the following test pressures:

b) 1,5 times the working pressure

c) 1,5 times the starting pressure

d) However, the test pressure is not to be less than 0,2 N/mm^2.

e) The turbine casings may be temporarily subdivided by diaphragms in order to obtain different pressure values for the various stages, if necessary.

f) Where it is not possible to perform hydrostatic tests, the manufacturer may submit to the Society, for consideration, alternative proposals for testing the integrity of turbine casings and the absence of defects therein.

g) For the bodies of quick-closing, safety, manoeuvring and control valves, the test pressure is to be 1,5 times the maximum allowable working pressure of the boiler (approval pressure). The sealing efficiency of these valves when closed is to be tested at 1,1 times the working pressure.

h) Intermediate coolers and heat exchangers are to be subjected to a hydrostatic test at 1,5 times the working pressure.

i) Pressure piping, valves and other fittings are to be subjected to hydrostatic tests in compliance with the normal requirements for these items.

4.2.5 Safety valves

All valves required in [2.4] are to be tested at their setting pressure in the presence of the Surveyor, as specified by the turbine manufacturer.

4.2.6 Thermal stability test of rotors

Solid forged and welded rotors of propulsion turbines are to be subjected to a thermal stability test where the service temperature exceeds 400°C. This test is to be carried out after heat treatment and rough machining or at a later stage of fabrication, in accordance with a procedure approved by the Society.

4.2.7 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.2.8 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above values of overspeed and that rotors are free from defects, as verified by means of non-destructive tests.

4.2.9 Shop trials

Where turbines are subjected to a trial run at the factory, the satisfactory functioning of the control, safety and monitoring equipment is to be verified during the trial run. Such verification is in any event to take place not later than the commissioning of the plant aboard ship.

In general, propulsion steam turbines are to be subjected to a works trial under steam but without load, up to the service rotational speed, as far as possible. In the course of the works trials, the overspeed devices for both main and auxiliary turbines are to be set.

4.3 Certification

4.3.1 Turbines required to be certified

For turbines required to be certified as per [1.1.1], Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 4 and for works trials as per [4.2.1]. Provided the manufacturer has a quality assurance system accepted by the Society, a reduced number of inspections and tests in the presence of the Surveyor may be agreed.

4.3.2 Turbines not required to be certified

For turbines not required to be certified as per [1.1.1], manufacturer's certificates including details of tests and inspections carried out at the shop are to be submitted. The acceptance of these turbines is, however, subject to their satisfactory performance during dock and sea trials.

4.3.3 Type approved turbines

For mass produced turbines which are requested to be type approved by the Society, the tests and trials on a prototype are to be carried out in the presence of the Surveyor as stated in [4.3.1]. The minimum required attendance of the Surveyor at the production tests and trials will be agreed between the manufacturer and the Society on a case by case basis.

Section 5 Gas Turbines

1 General

1.1 Application

1.1.1 Propulsion turbines and turbines for essential services

The requirements of this Section apply to:

a) all propulsion turbines

b) turbines intended for auxiliary services essential for safety and navigation.

1.1.2 Turbines for auxiliary generators

In addition to the requirements contained in this Section, auxiliary turbines driving electric generators are to comply with the applicable requirements of Part C, Chapter 2 of the Rules.

1.1.3 Type approval

Turbines intended for propulsion and essential services are to be type approved by the Society. Other procedures agreed with the Owner will be considered on a case by case basis.

1.2 Definition of rated power

1.2.1 For the definition of rated power, refer to ISO 2314 standard.

Table 1 : Documents to be submitted

No	A/I **(1)**	ITEM
1	I	Sectional assembly
2	A	Detailed drawings of rotors, casings, blades, combustion chambers and heat exchangers **(2)**
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties, the data relevant to rupture and creep at elevated temperatures, the fatigue strength, the corrosion resistance and the heat treatments **(2)**
4	A	Where the rotors, stators or other components of turbines are of welded construction, all particulars on the design of welded joints, welding procedures and sequences, heat treatments and non-destructive examinations after welding **(2)**
5	I	General specification of the turbine, including instruction manual, description of structures and specification of the properties of fuel and lubricating oil to be used
6	I	Details of operating conditions, including the pressure and temperature curves in the turbine and compressor at the rated power and corresponding rotational speeds, and details of permissible temporary operation beyond the values for the rated power
7	A	Diagrammatic layout of the fuel system, including control and safety devices, and of the lubricating oil system
8	A	Cooling system layout, if applicable
9	I	Where applicable, background information on previous operating experience in similar applications
10	I	Maintenance and overhaul procedures
11	A	Stress and temperature analysis in blades, rotors and combustion chamber **(2)**
12	A	Life time calculation of hot and high stress parts **(2)**
13	A	Blade and rotor vibration analysis **(2)**
14	A	Details of automatic safety devices together with failure mode and effect analysis (FMEA) **(2)**

(1) A = to be submitted for approval
I = to be submitted for information.

(2) As an alternative, the Society may, on a case by case basis, consider reviewing a number of selected packages relative to important and critical parts of the turbine, where all the design, construction, inspection, testing and acceptance criteria used by the manufacturer are clearly described, provided the Quality Assurance system of the manufacturer is approved and certified by the Society.

1.3 Documentation to be submitted

1.3.1 For propulsion turbines and turbines intended for driving machinery for essential services, the plans listed in Tab 1 are to be submitted.

The listed constructional plans are to be complete with all dimensions and are to contain full indication of the types of materials used.

2 Design and construction

2.1 General

2.1.1 Operating conditions

Attention is to be paid to the specific operating conditions of the turbine (e.g. continuous operation at low load) which may be imposed by the ship specification.

2.1.2 Availability of propulsion turbines

In accordance with Ch 1, Sec 1, [2.1.2], propulsion turbines are to remain operational as required to fulfil the machinery availability requirements stated in Part D for the service notation of the ship and with the requirements of Part E, Chapter 3 when the ship is to be assigned an **AVM** additional class notation. Where propulsion turbines are to remain operational in flooding conditions, the turbines' enclosures may be used for this purpose.

2.2 Materials

2.2.1 Approved materials

a) Gas turbine materials are to fulfil the requirements imposed by the operating conditions of the individual components. In the choice of materials, account is to be taken of effects such as creep, thermal fatigue, oxidation and corrosion to which individual components are subject when in service. Evidence of the suitability of the materials is to be supplied to the Society in the form of details of their chemical and mechanical properties and of the heat treatment applied. Where composite materials are used, their method of manufacture is to be described.

b) Turbine blades are to be built of corrosion and heat-resistant materials.

2.3 Stress analyses

2.3.1 Calculation

a) The manufacturer is to submit the results of calculation of the stresses on each rotor under the most severe service conditions.

b) Fatigue analysis on each rotor, taking into account the stress concentrations, is also to be submitted.

c) The results of previous in-service experience on similar applications may be considered by the Society as an alternative to items a) and b) above.

The calculations and analyses (see also [1.3.1]) are to be carried out in accordance with criteria agreed by the Society. Data on the design service life and test results used to substantiate calculation assumptions are also to be provided.

2.3.2 Vibrations

The range of service speeds is not to give rise to unacceptable bending vibrations or to vibrations affecting the entire installation. Calculations of the critical speeds including details of their basic assumptions are to be submitted.

2.4 Design and constructional details

2.4.1 Rotors and stators

a) All components of turbines and compressors are to be free from defects and are to be built and installed with tolerances and clearances in order to allow thermal expansion and to minimise the distortions of casings and rotors in all expected service conditions.

b) Adequate drain tubes and cocks are to be arranged in a suitable position, in the lower parts of the casings. Cocks are to be easily operated.

c) Suitable protective devices are to be provided in order to prevent heat, noise or possible failure of rotating parts from causing injury to personnel. If, to this end, the whole gas turbine is enclosed in a protective covering, the covering is to be adequately ventilated inside.

d) Particular attention is to be paid to the connection in the casings of pipes to the turbine stators in order to avoid abnormal loads in service.

e) Smooth fillets are to be provided at changes of sections of rotors, discs and blade roots. The holes in discs are to be well rounded and polished.

2.4.2 Access and inspection openings

a) Access to the combustion chambers is to be ensured. Means are to be provided to inspect the burner cans or combustion chamber without having to remove the gas generator.

b) Inspection openings are to be provided to allow the gas turbine flow path air to be inspected with special equipment, e.g. a bore-scope or similar, without the need for dismantling.

2.4.3 Bearings

a) Turbine bearings are to be so located that their lubrication is not impaired by overheating from hot gases or adjacent hot parts.

b) Lubricating oil or fuel oil is to be prevented from dripping on high temperature parts.

c) Suitable arrangements for cooling the bearings after the turbines have been stopped are to be provided, if necessary to prevent bearing cooking.

d) Roller bearings are to be identifiable and are to have a life adequate for their intended purpose. In any event, their life cannot be less than 40000 hours.

2.4.4 Turning gear

a) Main propulsion turbines are to be equipped with turning gear or a starter for cranking. The rotors of auxiliary turbines are to be capable of being turned by hand.

b) The engagement of the turning gear or starter is to be visually indicated at the control platform.

c) An interlock is to be provided to ensure that the main turbine cannot be started up when the turning gear is engaged.

2.4.5 Cooling

The turbines and their external exhaust system are to be suitably insulated or cooled to avoid excessive outside temperature.

2.4.6 Air supply

a) The air intake ducting is to be equipped to prevent extraneous substances from entering the compressor and turbine.

b) Measures are to be taken to control the salinity of the combustion air, to meet the manufacturer’s specification.

c) Cleaning equipment is to be provided to remove deposits from compressors and turbines.

d) Means are to be provided to prevent the formation of ice in the air intake.

2.4.7 Turbine exhaust arrangement

a) The gas exhaust arrangement is to be designed in such a way as to prevent the entrance of gases into the compressor.

b) Silencers or other equivalent arrangements are to be provided in the gas exhaust, to limit the airborne noise at one metre distance from the turbine to not more than 110 dB (A) in unmanned machinery spaces and not more than 90 dB (A) in manned spaces.

2.4.8 Multi-turbine installations

Multi-turbine installations are to have separate air inlets and exhaust systems to prevent recirculation through the idle turbine.

2.4.9 Fuel

a) Where the turbine is designed to burn non-distillate fuels, a fuel treatment system is to be provided to remove, as far as practicable, the corrosive constituents of the fuel or to inhibit their action in accordance with the manufacturer’s specification.

b) Suitable means are to be provided to remove the deposits resulting from the burning of the fuel while avoiding abrasive or corrosive action, if applicable.

2.4.10 Start-up equipment

a) Gas turbines are to be fitted with start-up equipment enabling them to be started up from the "shutdown" condition.

b) Provisions are to be made so that any dangerous accumulation of liquid or gaseous fuel inside the turbines is thoroughly removed before any attempt at starting or restarting.

c) Starting devices are to be so arranged that firing operation is discontinued and the main fuel valve is closed within a pre-determined time when ignition is failed.

d) The minimum number of starts is to be such as to satisfy the requirements of Ch 1, Sec 2, [3.1].

e) The arrangement is to be such as to grant redundancy of sources of energy for turbine starting.

2.4.11 Astern power

For main propulsion machinery with reverse gearing, controllable pitch propellers or an electrical transmission system, astern running maximum power is to be such as not to cause any overloading of the propulsion machinery.

2.4.12 Emergency operation

a) In installations with more than one propeller and connected shafting and more than one turbine, the failure of any gas turbine unit connected to a shafting line is not to affect the continued, independent operation of the remaining units.

b) In installations with only one propeller and connected shafting, driven by two or more main turbines, care is to be taken to ensure that, in the event of one of the turbines failing, the others are able to continue operation independently.

c) Ships classed for unrestricted service and fitted with only one propeller and connected shafting driven by a gas turbine are to be provided with means to ensure emergency propulsion in the event of failure of the main turbine.

2.5 Welded fabrication

2.5.1 The manufacturer's requirements relative to the welding of turbine rotors or major forged or cast pieces, where permitted, are to be readily identifiable by the Society in the plans submitted for approval.

In general, all weldings are to be carried out by qualified welders in accordance with qualified welding procedures using approved consumables.

2.6 Control, monitoring and shut-off devices

2.6.1 Control and monitoring arrangement

For each main propulsion system, the associated control and monitoring equipment is to be grouped together at each location from which the turbine may be controlled.

2.6.2 Governors and speed control system

a) Propulsion turbines which may be operated in no-load conditions are to be fitted with a control system capable of limiting the speed to a value not exceeding 10% of the maximum continuous speed or another figure proposed by the manufacturer.

b) Turbines for main propulsion machinery equipped with controllable pitch propellers, disengaging couplings or an electrical transmission system are to be fitted with a speed governor which, in the event of a sudden loss of load, prevents the revolutions from increasing to the trip speed.

c) In addition to the speed governor, turbines are to be fitted with a separate overspeed protective device, with a means for manual tripping, adjusted so as to prevent the rated speed from being exceeded by more than 15%.

d) The speed increase of turbines driving electric generators -except those for electrical propeller drive- resulting from a change from full load to no-load is not to exceed 5% on the resumption of steady running conditions. The transient speed increase resulting from a sudden change from full load to no-load conditions is not to exceed 10% and is to be separated by a sufficient margin from the trip speed. Alternative requirements may be considered by the Society on a case by case basis based on the actual turbine design and arrangement.

2.6.3 Monitoring system

The main operating parameters (pressure, temperature, rpm, etc.) are to be adequately monitored and displayed at the control console.

2.6.4 Emergency shut-off

a) An emergency push-button shut-off device is to be provided at the control console.

b) Any shut-off device provided in pursuance of the above is to shut off the fuel supply as near the burners as possible.

2.6.5 Quick-closing devices

a) Gas turbines are to be equipped with a quick closing device (shut-down device) which automatically shuts off the fuel supply to the turbines at least where required by Tab 2, unless the FMEA proves otherwise.

b) Re-setting of the quick-closing device may be effected only at the turbine or from the control platform with the fuel supply control valve in the closed position.

c) When the devices are operated by hydraulic oil systems fitted for automatic operation, they are to be fed by two pumps: one main pump and one standby pump. In any event, the standby pump is to be independent. In special cases, a hand-operated pump may be accepted as a standby pump.

d) The starting up of any turbine is to be possible only when the quick-closing devices are ready for operation.

2.6.6 Automatic temperature controls

The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions within the normal operating range of the main gas turbine:

a) lubricating oil supply and discharge

b) fuel oil supply (or, alternatively, automatic control of fuel oil viscosity)

c) exhaust gas in specific locations of the flow gas path as determined by the manufacturer.

2.6.7 Indicators, alarm and shutdown

Tab 2 indicates the minimum control, monitoring and shutdown requirements for main propulsion and auxiliary turbines. Alarms can be added or omitted, taking into account the result of FMEA.

Table 2 : Main propulsion and auxiliary turbines

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Turbine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
• Control system failure	X						
• Automatic starting failure	X						
Mechanical monitoring of gas turbine							
• Speed		local					
					X		
	H			X			
• Rotor axial displacement (not applicable to roller bearing)		local					
	H			X			
• Vibration	H **(1)**	local					
• Performed number of cycle of rotating part	H						
Gas generator monitoring							
• Flame and ignition failure	X			X			
• Fuel oil supply pressure	L	local					
• Fuel oil supply temperature	H	local					
• Cooling medium temperature	H	local					
• Exhaust gas temperature or gas temperature in specific locations of flow gas path		local					
	H **(1)**			X			
• Pressure at compressor inlet		local					
	L **(1)**			X			
Lubricating oil							
• Turbine supply pressure		local					
	L **(1)**			X			
• Reduction gear supply pressure		local					
	L **(1)**			X			
• Differential pressure across lubricating oil filter	H	local					
• Bearing or lubricating oil (discharge) temperature	H	local					
(1) Alarm to be activated at the suitable setting points prior to arriving the critical condition for the activation of shutdown devices.							

3 Arrangement and installation

3.1 Foundations

3.1.1 Foundations of turbines and connected reduction gears are to be designed and built so that hull movements do not give rise to significant movements between reduction gears and turbines. In any event, such movements are to be absorbed by suitable couplings.

3.2 Joints of mating surfaces

3.2.1 The mating flanges of casings are to form a tight joint without the use of any interposed material.

3.3 Piping installation

3.3.1 Pipes and mains connected to turbine and compressor casings are to be fitted in such a way as to minimise the thrust loads and moments. If flexible hoses are used for this purpose, they are to comply with the requirements in Ch 1, Sec 10, [2.6].

3.4 Hot surfaces

3.4.1 Hot surfaces with which the crew are likely to come into contact during operation are to be suitably guarded or insulated. See Ch 1, Sec 1, [3.7].

3.5 Alignment

3.5.1

a) Particular care is to be taken in the alignment of turbine-reduction gearing, taking account of all causes which may alter the alignment from cold conditions to normal service conditions.

b) When a structural tank is fitted in way of the turbine or gearing foundations, the expected tank temperature variations are to be taken into account during alignment operations.

c) Propulsion turbines are to be fitted with indicators showing the axial movements of rotors with respect to casings and the sliding movements of casings on the sliding feet. Such indicators are to be fitted in an easily visible position. This requirement does not apply to turbines fitted with roller bearings.

3.6 Gratings

3.6.1 Gratings and any other structures in way of the sliding feet or flexible supports are to be so arranged that turbine casing expansion is not restricted.

3.7 Drains

3.7.1 Turbines and the associated piping systems are to be equipped with adequate means of drainage.

3.8 Instruments

3.8.1 Main and auxiliary turbines are to be fitted with callipers and micrometers of a suitable type for verifying the alignment of rotors and pinion and gear-wheel shafts, when necessary.

At the time of installation on board, this check is to be performed in the presence and to the satisfaction of the Surveyor.

4 Material tests, workshop inspection and testing, certification

4.1 Type tests - General

4.1.1 Every new turbine type intended for installation on board ships is to undergo a type test whose program will be agreed on a case by case basis with the Society and the Owner.

4.2 Material tests

4.2.1 The materials for the construction of the parts listed in Tab 3 are to be tested in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 3 and are to be effected in positions mutually agreed upon by the manufacturer and the Surveyor, where experience shows defects are most likely to occur.

For important structural parts of the turbine, in addition to the above-mentioned non-destructive tests, examination of welded seams by approved methods of inspection may be required.

Where there is evidence to doubt the soundness of any turbine component, non-destructive tests using approved detecting methods may be required.

4.3 Inspections and testing during construction

4.3.1 Inspections during construction

The following inspections and tests are to be carried out in the presence of a Surveyor during the construction of all turbines which are indicated in [1.1.1]. For on-board trials see Ch 1, Sec 16, [3.4].

- Material tests as required (see [4.2])
- Welding fabrication (see [4.3.2])
- Hydrostatic tests (see [4.3.3])
- Rotor balancing and overspeed test (see [4.3.4], [4.3.5])
- Shop trials (see [4.3.6]).

Table 3 : Material and non-destructive tests

Turbine component	Material tests (mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic or X Ray examination
Rotating parts (compressors and turbine rotors, shafts, stiff and flexible couplings, bolts for couplings and other dynamically stressed parts, integral pinions and gears)	all	all	all
Stationary parts (castings for casings intended for a temperature exceeding 230°C and plates for casings intended for a temperature exceeding 370°C or pressure exceeding 4 Mpa)	all	spot as agreed between the Manufacturer and the Surveyor	–
Blades	sample	sample	sample
Piping and associated fittings	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules	as required in the appropriate section of the Rules

4.3.2 Welding fabrication

Welding fabrication and testing is to be attended by the Surveyor, as may be deemed necessary by the Society.

4.3.3 Hydrostatic tests

Finished casing parts and heat exchangers are to be subjected to hydrostatic testing at 1,5 times the maximum permissible working pressure. If it is demonstrated by other means that the strength of casing parts is sufficient, a tightness test at 1,1 times the maximum permissible working pressure may be accepted by the Society. Where the hydrostatic test cannot be performed, alternative methods for verifying the integrity of the casings may be agreed between the manufacturer and the Society on a case by case basis.

4.3.4 Balancing of rotors

Finished rotors, complete with all fittings and blades, are to be dynamically balanced in a balancing machine of appropriate sensitivity in relation to the size of the rotor. Normally this test is to be carried out with the primary part of the flexible coupling, if any.

4.3.5 Overspeed test of rotors

Finished rotors, complete with all fittings and blades, are to be subjected for at least 3 minutes to an overspeed test at the greater of the following values:

- 5% above the setting speed of the overspeed tripping device
- 15% above the maximum design speed.

The Society may waive this requirement provided that it can be demonstrated by the manufacturer, using an acceptable direct calculation procedure, that the rotor is able to safely withstand the above overspeed values and that rotors are free from defects, as verified by means of non-destructive tests.

4.3.6 Shop trials

For shop trials, see Ch 1, Sec 2, [4.5], as far as applicable.

4.4 Certification

4.4.1 Type approval certificate and its validity

Subject to the satisfactory outcome of the type tests and inspections specified in [4.2] or [4.3], the Society will issue to the turbine manufacturer a "Type Approval Certificate" valid for all turbines of the same type.

4.4.2 Testing certification

a) Turbines admitted to an alternative inspection scheme

   Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for components and tests indicated in Tab 3 and tests and trials listed in [4.3.1]. However, the shop trials are to be witnesses by a Surveyor.

b) Turbines not admitted to an alternative inspection scheme.

   Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of rotating components and blades listed in Tab 3 and for works trials as per [4.3.3], [4.3.4] and [4.3.6].

   Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for the other items listed in Tab 3 and for trials described in [4.3.2], [4.3.5].

Section 6 Gearing

1 General

1.1 Application

1.1.1 Unless otherwise specified, the requirements of this Section apply to:

- reduction and/or reverse gears intended for propulsion plants with a transmitted power of 220 kW and above
- other reduction and step-up gears with a transmitted power of 110 kW and above.

The provisions of Article [2] apply only to cylindrical involute spur or helical gears with external or internal teeth.

The provisions of Article [3] apply only to bevel gears (straight or oblique teeth). Application of other specific methods for the design of bevel gears could be taken into consideration by the Society.

Additional requirements for gears fitted to ships having an ice notation are given in NR467, Part F, Chapter 8.

1.2 Documentation to be submitted

1.2.1 Documents

Before starting construction, all plans, specifications and calculations listed in Tab 1 are to be submitted to the Society.

1.2.2 Data

The data listed in Tab 2 or Tab 3 and in Tab 4 are to be submitted with the documents required in [1.2.1].

Table 1 : Documents to be submitted for gearing

No.	A / I **(2)**	Description of the document **(1)**
1	A	Constructional drawings of shafts and flanges
2	A	Constructional drawings of pinions and wheels, including: a) specification and details of hardening procedure: • core and surface mechanical characteristics • diagram of the depth of the hardened layer as a function of hardness values b) specification and details of the finishing procedure: • finishing method of tooth flanks (hobbing, shaving, lapping, grinding, shot-peening) • surface roughness for tooth flank and root fillet • tooth flank corrections (helix modification, crowning, tip-relief, end-relief), if any • flank tolerance class according to ISO 1328-1:2013
3	A	Shrinkage calculation for shrunk-on pinions, wheels rims and/or hubs with indication of the minimum and maximum shrinkage allowances
4	I	Calculation of load capacity of the gears
5	A / I **(3)**	Constructional drawings of casings
6	A	Functional diagram of the lubricating system, with indication of the: • specified grade of lubricating oil • expected oil temperature in service • kinematic viscosity of the oil
7	A	Functional diagram of control, monitoring and safety systems
8	I	Longitudinal and transverse cross-sectional assembly of the gearing, with indication of the type of clutch
9	I	Data form for calculation of gears**(4)**
10	I	Detailed justification of material quality used for gearing calculation (ML, MQ, or ME according to ISO 6336-5)

(1) Constructional drawings are to be accompanied by the specification of the materials employed including the chemical composition, heat treatment and mechanical properties and, where applicable, the welding details, welding procedure and stress relieving procedure.
(2) Submission of the drawings may be requested:
A = to be submitted for approval
I = to be submitted for information.
(3) "A" for welded casing, "I" otherwise
(4) The forms are given in Tab 2, Tab 3 and Tab 4.

Table 2 : Data to be submitted for cylindrical gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
a			mm	Operating centre distance
b_B			mm	Common face width (for double helix gear, width of one helix)
A			–	Flank tolerance class according to ISO 1328-1:2013
b_S			mm	Web thickness
s_R			mm	Rim thickness
$R_{m,rim}$			N/mm^2	Ultimate tensile strength of the rim material
B			mm	Total face width of double helix gears, including gap
d_s			mm	Shrinkage diameter
m_n			mm	Normal module
α_n			deg or rad	Normal pressure angle at reference cylinder
β			deg or rad	Helix angle at reference cylinder
x			–	Addendum modification coefficient
z			–	Number of teeth
P			kW	Transmitted power
n			rpm	Rotational speed
d_a			mm	Tip diameter
ρ_{a0}			mm	Tip radius of the tool
h_{fp}			mm	Basic rack dedendum
HRC			–	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm^2	Minimum yield strength of the shaft material
ν_{40}			mm^2/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			$N^{1/2}/mm$	Elasticity factor

Table 3 : Data to be submitted for bevel gears

Symbol	Values		Unit	Description
	Pinion	Wheel		
A			–	Flank tolerance class according to ISO 1328-1:2013
s_R			mm	Rim thickness
d_s			mm	Shrinkage diameter
b			mm	Common face width (for double helix gear width of one helix)
m_{mn}			mm	Mean normal module
α_n			deg or rad	Normal pressure angle
β_m			deg or rad	Mean helix angle
z			–	Actual number of teeth
δ			deg or rad	Pitch angle
x_h			–	Addendum modification coefficient
x_s			–	Thickness modification coefficient
h_{aP}			mm	Addendum of the basic rack tooth profile
h_{fP}			mm	Dedendum of the basic rack tooth profile
ρ_{a0}			mm	Cutter edge radius
r_{c0}			mm	Cutter radius
P			kW	Transmitted power
n			rpm	Rotational speed
HRC			–	Rockwell hardness
R_{Zf}			µm	Mean peak-to-valley flank roughness of the gear pair
R_Z			µm	Mean peak-to-valley roughness of the gear pair
$R_{e,s}$			N/mm^2	Minimum yield strength of the shaft material
ν_{40}			mm^2/s	Nominal kinematic viscosity of oil at 40°C
pr			mm	Protuberance of the tool
q			mm	Material allowance for finish machining
d_{ext}			mm	External shaft diameter
d_{int}			mm	Internal shaft diameter
ℓ			mm	Bearing span
Z_E			$N^{1/2}/mm$	Elasticity factor

Table 4 : General data to be submitted for bevel and cylindrical gears

Condition of use — Tick the box

			Tick the box
Main gears (propulsion)	Diesel engine	with hydraulic coupling	
		with elastic coupling	
		with other type of coupling	
	Turbine		
	Electric motor		
Gears intended for ahead running			
Gears intended for astern running only			
Other intermittent running			
Gears with occasional part load in reverse direction (main wheel in reverse gearbox)			
Idler gears			
Shrunk on pinions and wheel rims			
Otherwise			

Arrangement

Single gear		
Dual tandem gear	without quill shaft **(1)**	
	with quill shaft **(1)**	
Epicyclic gear	with 3 planetary gears and less	
	with 4 planetary gears	
	with 5 planetary gears	
	with 6 planetary gears and more	

Machining

No modification	
Central crowning fma	
Central crowning fma + fsh	
Helix correction	
Helix correction + crowning	
End relief	
Maximum base pitch deviation of the wheel	
With optimum profile correction	

Material

			Pinion	Wheel
St	Normalized low carbon steels / cast steels	Wrought normalized low carbon steels		
St (Cast)		Cast steels		
GTS (Perl.)	Cast iron materials	Black malleable cast iron (perlitic structure)		
GGG (Perl.)		Nodular cast iron (perlitic structure)		
GGG (Bai.)		Nodular cast iron (bainitic structure)		
GGG (ferr.)		Nodular cast iron (ferritic structure)		
GG		Grey cast iron		
V	Through-hardened wrought steels	Carbon steels, alloy steels		
V (cast)	Through-hardened cast steels	Carbon steels, alloy steels		
Eh	Case-hardened wrought steels			
IF	Flame or induction hardened wrought or cast steels			
NT (nitr.)	Nitrided wrought steels/nitrided steels / nitrided through-hardening steels	Nitriding steels		
NV (nitr.)		Through-hardening steels		
NV (nitrocar.)	Wrought steels, nitrocarburized	Through-hardening steels		

(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.

2 Design of gears - Determination of the load capacity of cylindrical gears

2.1 Symbols, units, definitions

2.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013
a : Operating centre distance, in mm
b : Effective face width, in mm (for double helix gear, $b = 2\ b_B$)
b_B : Common face width, in mm (for double helix gear, width of one helix)
b_S : Web thickness, in mm
B : Total face width of double helix gear, including gap, in mm
d : Reference diameter, in mm
d_a : Tip diameter, in mm
d_b : Base diameter, in mm
d_{ext} : External diameter of shaft, in mm
d_{int} : Internal diameter of shaft, in mm
d_f : Root diameter, in mm
d_s : Shrinkage diameter, in mm
d_w : Working pitch diameter, in mm
F_t : Nominal tangential load, in N
F_β : Total helix deviation, in µm
h : Tooth depth, in mm
h_{fp} : Basic rack dedendum, in mm
HB : Brinell hardness, in N/mm²
HRC : Rockwell hardness
HV : Vickers hardness, in N/mm²
k : Gear axial position on shaft with respect to the bearings
ℓ : Bearing span, in mm
m_n : Normal module, in mm
n : Rotational speed, in rpm
P : Transmitted power, in kW
pr : Protuberance of the tool, in mm
q : Material allowance for finish machining, in mm
$R_{m,rim}$: Ultimate tensile strength of the rim material, in N/mm²
$R_{e,s}$: Minimum yield strength of the shaft material, in N/mm²
R_Z : Mean peak-to-valley roughness of the gear pair, in µm
R_{Zf} : Mean peak-to-valley flank roughness of the gear pair, in µm
s_R : Rim thickness, in mm
T : Transmitted torque, in kN.m
u : Reduction ratio
v : Linear speed at pitch diameter, in m/s
x : Addendum modification coefficient
z : Number of teeth
z_n : Virtual number of teeth
α_a : Transverse profile angle at tooth tip
α_n : Normal pressure angle at reference cylinder
α_t : Transverse pressure angle at reference cylinder
α_{tw} : Transverse pressure angle at working pitch cylinder
β : Helix angle at reference cylinder
β_b : Base helix angle
ε_α : Transverse contact ratio
ε_β : Overlap ratio
ε_γ : Total contact ratio

ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s

ρ_{a0} : Tip radius of the tool, in mm

σ_F : Tooth root bending stress, in N/mm²

σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²

σ_{FP} : Permissible tooth root bending stress, in N/mm²

σ_H : Contact stress, in N/mm²

$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²

σ_{HP} : Permissible contact stress, in N/mm²

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

2.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_n (in case of width of one gear much more important than the other).

For internal gear, z_2, a, d_2, d_{a2}, d_{b2}, x_2 and d_{w2} are to be taken negative.

$$u = \frac{z_2}{z_1}$$

Note 1: u > 0 for external gears, u < 0 for internal gears.

$$\tan\alpha_t = \frac{\tan\alpha_n}{\cos\beta}$$

$$d_i = \frac{z_i \cdot m_n}{\cos\beta}$$

$$d_{bi} = d_i \cdot \cos\alpha_t$$

$$d_{w1} = \frac{2 \cdot a}{1+u}$$

$$d_{w2} = \frac{2 \cdot a \cdot u}{1+u}$$

$$d_{fi} = d_i + 2 \cdot m_n \cdot x_i - 2 \cdot h_{fPi}$$

$$h_i = 0{,}5\ (d_{ai} - d_{fi})$$

$$\cos\alpha_{tw} = \frac{d_{b1} + d_{b2}}{2a}$$

$$\sin\beta_b = \sin\beta \cdot \cos\alpha_n$$

$$z_{ni} = \frac{z_i}{\cos\beta \cdot (\cos\beta_b)^2}$$

$$\cos\alpha_{ai} = \frac{d_{bi}}{d_{ai}}$$

$$\varepsilon_\alpha = \frac{z_1}{2\pi}(\tan\alpha_{a1} - \tan\alpha_{wt}) + \frac{z_2}{2\pi}(\tan\alpha_{a2} - \tan\alpha_{wt})$$

$$\varepsilon_\beta = \frac{b \cdot \sin\beta}{\pi \cdot m_n}$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta$$

$$F_{\beta i} = 2^{0{,}5\ \cdot (Q_i - 5)} \cdot (0{,}1\ \cdot |d_i|^{0{,}5} + 0{,}63\ \cdot b_B{}^{0{,}5} + 4{,}2\ )$$

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_t = \frac{P}{n_1} \cdot \frac{60}{\pi \cdot d_1} \cdot 10^6$$

$$v_i = \frac{\pi \cdot n_i}{60} \cdot \frac{d_{wi}}{10^3}$$

2.2 Principle

2.2.1

a) The following requirements apply to cylindrical involute spur or helical gears with external or internal teeth, and provide a method for the calculation of the load capacity with regard to:

- the surface durability (contact stress)
- the tooth root bending stress.

The cylindrical gears for marine application are to comply with the following restrictions:

- $1,2 < \varepsilon_\alpha < 2,5$
- $\beta < 30°$
- $s_R > 3,5\ m_n$

The relevant formulae are provided in [2.4] and [2.5].

The influence factors common to the formulae are given in [2.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with the ISO 6336 series standards.

2.3 General influence factors

2.3.1 General

General influence factors are defined in [2.3.2], [2.3.3], [2.3.4], [2.3.5] and [2.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

2.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A are given in Tab 5.

2.3.3 Load sharing factor K_γ

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ are given in Tab 6.

Table 5 : Application factor K_A

Type of installation			K_A
Main gears (propulsion)	Diesel engine	with hydraulic coupling	1,05
		with elastic coupling	1,30
		with other type of coupling	1,50
	Turbine		1,05
	Electric motor		1,05
Auxiliary gears	Diesel engine	with hydraulic coupling	1,00
		with elastic coupling	1,20
		with other type of coupling	1,40
	Electric motor		1,00

Table 6 : Load sharing factor K_γ

Type of gear		K_γ
Dual tandem gear	without quill shaft **(1)**	1,15
	with quill shaft **(1)**	1,10
Epicyclic gear	with 3 planetary gears and less	1,00
	with 4 planetary gears	1,20
	with 5 planetary gears	1,30
	with 6 planetary gears and more	1,40
(1) A quill shaft is a torsionally flexible shaft intended to improve the load distribution between the gears.		

2.3.4 Dynamic factor K_V (method B)

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and the wheel.

The calculation of the dynamic factor K_V is defined in Tab 7, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi z_1} \cdot \sqrt{\frac{c_{\gamma\alpha}}{m_{red}}}$$

with:

m_{red} : Reduced mass of gear pair, in kg/mm
In case of external gears, estimated calculation of m_{red} is given in Tab 8

$c_{\gamma\alpha}$: Mesh stiffness, in N/(mm·µm).
For gears with $\beta \le 30°$, the calculation of $c_{\gamma\alpha}$ is detailed in Tab 9.

The value of N determines the range of vibrations:

- subcritical range, when $N \le N_S$
- main resonance range, when $N_S < N < 1,15$
  This field is not permitted
- intermediate range, when $1,15 \le N \le 1,50$
  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

The lower limit of resonance N_S is defined as follows:

- if $F_t K_A / b \ge 100$ N/mm:
  $N_s = 0,85$
- if $F_t K_A / b < 100$ N/mm:

$$N_s = 0{,}5 + 0{,}35 \sqrt{\frac{F_t K_A}{100 b}}$$

2.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$ (method C)

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root bending stress, account for the effects of non-uniform distribution of load across the face width.

a) The values of $K_{H\beta}$ are given in Tab 10. They apply only to gears with:
   - wheel, case, wheel shaft and bearings of stiff construction
   - pinion on a solid or hollow shaft with an inner diameter ratio not exceeding 0,5 and located symmetrically between the bearings
   - no effect of clearances
   - no external loads acting on the pinion shaft.

Note 1: Gears for which the above conditions are not satisfied will be given special consideration by the Society.

The calculation of the initial equivalent misalignment $F_{\beta x}$ is defined in Tab 11.

The calculations of the running-in allowance $y\beta$ and the running-in factor χ_β are defined in Tab 12.

The calculation of the mesh misalignment due to deformations of shafts depends on the constant of the pinion K' and the distance s of the pinion. They are defined in Tab 13.

b) $K_{F\beta}$ is to be determined using the following formula:

$$K_{F\beta} = K_{H\beta}^{\frac{1}{1 + h/b_B + (h/b_B)^2}}$$

where b/h is the smaller of b_{B1}/h_1 and b_{B2}/h_2 but is not to be taken lower than 3.

2.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$ (method B)

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 14.

Table 7 : Dynamic factor K_V

Resonance domain	Factor K_V
$N \le N_S$	$K_V = N\,(C_{v1}\,B_P + C_{v2}\,B_F + C_{v3}\,B_K) + 1$
$N > 1{,}50$	$K_V = C_{v5}\,B_P + C_{v6}\,B_F + C_{v7}$

Note 1:

B_P : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_P = \frac{c' \cdot f_{pb,\,eff}}{K_A \cdot (F_t / b)}$$

with:

- c' : Single stiffness defined in Tab 9
- $f_{pb,eff}$: Effective base pitch deviation, in µm, equal to: $f_{pb,eff} = f_{pb} - y_\alpha$ with f_{pb} defined in Tab 14 and y_α defined in Tab 15

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications: $B_f = B_P$

B_k : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_k = \left|1 - \frac{c' \cdot C_a}{K_A \cdot F_t / b}\right|$$

with:

$$C_a = \frac{1}{18} \cdot \left(\frac{\sigma_{Hlim}}{97} - (18{,}45\ )\right)^2 + 1{,}5$$

When material of the pinion is different from that of the wheel: $C_a = 0{,}5\,(C_{a1} + C_{a2})$

C_{v1} : Factor for pitch deviation effects: $C_{v1} = 0{,}32$

C_{v2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v2} = 0{,}34$
- if $2 < \varepsilon_\gamma$: $C_{v2} = 0{,}57 / (\varepsilon_\gamma - 0{,}3)$

C_{v3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v3} = 0{,}23$
- if $2 < \varepsilon_\gamma$: $C_{v3} = 0{,}096 / (\varepsilon_\gamma - 1{,}56)$

C_{v5} : Factor: $C_{v5} = 0{,}47$

C_{v6} : Factor:

- if $1 < \varepsilon_\gamma \le 2$: $C_{v6} = 0{,}47$
- if $2 < \varepsilon_\gamma$: $C_{v6} = 0{,}12 / (\varepsilon_\gamma - 1{,}74)$

C_{v7} : Factor:

- if $1 < \varepsilon_\gamma \le 1{,}5$: $C_{v7} = 0{,}75$
- if $1{,}5 < \varepsilon_\gamma \le 2{,}5$: $C_{v7} = 0{,}125\,\sin[\pi\,(\varepsilon_\gamma - 2)] + 0{,}875$
- if $2{,}5 < \varepsilon_\gamma$: $C_{v7} = 1$

Table 8 : Estimated calculation of reduced mass m_{red}

Gear rim	Rim ratio	m_{red}, in kg/mm
$s_{Ri} = 0$	$1 - q_i^4 = 1$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left(\frac{1}{\rho_1} + \frac{1}{\rho_2 \cdot u^2}\right)}$
$s_{Ri} \ne 0$	$q_i = \frac{2 \cdot (d_{fi} - 2 \cdot s_{Ri})}{d_{fi} + d_{ai}}$	$m_{red} = \frac{\pi}{8} \cdot \left(\frac{d_{a1} + d_{f1}}{2\,d_{b1}}\right)^2 \cdot \frac{(d_{f1} + d_{a1})^2}{4 \cdot \left[\frac{1}{(1 - q_1^4) \cdot \rho_1} + \frac{1}{(1 - q_2^4) \cdot \rho_2 \cdot u^2}\right]}$

Note 1:

ρ_i is the density of gearing material ($\rho = 7{,}83 \cdot 10^{-6}$ for steel)

Table 9 : Mesh stiffness $c_{\gamma\alpha}$ (method B)

Specific load	$c_{\gamma\alpha}$, in N/(mm.µm)**(1)**
$F_t K_A / b \geq 100$ N/mm	$c_{\gamma\alpha} = c' (0{,}75\ \varepsilon_\alpha + 0{,}25) = c'_{th}\ C_M\ C_R\ C_B \cos\beta\ (0{,}75\ \varepsilon_\alpha + 0{,}25)$
$F_t K_A / b < 100$ N/mm	$c_{\gamma\alpha} = c'(0{,}75\ \varepsilon_\alpha + 0{,}25) = c'_{th} C_M C_R C_B \cos\beta\left(\frac{F_t K_A / b}{100}\right)(0{,}75\ \varepsilon_\alpha + 0{,}25)$

(1) When $\varepsilon_\alpha < 1{,}2$: $c_{\gamma\alpha}$ may be reduced up to 10% in case of spur gears.

Note 1:

c' : Single stiffness, in N/(mm.µm)

c'_{th} : Theoretical mesh stiffness, in N/(mm.µm), equal to:

$$c'_{th} = \frac{1}{0{,}04723 + \frac{0{,}15551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635\ x_1 - 0{,}00193\ x_2 - \frac{0{,}11654\ x_1}{z_{n1}} - \frac{0{,}24188\ x_2}{z_{n2}} + 0{,}00529\ x_1^{\ 2} + 0{,}00182\ x_2^{\ 2}}$$

where the following limitations are to be verified:

- $x_1 \geq x_2$, and
- $-0{,}5 \leq x_1 + x_2 \leq 2{,}0$

For internal gears, z_{n2} should be replaced by infinity

C_M : Measurements correction factor, equal to:

$C_M = 0{,}8$

C_R : Gear blank factor:

- for solid disc gears ($s_R = 0$):

  $C_R = 1{,}0$

- otherwise:

  $$C_R = 1 + \frac{\ln(b_s / b)}{5 \cdot e^{s_R / 5 m_n}}$$

  with the following limitations:

  $0{,}2 \leq b_s / b \leq 1{,}2$ and $s_R / m_n \geq 1$

C_B : Basic rack factor, equal to:

$$C_B = 1 + 0{,}5 \cdot \left(1{,}2 - \frac{h_{fP}}{m_n}\right) \cdot [1{,}0 - 0{,}02 \cdot (20 - \alpha_n)]$$

When pinion basic rack dedendum is different from that of the wheel, $C_B = 0{,}5\ (C_{B1} + C_{B2})$.

Table 10 : Face load factor for contact stress $K_{H\beta}$

	Calculated face width	Factor $K_{H\beta}$
$\frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} \geq 1$	$\frac{b_{cal}}{b} = \sqrt{\frac{2 F_m / b}{F_{\beta y} c_{\gamma\beta}}} \leq 1$	$K_{H\beta} = \sqrt{\frac{2 F_{\beta y} c_{\gamma\beta}}{F_m / b}} \geq 2$
$\frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} < 1$	$\frac{b_{cal}}{b} = 0{,}5 + \frac{F_m / b}{F_{\beta y} c_{\gamma\beta}} > 1$	$K_{H\beta} = 1 + \frac{F_{\beta y} c_{\gamma\beta}}{2 F_m / b} < 2$

Note 1:

b_{cal} : Calculated face width, in mm

F_m : Mean transverse tangential load, in N:

$F_m = F_t\ K_A\ K_V$

$F_{\beta y}$: Effective misalignment after running-in, in µm:

$F_{\beta y} = F_{\beta x} - y_\beta = F_{\beta x}\ \chi_\beta$

where:

$F_{\beta x}$: Initial equivalent misalignment. Estimated values are given in Tab 11

y_β, χ_β : Running-in allowance, in µm, and running-in factor, respectively, defined in Tab 12

$c_{\gamma\beta}$: Mesh stiffness, in N/(mm·µm):

$c_{\gamma\beta} = 0{,}85\ c_{\gamma\alpha}$

$c_{\gamma\alpha}$ being the mesh stiffness defined in Tab 9.

Table 11 : Initial equivalent misalignment $F_{\beta x}$

Helix modification	$F_{\beta x}$, in µm**(1)**	Default estimated values of f_{ma}
None	$F_{\beta x} = 1{,}33\ f_{sh} + f_{ma}$	$f_{ma} = F_{\beta}$
Central crowning with $C_{\beta} = 0{,}5\ f_{ma}$	$F_{\beta x} = 1{,}33\ f_{sh} + 0{,}5\ f_{ma}$	$f_{ma} = 0{,}5\ F_{\beta}$
Central crowning with $C_{\beta} = 0{,}5\ (f_{ma} + f_{sh})$	$F_{\beta x} = 0{,}665\ f_{sh} + 0{,}5\ f_{ma}$	$f_{ma} = 0{,}5\ F_{\beta}$
Helix correction	$F_{\beta x} = 0{,}133\ f_{sh} + f_{ma}$	$f_{ma} = 0{,}5\ F_{\beta}$
Helix correction plus central crowning	$F_{\beta x} = 0{,}133\ f_{sh} + 0{,}5\ f_{ma}$	$f_{ma} = 0{,}5\ F_{\beta}$
End relief	$F_{\beta x} = 0{,}931\ f_{sh} + 0{,}7\ f_{ma}$	$f_{ma} = 0{,}7\ F_{\beta}$

(1) The misalignment $F_{\beta x}$ is to be taken greater than $F_{\beta x,min} = 0{,}005\ F_m / b$

Note 1:

f_{sh} : Mesh misalignment due to deformations of shafts, in µm:

$$f_{sh} = \frac{F_m}{b} \cdot 0{,}023 \left(\left| B^* + K' \frac{\ell \cdot s \cdot d_1^{\ 2}}{d_{ext}^{\ 4}} - 0{,}3 \right| + 0{,}3 \right) \cdot \left(\frac{d_B}{d_1} \right)^2$$

where:

- B^* : Transmitted torque factor depending on k, percentage of input torque transmitted in one gear mesh:
  - for spur and single helical gears: $B^* = 1 + 2\ (100 - k) / k$
  - for double helical gears: $B^* = 0{,}5 + (200 - k) / k$
- K' : Constant of the pinion defined in Tab 13
- s : Distance of the pinion, in mm, as shown in Tab 13

f_{ma} : Mesh misalignment due to manufacturing deviations, in µm.

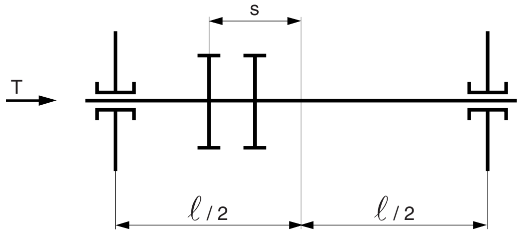
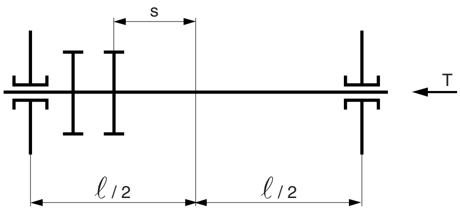
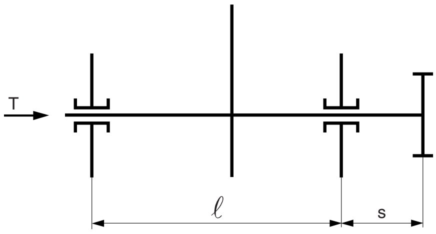
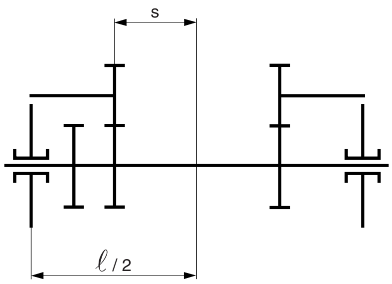
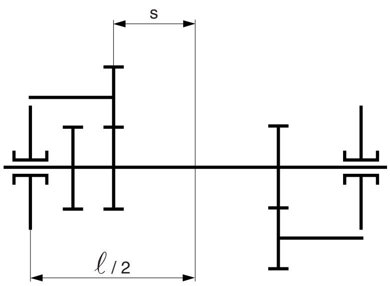
Table 12 : Running-in allowance y_{β} and running-in factor $\chi\beta$

Material	y_{β} , in µm	χ_{β}	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_{\beta} = \frac{320}{\sigma_{H,lim}} F_{\beta x}$	$\chi_{\beta} = 1 - \frac{320}{\sigma_{H,lim}}$	$y_{\beta} \le F_{\beta x}$ and $\chi_{\beta} \ge 0$ • if 5 m/s < v ≤ 10 m/s: $y_{\beta} \le 25600 / \sigma_{H,lim}$ • if 10 m/s < v: $y_{\beta} \le 12800 / \sigma_{H,lim}$
GGG (ferr.), GG	$y_{\beta} = 0{,}55\ F_{\beta x}$	$\chi_{\beta} = 0{,}45$	• if 5 m/s < v ≤ 10 m/s: $y_{\beta} \le 45$ • if 10 m/s < v: $y_{\beta} \le 22$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_{\beta} = 0{,}15\ F_{\beta x}$	$\chi_{\beta} = 0{,}85$	$y_{\beta} \le 6$

Note 1: $\sigma_{H,lim}$ is defined in [2.4.9].

Note 2: When material of the pinion differs from that of the wheel: $y_{\beta} = 0{,}5\ (y_{\beta 1} + y_{\beta 2})$ and $\chi_{\beta} = 0{,}5\ (\chi_{\beta 1} + \chi_{\beta 2})$

Table 13 : Constant of the pinion K' and distance of the pinion s

Arrangement **(1)**	Constant K′ with stiffening	Constant K′ without stiffening **(2)**
	0,48	0,8
	– 0,48	– 0,8
	1,33	1,33
	– 0,36	– 0,6
	– 0,6	– 1,0

(1) The following limitation is to be verified except when helix correction is applied:
$s / \ell < 0,3$

(2) No stiffening is assumed when $d_1 / d_{sh} < 1,15$ or when the pinion is keyed or shrinked to the shaft.

Table 14 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_\gamma \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_\gamma}{2}\left[0{,}9 + 0{,}4\ \frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}\right]$	$\frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2} \ge K_{H\alpha} \ge 1$
$\varepsilon_\gamma > 2$	$K_{H\alpha} = K_{F\alpha} = 0{,}9 + 0{,}4\ \sqrt{\frac{2(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}\frac{c_{\gamma\alpha}(f_{pb} - y_\alpha)}{F_{tH}/b}}$	$\frac{\varepsilon_\gamma}{0{,}25\ \varepsilon_\alpha + 0{,}75} \ge K_{F\alpha} \ge 1$

Note 1:
$c_{\gamma\alpha}$: Mesh stiffness, in N/mm.µm, defined in Tab 9
f_{pb} : Larger value of the base pitch deviation of pinion or wheel, in µm.
Default value: $f_{pb} = 0{,}3\ (m_n + 0{,}4\ |d_{bi}|^{0{,}5} + 4) \cdot 2^{0{,}5\ (Q_i - 5)}$
In case of optimum profile correction, f_{pb} is to be replaced by f_{pb} / 2
y_α : Running-in allowance, in µm, defined in Tab 15
F_{tH} : Determinant tangential load in transverse plane, in N:
$F_{tH} = F_t \cdot K_A \cdot K_V \cdot K_{H\beta}$

Table 15 : Running-in allowance y_α

Material	y_α, in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$y_\alpha = \frac{160}{\sigma_{H,lim}} f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 12800 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\alpha \le 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	$y_\alpha = 0{,}275\ f_{pb}$	• if 5 m/s < v ≤ 10 m/s: $y_\alpha \le 22$ • if 10 m/s < v: $y_\alpha \le 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$y_\alpha = 0{,}075\ f_{pb}$	$y_\alpha \le 3$

Note 1: f_{pb} is defined in Tab 14 and $\sigma_{H,lim}$ is defined in [2.4.9].
Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0{,}5\ (y_{\alpha 1} + y_{\alpha 2})$.

2.4 Calculation of surface durability

2.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H, defined in [2.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [2.4.8].

2.4.2 Contact stress σ_H

The contact stress σ_H, in N/mm², is to be determined as follows.

- for the pinion:

$$\sigma_H = Z_B \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

- for the wheel:

$$\sigma_H = Z_D \cdot \sigma_{H0} \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

Z_B, Z_D : Single pair mesh factors, respectively for pinion and for wheel, defined in [2.4.3]
K_A : Application factor (see [2.3.2])
K_γ : Load sharing factor (see [2.3.3])
K_V : Dynamic factor (see [2.3.4])
$K_{H\beta}$: Face load distribution factor (see [2.3.5])
$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

$$\sigma_{H0} = Z_H \cdot Z_E \cdot Z_\varepsilon \cdot Z_\beta \sqrt{\frac{F_t}{d_1 \cdot b} \cdot \frac{|u| + 1}{|u|}}$$

with:

Z_H : Zone factor, defined in [2.4.4]
Z_E : Elasticity factor, defined in [2.4.5]
Z_ε : Contact ratio factor, defined in [2.4.6]
Z_β : Helix angle factor, defined in [2.4.7].

2.4.3 Single pair mesh factors Z_B and Z_D

The single pair mesh factors Z_B for pinion and Z_D for wheel account for the influence on contact stresses of the tooth flank curvature at the inner point of single pair contact in relation to Z_H. These factors transform the contact stress determined at the pitch point to contact stresses, considering the flank curvature at the inner point of single pair contact.

Z_B and Z_D are to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

- $Z_B = M_1$ or 1, whichever is the greater, with:

$$M_1 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{z_1}\right] \cdot \left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_2}\right]}}$$

- $Z_D = M_2$ or 1, whichever is the greater, with:

$$M_2 = \frac{\tan\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} - \frac{2\pi}{z_2}\right] \cdot \left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{z_1}\right]}}$$

b) for helical gears:

- if $\varepsilon_\beta \geq 1$: $Z_B = Z_D = 1$
- if $\varepsilon_\beta < 1$:

  $Z_B = M_1 - \varepsilon_\beta (M_1 - 1)$ or 1, whichever is the greater

  $Z_D = M_2 - \varepsilon_\beta (M_2 - 1)$ or 1, whichever is the greater.

Note 1: For gears with $\varepsilon_\alpha \leq 1$, a specific analysis of the decisive contact stress along the path of contact is necessary.

Note 2: For internal gears, $Z_D = 1$.

2.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point and transforms the tangential force at the reference cylinder to normal force at the pitch cylinder.

Z_H is to be determined as follows:

$$Z_H = \sqrt{\frac{2 \cdot \cos\beta_b \cdot \cos\alpha_{tw}}{(\cos\alpha_t)^2 \cdot \sin\alpha_{tw}}}$$

2.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

For steel gears: $Z_E = 189{,}8\ N^{1/2}/mm$.

Note 1: Refer to ISO 6336-2 for other materials.

2.4.6 Contact ratio factor Z_ε

The contact ratio factor Z_ε accounts for the influence of the transverse contact ratio and the overlap ratio on the specific surface load of gears.

Z_ε is to be determined as follows:

a) for spur gears ($\varepsilon_\beta = 0$):

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3}}$$

b) for helical gears:

- for $\varepsilon_\beta \geq 1$:

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}$$

- for $\varepsilon_\beta < 1$:

$$Z_\varepsilon = \sqrt{\frac{4 - \varepsilon_\alpha}{3} \cdot (1 - \varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}}$$

2.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact. Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos\beta(2,\ \ )}}$$

Table 16 : Constants A and B and limitations on surface hardness HB or HV

	Quality **(1)**	A	B (N/mm^2)	Hardness	x_{min} (N/mm^2)	x_{max} (N/mm^2)
St	ML	1,000	190	HB	110	210
	MQ	1,000	190	HB	110	210
	ME	1,520	250	HB	110	210
St (cast)	ML	0,986	131	HB	140	210
	MQ	0,986	131	HB	140	210
	ME	1,143	237	HB	140	210
GTS (perl.)	ML	1,371	143	HB	135	250
	MQ	1,371	143	HB	135	250
	ME	1,333	267	HB	175	250
GGG	ML	1,434	211	HB	175	300
	MQ	1,434	211	HB	175	300
	ME	1,500	250	HB	200	300
GG	ML	1,033	132	HB	150	240
	MQ	1,033	132	HB	150	240
	ME	1,465	122	HB	175	275
V (carbon steels)	ML	0,963	283	HV	135	210
	MQ	0,925	360	HV	135	210
	ME	0,838	432	HV	135	210
V (alloy steels)	ML	1,313	188	HV	200	360
	MQ	1,313	373	HV	200	360
	ME	2,213	260	HV	200	390
V (cast, carbon steels)	ML	0,831	300	HV	130	215
	MQ	0,831	300	HV	130	215
	ME	0,951	345	HV	130	215
V (cast, alloy steels)	ML	1,276	298	HV	200	360
	MQ	1,276	298	HV	200	360
	ME	1,350	356	HV	200	360
Eh	ML	0,000	1300	HV	600	800
	MQ	0,000	1500	HV	660	800
	ME	0,000	1650	HV	660	800
IF	ML	0,740	602	HV	485	615
	MQ	0,541	882	HV	500	615
	ME	0,505	1013	HV	500	615
NT (nitr.)	ML	0,000	1125	HV	650	900
	MQ	0,000	1250	HV	650	900
	ME	0,000	1450	HV	650	900
NV (nitr.)	ML	0,000	788	HV	450	650
	MQ	0,000	998	HV	450	650
	ME	0,000	1217	HV	450	650
NV (nitrocar.)	ML	0,000	650	HV	300	650
	MQ	1,167	425	HV	300	450
	ME	1,167	425	HV	300	450

(1) The requirements for each material quality are defined in ISO 6336-5.

2.4.8 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP} , in N/mm², is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [2.4.9]

Z_{NT} : Life factor for contact stress, defined in [2.4.10]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [2.4.11]

Z_W : Hardness ratio factor, defined in [2.4.12]

Z_X : Size factor for contact stress, defined in [2.4.13]

S_H : Safety factor for contact stress, defined in [2.4.14].

2.4.9 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$, in N/mm², is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given, in N/mm², with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{H,lim} = A\,x + B$

where:

A, B : Constants determined in Tab 16

x : Surface hardness HB or HV, in N/mm². The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 16.

Special consideration will be given to other values of $\sigma_{H,lim}$, depending on the material category and specification of the steel employed.

2.4.10 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given for information in Tab 17.

The value of Z_{NT} to be used will be given special consideration by the Society, depending on the equipment's arrangement and use.

Table 17 : Life factor Z_{NT}

Material	Number of load cycles N_L	Z_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.),V, V (cast), Eh, IF	$N_L \le 10^5$ or static	1,6
	$N_L = 5 \cdot 10^7$	1,0
	$N_L = 10^9$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \le 10^5$ or static	1,3
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \le 10^5$ or static	1,1
	$N_L = 2 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.4.11 Lubricant factor Z_L , speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined as follows:

a) Lubricant factor Z_L

$$Z_L = C_{ZL} + \frac{4 \cdot (1{,}0 - C_{ZL})}{\left(1{,}2 + \frac{134}{\nu_{40}}\right)^2}$$

where:

C_{ZL} : Constant for lubricant factor, equal to:

- for $\sigma_{H,lim} < 850$ N/mm²:

  $C_{ZL} = 0,83$

- if 850 N/mm² $\le \sigma_{H,lim} \le$ 1200 N/mm²:

  $$C_{ZL} = \frac{\sigma_{H,lim}}{4375} + 0,6357$$

- if $\sigma_{H,lim} > 1200$ N/mm²:

  $C_{ZL} = 0,91$

b) Speed factor Z_V

$$Z_V = C_{ZV} + \frac{2 \cdot (1,0 - C_{ZV})}{\sqrt{0,8 + \frac{32}{v}}}$$

where:

C_{ZV} : Constant for speed factor, equal to:

$C_{ZV} = C_{ZL} + 0,02$

c) Roughness factor Z_R

$$Z_R = \left(\frac{3}{R_{Z10}}\right)^{C_{ZR}}$$

where:

R_{Z10} : Mean relative peak-to-valley roughness for the gear pair, in µm, equal to:

$$R_{Z10} = R_{Zf}\left(\frac{10}{\rho_{red}}\right)^{1/3}$$

ρ_{red} : Relative radius of curvature, in mm, equal to:

$$\rho_{red} = \frac{0,5 \cdot d_{b1} \cdot d_{b2} \cdot \tan\alpha_{wt}}{d_{b1} + d_{b2}}$$

d_b being taken negative for internal gears

R_{Zf} : Mean peak-to-valley flank roughness for the gear pair, in µm, equal to:

$$R_{Zf} = \frac{R_{Zf1} + R_{Zf2}}{2}$$

C_{ZR} : Constant for roughness factor, equal to:

- if $\sigma_{H,lim} < 850$ N/mm²:

  $C_{ZR} = 0,15$

- if 850 N/mm² $\le \sigma_{H,lim} \le$ 1200 N/mm²:

  $$C_{ZR} = 0,32 - \frac{\sigma_{H,lim}}{5000}$$

- if $\sigma_{H,lim} > 1200$ N/mm²:

  $C_{ZR} = 0,08$

2.4.12 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability in the following cases:

a) Surface-hardened with through-hardened wheel

- if HB < 130:

  $$Z_W = 1,2 \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

- if 130 ≤ HB ≤ 470:

  $$Z_W = \left(1,2 - \frac{HB - 130}{1700}\right) \cdot \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

- if HB > 470:

  $$Z_W = \left(\frac{3}{R_{ZH}}\right)^{0,15}$$

where:

R_{ZH} : Equivalent roughness, in µm, equal to:

$$R_{ZH} = \frac{R_{Zf1}(10/\rho_{red})^{0,33} \cdot (R_{Zf1}/R_{Zf2})^{0,66}}{(\nu_{40} \cdot v/1500)^{0,33}}$$

ρ_{red} being the relative radius of curvature defined in [2.4.11].

b) Through-hardened pinion and wheel with pinion substantially harder than the wheel (in that case, the hardness factor is to be applied only to the wheel)

- if $HB_1 / HB_2 < 1,2$:

  $Z_W = 1,0$

- if $1,2 \le HB_1 / HB_2 \le 1,7$:

$$Z_W = 1 + \left(0,00898\frac{HB_1}{HB_2} - 0,00829\right) \cdot (u - 1,0\ )$$

- if $HB_1 / HB_2 > 1,7$:

  $Z_W = 1,0 + 0,00698\ (u - 1,0)$

Note 1: In any cases, $Z_W \ge 1$

Note 2: If $u > 20$, $u = 20$ is to be taken.

2.4.13 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value of Z_X to be used will be given special consideration by the Society depending on the material.

2.4.14 Safety factor for contact stress S_H

The values to be adopted for safety factor for contact stress S_H are given in Tab 18.

Table 18 : Safety factor for contact stress S_H

Type of installation		S_H
Main gears (propulsion)	single machinery	1,25
	duplicate machinery	1,25
Auxiliary gears		1,20

2.5 Calculation of tooth bending strength

2.5.1 General

The criterion for the tooth root bending strength is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F , defined in [2.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [2.5.8].

2.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_t}{b \cdot m_n} Y_F \cdot Y_S \cdot Y_\beta \cdot Y_B \cdot Y_{DT} \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_F : Tooth form factor, defined in [2.5.3]

Y_S : Stress correction factor, defined in [2.5.4]

Y_β : Helix angle factor, defined in [2.5.5]

Y_B : Rim thickness factor, defined in [2.5.6]

Y_{DT} : Deep tooth factor, defined in [2.5.7]

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

K_V : Dynamic factor (see [2.3.4])

$K_{F\beta}$: Face load distribution factor (see [2.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [2.3.6]).

When a shot peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

2.5.3 Tooth form factor Y_F (method B)

The tooth form factor Y_F takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact.

In the case of helical gears, the form factors are to be determined in the normal section, i.e. for the virtual spur gear with the virtual number of teeth z_n.

Y_F is to be determined separately for the pinion and the wheel, using the following formula:

$$Y_F = \frac{6\dfrac{h_{Fe}}{m_n}\cos\alpha_{Fen}}{\left(\dfrac{s_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where:

h_{Fe} : Bending moment arm, in mm:

- for external gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{3}-\theta\right) - \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

- for internal gears:

$$\frac{h_{Fe}}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{Fen})\frac{d_{en}}{m_n}\right] - \frac{1}{2}\left[z_n\cos\left(\frac{\pi}{6}-\theta\right) - \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

- for external gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3}-\theta\right) + \sqrt{3}\left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

- for internal gears:

$$\frac{s_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{6}-\theta\right) + \left(\frac{G}{\cos\theta} - \frac{\rho_{fPv}}{m_n}\right)$$

ρ_{fPv} : Fillet radius at the basic rack, in mm:

- for external gears:

$\rho_{fPv} = \rho_{a0}$

- for internal gears:

$$\rho_{fPv} = \rho_{a0} + m_n \cdot \frac{(x_2 + h_{fP}/m_n - \rho_{a0}/m_n)^{1,95}}{3,156 \cdot 1,036^{z_2}}$$

G : Parameter defined by the following formula:

$$G = \frac{\rho_{fPv}}{m_n} - \frac{h_{fP}}{m_n} + x$$

θ : Parameter defined by the following formula:

$$\theta = \frac{2G}{z_n}\tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by the following formulae:

- for external gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

- for internal gears:

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{6}$$

E : Parameter defined by the following formula:

$$E = \frac{\pi}{4}m_n - h_{fP}\tan\alpha_n + \frac{s_{pr}}{\cos\alpha_n} - (1-\sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fen} : Load direction angle:

$\alpha_{Fen} = \alpha_{en} - \gamma_e$

γ_e : Parameter defined by the following formula:

$$\gamma_e = \frac{0,5\ \pi + 2 \cdot \tan\alpha_n \cdot x}{z_n} + \mathrm{inv}\alpha_n - \mathrm{inv}\alpha_{en}$$

with inv, involute function, equal to:

inv $\alpha = \tau\alpha\nu\ \alpha - \alpha$

α_{en} : Form factor pressure angle:

$$\cos\alpha_{en} = \frac{d_{bn}}{d_{en}}$$

d_{bn} : Virtual base diameter, in mm:

$d_{bn} = d_n \cos\alpha_n$

with:

d_n : Virtual reference diameter, in mm:

$$d_n = \frac{d}{(\cos\beta_b)^2} = m_n z_n$$

d_{en} : Parameter defined by the following formula:

$$d_{en} = \frac{2z}{|z|}\sqrt{\left[\frac{\sqrt{d_{an}^{\ 2} - d_{bn}^{\ 2}}}{2} - \frac{\pi d \cos\beta \cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \frac{d_{bn}^{\ 2}}{4}}$$

with:

d_{an} : Virtual tip diameter, in mm:

$d_{an} = d_n + d_a - d$

$\varepsilon_{\alpha n}$: Virtual transverse contact ratio:

$$\varepsilon_{\alpha n} = \frac{\varepsilon_\alpha}{(\cos\beta_b)^2}$$

2.5.4 Stress correction factor Y_S (method B)

The stress correction factor Y_S is used to convert the nominal bending stress to local tooth root stress, assuming the load is applied at the outer point of a single pair tooth contact. It takes into account the influence of:

- the bending moment
- the proximity of the load application to the critical section.

Y_S is to be determined as follows:

$$Y_S = (1,2 + 0,13L)q_s^{\left(\frac{1}{1,21 + (2,3/L)}\right)}$$

where:

$$L = \frac{s_{Fn}}{h_{Fe}}$$

with s_{Fn} and h_{Fe} defined in [2.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [2.5.3]

Note 1: The notch parameter should be within the range:
$1 \le q_s < 8$

ρ_F : Radius of root fillet, in mm:

$$\frac{\rho_F}{m_n} = \frac{\rho_{fPv}}{m_n} + \frac{2G^2}{\cos\theta \cdot (|z_n| \cdot \cos^2\theta - 2G)}$$

2.5.5 Helix angle factor Y_β

The helix angle factor Y_β converts the tooth root stress of a virtual spur gear to that of the corresponding helical gear, taking into account the oblique orientation of the lines of mesh contact.

Y_β is to be determined as follows:

if $\varepsilon_\beta \le 1$ and $\beta \le 30°$: $Y_\beta = 1 - \varepsilon_\beta \beta / 120$

if $\varepsilon_\beta \le 1$ and $\beta > 30°$: $Y_\beta = 1 - 0,25\ \varepsilon_\beta$

if $\varepsilon_\beta > 1$ and $\beta \le 30°$: $Y_\beta = 1 - \beta / 120$

if $\varepsilon_\beta > 1$ and $\beta > 30°$: $Y_\beta = 0,75$

2.5.6 Rim thickness factor Y_B

The rim thickness factor Y_B is a simplified factor used to de-rate thin rimmed gears. For critically loaded applications, this method should be replaced by a more comprehensive analysis.

Y_B is to be determined as follows:

- for external gears:
  - when $s_R / h \ge 1,2$:

    $Y_B = 1,0$
  - when $1,2 > s_R / h > 0,5$:

$$Y_B = 1,6 \ \ln\left(2,242 \ \frac{h}{s_R}\right)$$

Note 1: $s_R / h \le 0,5$ is to be avoided.

- for internal gears:
  - when $s_R / m_n \ge 3$:

    $Y_B = 1,0$
  - when $3 > s_R / m_n > 1,75$:

$$Y_B = 1,15 \ \ln\left(8,324 \ \frac{m_n}{s_R}\right)$$

Note 2: $s_R / h \le 1,75$ is to be avoided.

2.5.7 Deep tooth factor Y_{DT}

The deep tooth factor Y_{DT} adjusts the tooth root stress to take into account high precision gears and contact ratios within the range $2,05 < \varepsilon_{\alpha n} \le 2,5$ (where $\varepsilon_{\alpha n}$ is defined in [2.5.3]).

Y_{DT} is to be determined as follows:

- if $\varepsilon_{\alpha n} > 2,5$ and $A \le 4$: $Y_{DT} = 0,7$
- if $2,05 < \varepsilon_{\alpha n} \le 2,5$ and $A \le 4$: $Y_{DT} = -0,666\ \varepsilon_{\alpha n} + 2,366$
- otherwise: $Y_{DT} = 1,0$

2.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE}	:	Endurance limit for tooth root bending stress, defined in [2.5.9]
Y_d	:	Design factor, defined in [2.5.10]
Y_{NT}	:	Life factor for tooth root bending stress, defined in [2.5.11]
$Y_{\delta relT}$	:	Relative notch sensitive factor, defined in [2.5.12]
Y_{RrelT}	:	Relative surface factor, defined in [2.5.13]
Y_X	:	Size factor for tooth root bending stress, defined in [2.5.14]
S_F	:	Safety factor for tooth root bending stress, defined in [2.5.15].

Table 19 : Constants A and B and limitations on surface hardness HB or HV

Material	Quality **(1)**	A	B (N/mm^2)	Hardness	x_{min} (N/mm^2)	x_{max} (N/mm^2)
St	ML	0,910	138	HB	110	210
	MQ	0,910	138	HB	110	210
	ME	0,772	294	HB	110	210
St (cast)	ML	0,626	124	HB	140	210
	MQ	0,626	124	HB	140	210
	ME	0,508	274	HB	140	210
GTS (perl.)	ML	0,700	154	HB	135	250
	MQ	0,700	154	HB	135	250
	ME	0,806	256	HB	175	250
GGG	ML	0,700	238	HB	175	300
	MQ	0,700	238	HB	175	300
	ME	0,760	268	HB	200	300
GG	ML	0,512	16	HB	150	240
	MQ	0,512	16	HB	150	240
	ME	0,400	106	HB	175	275
V (carbon steels)	ML	0,500	216	HV	115	215
	MQ	0,480	326	HV	115	215
	ME	0,566	404	HV	115	215
V (alloy steels)	ML	0,846	208	HV	200	360
	MQ	0,850	374	HV	200	360
	ME	0,716	462	HV	200	390
V (cast, carbon steels)	ML	0,448	234	HV	130	215
	MQ	0,448	234	HV	130	215
	ME	0,572	334	HV	130	215
V (cast, alloy steels)	ML	0,728	322	HV	200	360
	MQ	0,728	322	HV	200	360
	ME	0,712	372	HV	200	360
Eh	ML	0,000	624	HV	600	800
	MQ, > 25HRC lower	0,000	850	HV	660	800
	MQ, > 25HRC upper	0,000	922	HV	660	800
	MQ, > 35 HRC	0,000	1000	HV	660	800
	ME	0,000	1050	HV	660	800
IF	ML	0,610	152	HV	485	615
	MQ	0,276	580	HV	500	570
	ME	0,542	474	HV	500	615
NT (nitr.)	ML	0,000	540	HV	650	900
	MQ	0,000	840	HV	650	900
	ME	0,000	936	HV	650	900
NV (nitr.)	ML	0,000	516	HV	450	650
	MQ	0,000	726	HV	450	650
	ME	0,000	864	HV	450	650
NV (nitrocar.)	ML	0,000	448	HV	300	650
	MQ	1,306	188	HV	300	450
	ME	1,306	188	HV	300	450

(1) The requirements for each material quality are defined in ISO 6336-5.

2.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given, in N/mm², with the following formula, in relation to the type of steel employed and the heat treatment performed:

$\sigma_{FE} = A\,x + B$

where:

A, B : Constants determined in Tab 19

x : Surface hardness HB or HV, in N/mm². The limitations x_{min} and x_{max} on surface hardness are indicated in Tab 19.

Special consideration will be given to other values of σ_{FE}, depending on the material category and specification of the steel employed.

2.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit prestressing on the tooth root strength.

Y_d is to be determined as follows:

- for gears with occasional part load in reverse direction, such as main wheel in reverse gearboxes:
  $Y_d = 0,9$
- for idler gears (driven and driving tooth for each cycle i.e. alternating load):
  $Y_d = 0,7$
- for shrunk on pinions and wheel rims:
  $Y_d = 1 - \sigma_T / \sigma_{FE}$
  with:
  σ_{FE} : Endurance limit for tooth root bending stress (see [2.5.9])
  σ_T : Tangential stress induced by the shrinkage at the tooth root diameter.
  The maximum equivalent stress induced by the shrinkage in the inner diameter of the rim is not to exceed 80% of the yield strength of the rim material.
- otherwise: $Y_d = 1,0$

2.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

Table 20 : Life factor Y_{NT}

Material	Number of load cycles N_L	Y_{NT}
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast), Eh, IF	$N_L \le 10^3$ or static	2,5
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
GGG (ferr.), GG, NT (nitr.), NV (nitr.)	$N_L \le 10^3$ or static	1,6
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0
NV (nitrocar.)	$N_L \le 10^3$ or static	1,1
	$N_L = 3 \cdot 10^6$	1,0
	$N_L = 10^{10}$	0,85 up to 1,0

2.5.12 Relative notch sensitivity factor $Y_{\delta rel\,T}$

The relative notch sensitivity factor $Y_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$Y_{\delta relT}$ is to be determined as follows:

$$Y_{\delta relT} = \frac{1 + \sqrt{\rho' \cdot 0,2 \cdot (1 + 2q_s)}}{1 + \sqrt{\rho' \cdot 1,2}}$$

where:

q_s : Notch parameter, as defined in [2.5.4]

ρ' : Slip-layer thickness, in mm, defined in Tab 21.

Table 21 : Slip-layer thickness ρ'

Material	ρ' (mm)
GG, R_m = 150 N/mm²	0,3124
GG, GGG (ferr.) R_m = 300 N/mm²	0,3095
NT, NV	0,1005
St, R_e = 300 N/mm²	0,0833
St, R_e = 400 N/mm²	0,0445
V, GTS, GGG (perl. bai.), R_e = 500 N/mm²	0,0281
V, GTS, GGG (perl. bai.), R_e = 600 N/mm²	0,0194
V, GTS, GGG (perl. bai.), R_e = 800 N/mm²	0,0064
V, GTS, GGG (perl. bai.), R_e = 1000 N/mm²	0,0014
Eh, IF	0,0030

2.5.13 Relative surface factor $Y_{Rrel\ T}$

The relative surface factor $Y_{Rrel\ T}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $Y_{Rrel\ T}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

Table 22 : Relative surface factor $Y_{Rrel\ T}$

Material	Y_{RrelT}	
	$R_z < 0,1$	$0,1 \le R_z \le 40$
V, V (cast), GGG (perl.), GGG (bai.), Eh, IF	1,120	$1,674 - 0,529\ (R_z + 1)^{0,1}$
St	1,070	$5,306 - 4,203\ (R_z + 1)^{0,01}$
GG, GGG (ferr.), NT, NV	1,025	$4,299 - 3,259\ (R_z + 1)^{0,0058}$
Note 1: R_z : Mean peak-to-valley roughness, in µm: $R_z = 6\ R_a$ with R_a : Arithmetic mean roughness.		

2.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of the normal module m_n.

Table 23 : Size factor Y_X

Material	Normal module	Y_X
St, V, V (cast), GGG (perl.), GGG (bai.), GTS (perl.)	$m_n \le 5$	1,00
	$5 < m_n < 30$	$1,03 - 0,006\ m_n$
	$m_n \ge 30$	0,85
Eh, IF, NT, NV	$m_n \le 5$	1,00
	$5 < m_n < 25$	$1,05 - 0,01\ m_n$
	$m_n \ge 25$	0,80
GG, GGG (ferr.)	$m_n \le 5$	1,00
	$5 < m_n < 25$	$1,075 - 0,015\ m_n$
	$m_n \ge 25$	0,70

2.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

Table 24 : Safety factor for tooth root bending stress S_F

Type of installation		S_F
Main gears (propulsion)	single machinery	1,80
	duplicate machinery	1,60
Auxiliary gears		1,40

2.6 Calculation of scuffing resistance

2.6.1 General

The following calculations are requested for equipment running in supercritical domain, i.e. when N > 1,5 (see [2.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$(\Theta_{B,Max} - \Theta_{oil}) \leq 0{,}8\ (\Theta_S - \Theta_{oil})$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [2.6.2]

Θ_{oil} : Oil temperature, in °C

Θ_S : Scuffing temperature, in °C, defined in [2.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$(\Theta_S - \Theta_{B,Max}) \geq 30°C$

Other methods of determination of the scuffing resistance could be accepted by the Society.

2.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$\Theta_{B,Max} = \Theta_{Mi} - \Theta_{fl,Max}$

where:

Θ_{Mi} : Interfacial bulk temperature, in °C, defined in [2.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [2.6.3].

The flash temperature should be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

2.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G \cdot (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v^{0,5}}{a^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [2.6.4]

X_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [2.6.5]

X_J : Approach factor, defined in [2.6.6]

X_G : Geometry factor, defined in [2.6.7]

X_Γ : Load sharing factor, defined in [2.6.8]

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9].

2.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0{,}6 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}}\right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm, defined in [2.6.9]

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\ v \sin \alpha_{wt}$

with v not taken greater than 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u}{(1+u)^2} \cdot a \cdot \sin\alpha_{wt}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor, equal to:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2}\right)^{0,25}$$

Table 25 : Lubricant factor X_L

Type of lubricant	X_L **(1)**
Mineral oils	$X_L = 1,0\ \eta_{oil}^{\ -0,05}$
Water soluble polyglycols	$X_L = 0,6\ \eta_{oil}^{\ -0,05}$
Non water soluble polyglycols	$X_L = 0,7\ \eta_{oil}^{\ -0,05}$
Polyalfaolefins	$X_L = 0,8\ \eta_{oil}^{\ -0,05}$
Phosphate esters	$X_L = 1,3\ \eta_{oil}^{\ -0,05}$
Traction fluids	$X_L = 1,5\ \eta_{oil}^{\ -0,05}$
(1) η_{oil} is the dynamic viscosity at oil temperature Θ_{oil}.	

2.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel:

$$X_M = 1000\frac{E_r^{0,25}}{B_M}$$

where:

E_r : Reduced modulus of elasticity, in N/mm²:

$$E_r = \frac{2}{(1-\nu_1)/E_1 + (1-\nu_2)/E_2}$$

E_1, E_2 : Moduli of elasticity of pinion and wheel material, in N/mm²

ν_1, ν_2 : Poisson's ratios of pinion and wheel material

B_M : Mean thermal contact coefficient, in $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$, equal to:

$B_M = (B_{M1} + B_{M2}) / 2$

B_{Mi} : Thermal contact coefficient of pinion material (i = 1) and wheel material (i = 2), given in $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$ and equal to:

$B_{Mi} = (0,001\ \lambda_{Mi}\ \rho_{Mi}\ c_{Mi})^{0,5}$

An average value of 435 $N \cdot mm^{-1/2} \cdot m^{-1/2} \cdot s^{-1/2} \cdot K^{-1}$ for martensitic steels could be used when thermo-elastic coefficient is not known

λ_{Mi} : Heat conductivity of pinion material (i = 1) and wheel material (i = 2), in $N \cdot s^{-1} \cdot K^{-1}$

ρ_{Mi} : Density of pinion material (i = 1) and wheel material (i = 2), in $kg \cdot m^{-3}$

c_{Mi} : Specific heat per unit mass of pinion material (i = 1) and wheel material (i = 2), in $J \cdot kg^{-1} \cdot K^{-1}$.

2.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film. The approach factor at any point should be calculated according to the following formula:

- when pinion drives the wheel:
  - for $\Gamma \geq 0$:

    $X_J = 1$
  - for $\Gamma < 0$, provided that $X_J \geq 1$:

$$X_J = 1 + \frac{C_{eff} - C_{a2}}{50}\left(\frac{-\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$

- when wheel drives the pinion:
  - for $\Gamma \leq 0$:

    $X_J = 1$
  - for $\Gamma > 0$, provided that $X_J \geq 1$:

$$X_J = 1 + \frac{C_{eff} - C_{a1}}{50}\left(\frac{\Gamma}{\Gamma_E - \Gamma_A}\right)^3$$

where:

C_{eff} : Optimal tip relief, in µm:

$$C_{eff} = \frac{K_A K_\gamma F_t}{b \cdot \cos\alpha_t \cdot c_\gamma}$$

K_A : Application factor (see [2.3.2])

K_γ : Load sharing factor (see [2.3.3])

$c_{\alpha\gamma}$: Mesh stiffness, in N/(mm.µm) (see Tab 9)

C_{ai} : Tip relief of pinion or wheel, in µm

Γ : Parameter of the point on the line of action, defined in Tab 26

Γ_A : Parameter of the lower end point of the path of contact, defined in Tab 26

Γ_E : Parameter of the upper end point of the path of contact, defined in Tab 26.

2.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following conditions:

- for external gear pair:

$$X_G = 0{,}51\ X_{\alpha\beta}(u+1)^{0{,}5}\frac{\left|(1+\Gamma)^{0{,}5} - (1-\Gamma/u)^{0{,}5}\right|}{(1+\Gamma)^{0{,}25}(u-\Gamma)^{0{,}25}}$$

- for internal gear pair:

$$X_G = 0{,}51\ X_{\alpha\beta}(u-1)^{0{,}5}\frac{\left|(1+\Gamma)^{0{,}5} - (1+\Gamma/u)^{0{,}5}\right|}{(1+\Gamma)^{0{,}25}(u+\Gamma)^{0{,}25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1{,}22\ (\sin\alpha_{wt})^{0{,}25}\ (\cos\alpha_{wt})^{-0{,}5}\ (\cos\beta_b)^{0{,}25}$

Γ : Parameter of the point on the line of action, defined in Tab 26.

Table 26 : Parameter Γ on the line of action

Point	Γ
A : Lower end point of the path of contact	$\Gamma_A = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right)$
AU: Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0{,}2\sin\beta_b$
AB : Intermediate point between A and B	$\Gamma_{AB} = 0{,}5\ (\Gamma_A + \Gamma_B)$
B : Lower point of single pair tooth contact	$\Gamma_B = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1 - \frac{2\pi}{z_1\tan\alpha_{wt}}$
C : Point with parameter equal to 0	$\Gamma_C = 0$
M : Intermediate point between A and E	$\Gamma_M = 0{,}5\ (\Gamma_A + \Gamma_E)$
D : Upper point of single pair tooth contact	$\Gamma_D = -\frac{z_2}{z_1}\left(\frac{\tan\alpha_{a2}}{\tan\alpha_{wt}} - 1\right) + \frac{2\pi}{z_1\tan\alpha_{wt}}$
DE : Intermediate point between D and E	$\Gamma_{DE} = 0{,}5\ (\Gamma_D + \Gamma_E)$
EU : Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0{,}2\sin\beta_b$
E : Upper end point of the path of contact	$\Gamma_E = \frac{\tan\alpha_{a1}}{\tan\alpha_{wt}} - 1$

2.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

- for narrow helical gears ($\varepsilon_\gamma < 2$) with unmodified profiles:

  $X_\Gamma = X_{\Gamma,u}\, X_{but}$
- for narrow helical gears ($\varepsilon_\gamma < 2$) with profile modification:

  $X_\Gamma = X_{\Gamma,m}\, X_{but}$
- for wide helical gears ($\varepsilon_\gamma \geq 2$) with unmodified profiles:

  $$X_\Gamma = \frac{1}{\varepsilon_\alpha} X_{but}$$
- for wide helical gears ($\varepsilon_\gamma \geq 2$) with profile modification:

  $X_\Gamma = X_{\Gamma,wm}\, X_{but}$

where:

X_{but} : Buttressing factor:

- for $\Gamma < \Gamma_{AU}$:

  $$X_{but} = X_{butA} - \frac{\Gamma - \Gamma_A}{\Gamma_{AU} - \Gamma_A}(X_{butA} - 1)$$
- for $\Gamma_{AU} \leq \Gamma \leq \Gamma_{EU}$:

  $X_{but} = 1$
- for $\Gamma_{EU} < \Gamma$:

  $$X_{but} = X_{butE} - \frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{EU}}(X_{butE} - 1)$$

Note 1: X_{but} is to be taken equal to 1 if $C_{ai} \geq C_{eff}$

X_{butA} , X_{butE} : Buttressing factors at, respectively, lower and upper end points of the path of contact:

$X_{butA} = X_{butE} = 1 + 0{,}3\ \varepsilon_\beta$, provided that

$X_{butA} = X_{butE} < 1{,}3$

$X_{\Gamma,u}$: Load sharing factor for unmodified profiles:

- for $\Gamma < \Gamma_B$:

  $$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_B \leq \Gamma \leq \Gamma_D$:

  $X_{\Gamma,u} = 1$
- for $\Gamma_D < \Gamma$:

  $$X_{\Gamma,u} = \frac{A-3}{12} + \frac{1}{3}\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

Note 2: A is to be taken at least equal to 7.

$X_{\Gamma,m}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,m} \geq 0$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_{AB} \leq \Gamma < \Gamma_B$, provided that $X_{\Gamma,m} \leq 1$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$
- for $\Gamma_B \leq \Gamma \leq \Gamma_D$:

  $X_{\Gamma,m} = 1$
- for $\Gamma_D < \Gamma \leq \Gamma_{DE}$, provided that $X_{\Gamma,m} \leq 1$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a2}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$
- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,m} \geq 0$:

  $$X_{\Gamma,m} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{3} + \left(\frac{1}{3} + \frac{2}{3}\frac{C_{a1}}{C_{eff}}\right)\frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_D}$$

$X_{\Gamma,wm}$: Load sharing factor for profile modification:

- for $\Gamma < \Gamma_{AB}$, provided that $X_{\Gamma,wm} \geq 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a2}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a1} + (3\varepsilon_\alpha + 1)C_{a2}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}} \cdot \frac{\Gamma - \Gamma_A}{\Gamma_B - \Gamma_A}$$

- for $\Gamma_{AB} \leq \Gamma \leq \Gamma_{DE}$, provided that $X_{\Gamma,wm} \leq 1$:

$$X_{\Gamma,wm} = \frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)(C_{a1} + C_{a2})}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}}$$

- for $\Gamma_{DE} < \Gamma$, provided that $X_{\Gamma,wm} \geq 0$:

$$X_{\Gamma,wm} = \left(1 - \frac{C_{a1}}{C_{eff}}\right)\frac{1}{\varepsilon_\alpha} + \frac{(\varepsilon_\alpha - 1)C_{a2} + (3\varepsilon_\alpha + 1)C_{a1}}{2\varepsilon_\alpha(\varepsilon_\alpha + 1)C_{eff}} \cdot \frac{\Gamma_E - \Gamma}{\Gamma_E - \Gamma_{DE}}$$

C_{eff} : Optimal tip relief, in µm (see [2.6.6])

C_{ai} : Tip relief of pinion or wheel, in µm

Γ_i : Parameter of any point on the line of action, given in Tab 26.

2.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha} \cdot K_\gamma \cdot \frac{F_t}{b}$$

where:

K_A : Application factor (see [2.3.2])

K_V : Dynamic factor (see [2.3.4])

$K_{H\beta}$: Face load distribution factor (see [2.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [2.3.6])

K_γ : Load sharing factor (see [2.3.3]).

2.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. The following estimation could be used in general configurations:

$\Theta_{Mi} = \Theta_{oil} + 0{,}47\ X_S\ X_{mp}\ \Theta_{fl,m}$

where:

Θ_{oil} : Oil temperature, in °C

X_S : Lubrication system factor:

- for spray lubrication: $X_S = 1{,}2$
- for dip lubrication: $X_S = 1{,}0$
- for meshes with additional spray for cooling purpose: $X_S = 1{,}0$
- for gears submerged in oil, provided sufficient cooling: $X_S = 0{,}2$

X_{mp} : Multiple mating pinion factor:

$$X_{mp} = \frac{3 + n_p}{4}$$

n_p : Number of mesh in contact

$\Theta_{fl,m}$: Average flash temperature on the path of contact, in °C.
The average temperature should be calculated on at least ten equidistant points on the path line of contact between Γ_A and Γ_E.

2.6.11 Scuffing temperature Θ_S

The scuffing temperature Θ_S may be determined according to the following formula:

$\Theta_S = 80 + (0{,}85 + 1{,}4\ X_W)\ X_L\ (S_{FZG} - 1)^2$

where:

X_W : Structural factor given in Tab 27

X_L : Lubricant factor given in Tab 25

S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

Table 27 : Structural factor X_W

Material	X_W
Through-hardened steel	1,00
Phosphated steel	1,25
Copper-plated steel	1,50
Bath or gas nitrided steel	1,50
Hardened carburized steel, with austenite content less than 10%	1,15
Hardened carburized steel, with austenite content between 10% and 20%	1,00
Hardened carburized steel, with austenite content above 20%	0,85
Austenite steel (stainless steel)	0,45

3 Design of gears - Determination of the load capacity of bevel gears

3.1 Symbols, units, definitions

3.1.1 Symbols and units

The meaning of the main symbols used in this Article is specified below.

Other symbols introduced in connection with the definition of influence factors are defined in the appropriate sub-articles.

A : Flank tolerance class according to ISO 1328-1:2013

a_v : Virtual operating centre distance, in mm

a_{vn} : Virtual operating centre distance, in mm

b : Effective face width, in mm

d_e : Outer pitch diameter, in mm

d_{ext} : External diameter of shaft, in mm

d_{int} : Internal diameter of shaft, in mm

d_m : Mean pitch diameter, in mm

d_s : Shrinkage diameter of the wheel, in mm

d_v : Virtual reference diameter, in mm

d_{va} : Virtual tip diameter, in mm

d_{van} : Virtual tip diameter, in mm

d_{vb} : Virtual base diameter, in mm

d_{vbn} : Virtual base diameter, in mm

d_{vf} : Virtual root diameter, in mm

d_{vn} : Virtual reference diameter, in mm

F_{mt} : Nominal tangential load, in N

F_β : Total helix deviation, in µm

$g_{v\alpha}$: Length of path of contact, in mm

$g_{v\alpha n}$: Length of path of contact, in mm

h_{aP} : Basic rack addendum, in mm

h_{fP} : Basic rack dedendum, in mm

h_v : Virtual tooth depth, in mm

HB : Brinell hardness, in N/mm²

HPX : Rockwell hardness

Hς : Vickers hardness, in N/mm²

κ : Gear axial position on shaft with respect to the bearings

ℓ : Bearing span, in mm

ℓ_{bm} : Length of the line of contact, in mm

ℓ'_{bm} : Length of the line of contact, in mm

m_{et} : Outer transverse module, in mm

m_{mn} : Mean normal module, in mm

m_{mt} : Mean transverse module, in mm

n : Rotational speed, in rpm

Π : Transmitted power, in kW

p_{et} : Transverse base pitch, in mm
pr : Protuberance of the tool, in mm
q : Material allowance for finish machining, in mm
r_{c0} : Cutter radius, in mm
ρ_e : Outer cone distance, in mm
$P_{\varepsilon,\sigma}$: Minimum yield strength of the shaft material, in N/mm²
ρ_m : Mean cone distance, in mm
$P_{m,rim}$: Ultimate tensile strength of the rim material, in N/mm²
P_Z : Mean peak-to-valley roughness, in µm
P_{Zf} : Mean peak-to-valley flank roughness, in µm
s_R : Rim thickness, in mm
T : Transmitted torque, in kN·m
u : Reduction ratio
u_v : Virtual reduction ratio
v_{mt} : Linear speed at mean pitch diameter, in m/s
x_h : Addendum modification coefficient
x_S : Thickness modification coefficient
z : Number of teeth
z_v : Virtual number of teeth
z_{vn} : Virtual number of teeth
α_n : Normal pressure angle
α_{vt} : Virtual transverse pressure angle
β_m : Mean helix angle
β_{vb} : Virtual base helix angle
δ : Pitch angle
$\varepsilon_{v\alpha}$: Virtual transverse contact ratio
$\varepsilon_{v\alpha n}$: Virtual transverse contact ratio
$\varepsilon_{v\beta}$: Virtual overlap ratio
$\varepsilon_{v\gamma}$: Virtual total contact ratio
ν_{40} : Nominal kinematic viscosity of oil at 40°C, in mm²/s
ρ_{a0} : Tip radius of the tool, in mm
σ_F : Tooth root bending stress, in N/mm²
σ_{FE} : Endurance limit for tooth root bending stress, in N/mm²
σ_{FP} : Permissible tooth root bending stress, in N/mm²
σ_H : Contact stress, in N/mm²
$\sigma_{H,lim}$: Endurance limit for contact stress, in N/mm²
σ_{HP} : Permissible contact stress, in N/mm².

Subscripts:

- 1 for pinion, i.e. the gear having the smaller number of teeth
- 2 for wheel.

3.1.2 Geometrical definitions

In the calculation of surface durability, b is the minimum face width on the pitch diameter between pinion and wheel.

In tooth strength calculations, b_1 and b_2 are the face widths at the respective tooth roots. In any case, b_1 or b_2 are not to be taken greater than b by more than one module m_{mn} (in case of width of one gear much more important than the other).

a) General geometrical definitions

$$u = \frac{z_2}{z_1}$$

$$d_{ei} = \frac{z_i m_{mn}}{\cos\beta_m} + b_i \sin\delta_i$$

$$r_e = \frac{d_{e1}}{2\sin\delta_1} = \frac{d_{e2}}{2\sin\delta_2}$$

$$r_m = r_e - 0{,}5\ b$$

$$m_{et} = \frac{d_{e1}}{z_1} = \frac{d_{e2}}{z_2}$$

$$m_{mt} = \frac{r_m m_{et}}{r_e}$$

$$d_{mi} = \frac{z_i m_{mn}}{\cos\beta_m}$$

b) Geometrical definitions of virtual cylindrical gears in transverse section (suffix v)

$$z_{vi} = \frac{z_i}{\cos\delta_i}$$

$$u_v = \frac{z_{v2}}{z_{v1}}$$

$$\tan\alpha_{vt} = \frac{\tan\alpha_n}{\cos\beta_m}$$

$\sin\beta_{vb} = \sin\beta_m \cdot \cos\alpha_n$

$$d_{vi} = \frac{d_{mi}}{\cos\delta_i}$$

$a_v = 0{,}5\ (d_{v1} + d_{v2})$

$d_{v\alpha\iota} = d_{vi} + 2\ h_{aPi}$

$d_{v\beta\iota} = d_{vi} \cos\alpha_{vt}$

$d_{v\phi\iota} = d_{vi} + 2\ m_{mn}\ x_{hi} - 2\ h_{fPi}$

$h_{v\iota} = 0{,}5\ (d_{vai} - d_{vfi})$

$p_{\varepsilon\tau} = m_{mt}\ \pi\ \cos\alpha_{vt}$

$$g_{v\alpha} = 0{,}5\ \left(\sqrt{d_{va1}^2 - d_{vb1}^2} + \sqrt{d_{va2}^2 - d_{vb2}^2}\right) - a_v \sin\alpha_{vt}$$

$$\varepsilon_{v\alpha} = \frac{g_{v\alpha}}{p_{et}}$$

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{\pi m_{mn}}$$

$$\varepsilon_{v\gamma} = \sqrt{\varepsilon_{v\alpha}^2 + \varepsilon_{v\beta}^2}$$

- if $\varepsilon_{v\beta} < 1$:

$$\ell_{bm} = \frac{b\varepsilon_{v\alpha}}{\cos\beta_{vb} \cdot \varepsilon_{v\gamma}^2} \cdot \sqrt{\varepsilon_{v\gamma}^2 - (2-\varepsilon_{v\alpha})^2 \cdot (1-\varepsilon_{v\beta})^2}$$

- if $\varepsilon_{v\beta} \geq 1$:

$$\ell_{bm} = \frac{b\varepsilon_{v\alpha}}{\cos\beta_{vb} \cdot \varepsilon_{v\gamma}}$$

$\ell'_{bm} = \ell_{\beta\mu} \cos\beta_{vb}$

c) Geometrical definitions of virtual cylindrical gears in normal section (suffix vn)

$$z_{vni} = \frac{z_{vi}}{\cos\beta_m \cdot (\cos\beta_{vb})^2}$$

$d_{v\nu\iota} = m_{mn}\ \zeta_{v\nu\iota}$

$a_{vn} = 0{,}5\ (d_{vn1} + d_{vn2})$

$d_{v\alpha\nu\iota} = d_{vni} + 2\ h_{aPi}$

$d_{v\beta\nu\iota} = d_{vni} \cos\alpha_v$

$$g_{v\alpha n} = 0{,}5\ \left(\sqrt{d_{van1}^2 - d_{vbn1}^2} + \sqrt{d_{van2}^2 - d_{vbn2}^2}\right) - a_{vn}\sin\alpha_n$$

$$\varepsilon_{v\alpha n} = \frac{\varepsilon_{v\alpha}}{(\cos\beta_{vb})^2}$$

d) Definitions of transmissions characteristics

$$T_i = \frac{60}{2\pi} \cdot \frac{P}{n_i}$$

$$F_{mt} = \frac{P}{n_1} \cdot \frac{60}{\pi d_{m1}} \cdot 10^6$$

$$v_{mt} = \frac{\pi n_1}{60} \cdot \frac{d_{m1}}{10^3} = \frac{\pi n_2}{60} \cdot \frac{d_{m2}}{10^3}$$

$$F_{\beta i} = 2^{0,5 \cdot (Q_i - 5)} \cdot (0{,}1\ \cdot d_{vi}^{0,5} + 0{,}63\ \sqrt{b} + 4{,}2)$$

3.2 Principle

3.2.1

a) The following requirements apply to bevel spur or helical gears with external teeth, and provide a method for the calculation of the load capacity with regard to:

- the surface durability (contact stress)
- the tooth root bending stress.

The bevel gears for marine application are to comply with the following restrictions:

- $1,2 < \varepsilon_{v\alpha} < 2,5$
- $\beta_m < 30°$
- $s_R > 3,5\ m_{mn}$

The relevant formulae are provided in [3.4] and [3.5].

The influence factors common to the formulae are given in [3.3].

b) Gears, for which the conditions of validity of some factors or formulae are not satisfied, will be given special consideration by the Society.

c) Other methods of determination of load capacity will be given special consideration by the Society. Any alternative calculations are to comply with the ISO 6336 series standards.

3.3 General influence factors

3.3.1 General

General influence factors are defined in [3.3.2], [3.3.3], [3.3.4], [3.3.5] and [3.3.6]. Alternative values may be used provided they are derived from appropriate measurements.

3.3.2 Application factor K_A

The application factor K_A accounts for dynamic overloads from sources external to the gearing (driven and driving machines).

The values of K_A to be used are given in Tab 5.

3.3.3 Load sharing factor K_γ

The load sharing factor K_γ accounts for the uneven sharing of load on multiple path transmissions, such as epicyclic gears or tandem gears.

The values of K_γ to be used are given in Tab 6.

3.3.4 Dynamic factor K_v

The dynamic factor K_V accounts for the additional internal dynamic loads acting on the tooth flanks and due to the vibrations of the pinion and wheel.

The calculation of the dynamic factor K_V is defined in Tab 31, where:

N : Resonance ratio, i.e. ratio of the pinion speed to the resonance speed:

$N = n_1 / n_{E1}$, with:

n_{E1} : Resonance speed, in rpm, defined by the following formula:

$$n_{E1} = \frac{30000}{\pi \cdot z_1} \cdot \sqrt{\frac{c_\gamma}{m_{red}}}$$

where:

m_{red} : Reduced mass of gear pair, in kg/mm. Estimated calculation of m_{red} is given by the following formula:

$$m_{red} = \frac{\rho \cdot \pi}{8} \cdot \frac{d_{m1}^2}{(\cos\alpha_n)^2} \cdot \frac{u^2}{1+u^2}$$

ρ : Density of gearing material, equal to:

$\rho = 7,83 \cdot 10^6$ for steel

c_γ : Mesh stiffness, in N/(mm.µm):

$c_\gamma = 20\ C_F\ C_b$

C_F and C_b being the correction factors for non average conditions defined in Tab 28.

The value of N determines the range of vibrations:

- subcritical range, when $N \leq 0,75$
- main resonance range, when $0,75 < N < 1,25$

  This field is not permitted

- intermediate range, when $1,25 \le N \le 1,50$

  This field is normally to be avoided. Some alternative and more precise calculation could be accepted and special consideration will be given by the Society
- supercritical range, when $1,50 < N$.

3.3.5 Face load distribution factors $K_{H\beta}$ and $K_{F\beta}$

The face load distribution factors, $K_{H\beta}$ for contact stress and $K_{F\beta}$ for tooth root ending stress, account for the effects of non-uniform distribution of load across the face width.

a) The calculation of $K_{H\beta}$ is to be defined according to the mounting conditions of pinion and wheel:

- neither member cantilever mounted:

  $K_{H\beta} = 1,575 / C_b$
- one member cantilever mounted:

  $K_{H\beta} = 1,650 / C_b$
- both members cantilever mounted:

  $K_{H\beta} = 1,875 / C_b$

where C_b is the correction factor defined in Tab 28

b) $K_{F\beta}$ is to be determined using the following formula:

$K_{F\beta} = K_{H\beta} / K_{F0}$, with:

K_{F0} : Lengthwise curvature factor. It is to be taken above 1,0 and below 1,15 considering the following formula:

$$K_{F0} = 0,211 \cdot \left(\frac{r_{c0}}{r_m}\right)^{\frac{0,279}{\log(\sin\beta_m)}} + 0,789$$

3.3.6 Transverse load distribution factors $K_{H\alpha}$ and $K_{F\alpha}$

The transverse load distribution factors, $K_{H\alpha}$ for contact stress and $K_{F\alpha}$ for tooth root bending stress, account for the effects of pitch and profile errors on the transversal load distribution between two or more pairs of teeth in mesh.

The values of $K_{H\alpha}$ and $K_{F\alpha}$ are given in Tab 29.

Table 28 : Correction factors C_F and C_b

Conditions	Factors C_F and C_b
if $F_{mt}\ K_A / b_e \ge 100$ N/mm	$C_F = 1$
if $F_{mt}\ K_A / b_e < 100$ N/mm	$C_F = (F_{mt}\ K_A / b_e) / 100$
if $b_e / b \ge 0,85$	$C_b = 1$
if $b_e / b < 0,85$	$C_b = (b_e / b) / 0,85$
b_e : Effective face width, the real length of contact pattern. When b_e is not supplied, $b_e = 0,85\ b$ could be used.	

Table 29 : Transverse load factors $K_{H\alpha}$ and $K_{F\alpha}$

	Factors $K_{H\alpha}$ and $K_{F\alpha}$	Limitations
$\varepsilon_{v\gamma} \le 2$	$K_{H\alpha} = K_{F\alpha} = \frac{\varepsilon_{v\gamma}}{2} \cdot \left(0,9 + 0,4 \cdot \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}\right)$	$\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Z_{LS}^2} \ge K_{H\alpha} \ge 1$
$\varepsilon_{v\gamma} > 2$	$K_{H\alpha} = K_{F\alpha} = 0,9 + 0,4 \cdot \sqrt{\frac{2 \cdot (\varepsilon_{v\gamma} - 1)}{\varepsilon_{v\gamma}}} \cdot \frac{c_\gamma \cdot (f_{pt} - y_\alpha)}{F_{mtH}/b}$	$\frac{\varepsilon_{v\gamma}}{\varepsilon_{v\alpha} \cdot Y_\varepsilon} \ge K_{F\alpha} \ge 1$

Note 1:

c_γ : Mesh stiffness, in N/mm.µm, defined in [3.3.4]

$f_{\pi\tau}$: Larger value of the single pitch deviation of pinion or wheel, in µm.

Default value: $f_{pt} = 0,3\ (m_{mn} + 0,4\ |d_{bi}|^{0,5} + 4) \cdot 2^{0,5\ (Q_i - 5)}$

In case of optimum profile correction, f_{pt} is to be replaced by $f_{pt} / 2$

y_α : Running-in allowance, in µm, defined in Tab 30

$f_{\mu\tau H}$: Determinant tangential load at mid-face width on the reference cone, in N:

$F_{\mu\tau H} = F_{\mu\tau} \cdot K_A \cdot K_V \cdot K_{H\beta}$

Table 30 : Running-in allowance y_α

Material	y_α , in µm	Limitations
St, St (cast), GTS (perl.), GGG (perl.), GGG (bai.), V, V (cast)	$\frac{160}{\sigma_{H,\,lim}} f_{pt}$	• if 5 m/s < v ≤ 10 mm/s: $y_\alpha \leq 12800 / \sigma_{H,lim}$ • if 10 m/s < v: $y_\alpha \leq 6400 / \sigma_{H,lim}$
GGG (ferr.), GG	$0,275\ f_{pt}$	• if 5 m/s < v ≤ 10 mm/s: $y_\alpha \leq 22$ • if 10 m/s < v: $y_\alpha \leq 11$
Eh, IF, NT (nitr.), NV (nitr.), NV (nitrocar.)	$0,075\ f_{pt}$	$y_\alpha \leq 3$

Note 1: f_{pt} ισ δεφινεδ ιν Tab 29 ανδ $\sigma_{H,lim}$ is defined in [3.4.10].
Note 2: When material of the pinion differs from that of the wheel: $y_\alpha = 0,5\ (y_{\alpha 1} + y_{\alpha 2})$

Table 31 : Dynamic factor K_V

Resonance domain	Factor K_V
$N \leq 0,75$	$K_V = N\ (C_{V1}\ B_p + C_{V2}\ B_f + C_{V3}) + 1$
$N > 1,50$	$K_V = C_{V5}\ B_p + C_{V6}\ B_f + C_{V7}$

Note 1:

B_p : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:

$$B_p = \frac{c' f_{p,\,eff}}{K_A (F_{mt} / b)}$$

with:

c' : Single stiffness, in N/(mm·µm):
$c' = 14\ C_F\ C_b$, with C_F and C_b defined in Tab 28

$f_{\pi,\epsilon\phi\phi}$: Effective base pitch deviation, in µm:
$f_{\pi,\epsilon\phi\phi} = f_{\pi\tau} - y_\alpha$
with f_{pt} defined in Tab 29 and y_α defined in Tab 30

B_f : Non-dimensional parameter taking into account the effect of tooth deviations and profile modifications:
$B_f = B_p$

C_{V1} : Factor for pitch deviation effects:
$C_{v1} = 0,32$

C_{V2} : Factor for tooth profile deviation effects:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V2} = 0,34$
- if $2 < \varepsilon_\gamma$:

$$C_{V2} = \frac{0,57}{\varepsilon_\gamma - 0,3}$$

C_{V3} : Factor for cyclic variation effect in mesh stiffness:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V3} = 0,23$
- if $2 < \varepsilon_\gamma$:

$$C_{V3} = \frac{0,096}{\varepsilon_\gamma - 1,56}$$

C_{V5} : Factor equal to: $C_{V5} = 0,47$

C_{V6} : Factor:

- if $1 < \varepsilon_\gamma \leq 2$:
  $C_{V6} = 0,47$
- if $2 < \varepsilon_\gamma$:

$$C_{V6} = \frac{0,12}{\varepsilon_\gamma - 1,74}$$

C_{V7} : Factor:

- if $1 < \varepsilon_\gamma \leq 1,5$:
  $C_{V7} = 0,75$
- if $1,5 < \varepsilon_\gamma \leq 2,5$:
  $C_{V7} = 0,125\ \sin[\pi\ (\varepsilon_\gamma - 2)] + 0,875$
- if $2,5 < \varepsilon_\gamma$:
  $C_{V7} = 1$

3.4 Calculation of surface durability

3.4.1 General

The criterion for surface durability is based on the contact stress (hertzian pressure) σ_H on the pitch point or at the inner point of single pair contact.

The contact stress σ_H , defined in [3.4.2], is not to exceed the permissible contact stress σ_{HP} defined in [3.4.9].

3.4.2 Contact stress σ_H

The contact stress σ_H is to be determined as follows:

$$\sigma_H = \sigma_{H0} \cdot \sqrt{K_A \cdot K_\gamma \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha}}$$

where:

K_A : Application factor (see [3.3.2])

K_γ : Load sharing factor (see [3.3.3])

K_ς : Dynamic factor (see [3.3.4])

$K_{H\beta}$: Face load distribution factor (see [3.3.5])

$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])

$$\sigma_{H0} = Z_{M-B} \cdot Z_H \cdot Z_E \cdot Z_{LS} \cdot Z_\beta \cdot Z_K \cdot \sqrt{\frac{F_{mt}}{d_{v1} \cdot \ell_{bm}} \cdot \frac{u_v + 1}{u_v}}$$

with:

Z_{M-B} : Mid-zone factor, defined in [3.4.3]

Z_H : Zone factor, defined in [3.4.4]

Z_E : Elasticity factor, defined in [3.4.5]

$Z_{\Lambda\Sigma}$: Load-sharing factor, defined in [3.4.6]

Z_β : Helix angle factor, defined in [3.4.7]

Z_K : Bevel gear ratio factor, defined in [3.4.8].

3.4.3 Mid-zone factor Z_{M-B}

The mid-zone factor Z_{M-B} accounts for the difference of contact pressure between the pitch point and the determinant point of load application.

Z_{M-B} is to be determined as follows:

$$Z_{M-B} = \frac{\tan\alpha_{vt}}{\sqrt{\left[\sqrt{\frac{d_{va1}^2}{d_{vb1}^2}} - 1 - \left(F_1 \cdot \frac{\pi}{Z_{v1}}\right)\right] \cdot \left[\sqrt{\frac{d_{va2}^2}{d_{vb2}^2}} - 1 - \left(F_2 \cdot \frac{\pi}{z_{v2}}\right)\right]}}$$

where F_1 and F_2 are defined according to the following conditions:

- if $0 \le \varepsilon_{v\beta} < 1$:

  $F_1 = 2 + (\varepsilon_{v\alpha} - 2) \cdot \varepsilon_{v\beta}$

  $F_2 = 2\ \varepsilon_{v\alpha} - 2 + (2 - \varepsilon_{v\alpha}) \cdot \varepsilon_{v\beta}$

- if $\varepsilon_{v\beta} \ge 1$:

  $F_1 = \varepsilon_{v\alpha}$

  $F_2 = \varepsilon_{v\alpha}$

3.4.4 Zone factor Z_H

The zone factor Z_H accounts for the influence on the hertzian pressure of tooth flank curvature at the pitch point.

Z_H is to be determined as follows:

$$Z_H = 2 \cdot \sqrt{\frac{\cos\beta_{vb}}{\sin(2 \cdot \alpha_{vt})}}$$

3.4.5 Elasticity factor Z_E

The elasticity factor Z_E accounts for the influence of the metal properties (module of elasticity E and Poisson's ratio ν) on the hertzian pressure.

The values of Z_E to be used are given in [2.4.5].

3.4.6 Load-sharing factor Z_{LS}

The load-sharing factor Z_{LS} accounts for load sharing between two or more pairs of teeth.

Z_{LS} is to be determined as follows:

- if $\varepsilon_{v\gamma} > 2$ and $\varepsilon_{v\beta} > 1$:

$$Z_{LS} = \left\{1 + 2\left[1 - \left(\frac{2}{\varepsilon_{v\gamma}}\right)^{1,5}\right] \cdot \sqrt{1 - \frac{4}{\varepsilon_{v\gamma}^2}}\right\}^{-0,5}$$

- if $\varepsilon_{v\gamma} \le 2$:

  $Z_{LS} = 1$

- otherwise, an alternative calculation should be supplied and will be given special consideration by the Society.

3.4.7 Helix angle factor Z_β

The helix angle factor Z_β accounts for the influence of helix angle on the surface durability, allowing for such variables as the distribution of the load along the lines of contact.

Z_β is to be determined as follows:

$$Z_\beta = \frac{1}{\sqrt{\cos\beta_m}}$$

3.4.8 Bevel gear factor Z_K

The bevel gear factor Z_K is an empirical factor which accounts for the difference between bevel and cylindrical gears loading.

Z_K is to be determined as follows:

$Z_K = 0,8$

3.4.9 Permissible contact stress σ_{HP}

The permissible contact stress σ_{HP}, in N/mm², is to be determined separately for pinion and wheel, using the following formula:

$$\sigma_{HP} = \frac{\sigma_{H,lim}}{S_H} \cdot Z_{NT} \cdot Z_L \cdot Z_V \cdot Z_R \cdot Z_W \cdot Z_X$$

where:

$\sigma_{H,lim}$: Endurance limit for contact stress, defined in [3.4.10]

Z_{NT} : Life factor for contact stress, defined in [3.4.11]

Z_L, Z_V, Z_R: Lubrication, speed and roughness factors, respectively, defined in [3.4.12]

Z_Ω : Hardness ratio factor, defined in [3.4.13]

Z_Ξ : Size factor for contact stress, defined in [3.4.14]

Σ_H : Safety factor for contact stress, defined in [3.4.15].

3.4.10 Endurance limit for contact stress $\sigma_{H,lim}$

The endurance limit for contact stress $\sigma_{H,lim}$, in N/mm², is the limit of repeated contact stress which can be permanently endured.

The values to be adopted for $\sigma_{H,lim}$ are given in [2.4.9] in relation to the type of steel employed and the heat treatment performed.

3.4.11 Life factor for contact stress Z_{NT}

The life factor Z_{NT} accounts for the influence of limited service life on the permissible contact stress.

Some values of Z_{NT} are given in Tab 17 for information.

The value of Z_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.4.12 Lubrication factor Z_L, speed factor Z_V and roughness factor Z_R

The lubricant factor Z_L accounts for the influence of the type of the lubricant and the influence of its viscosity, the speed factor Z_V accounts for the influence of the pitch line velocity, and the roughness factor Z_R accounts for the influence of the surface roughness on the surface endurance capacity.

These factors are to be determined according to the formulae of [2.4.11], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculation of Z_V

ρ_{red} : Relative radius of curvature, in mm:

$$\rho_{red} = \frac{a_v \cdot \sin\alpha_{vt}}{\cos\beta_{vb}} \cdot \frac{u_v}{(1 + u_v)^2}$$

3.4.13 Hardness ratio factor Z_W

The hardness ratio factor Z_W accounts for the increase of the surface durability. This factor is to be determined according to the formulae of [2.4.12], using the following parameters:

ϖ_{mt} : Linear speed at mean pitch diameter, in m/s. It is to replace ϖ in the calculations

ρ_{red} : Relative radius of curvature, in mm, as defined in [3.4.12]

υ_ϖ : Virtual reduction ratio. It is to replace u in the calculations.

3.4.14 Size factor Z_X

The size factor Z_X accounts for the influence of tooth dimensions on permissible contact stress and reflects the non-uniformity of material properties.

Z_X is in general equal to 1.

The value Z_X to be used will be given special consideration by the Society depending on the material.

3.4.15 Safety factor for contact stress S_H

The values to be adopted for the safety factor for contact stress S_H are given in Tab 18.

3.5 Calculation of tooth bending strength

3.5.1 General

The criterion for tooth root bending stress is based on the local tensile stress at the tooth root in the direction of the tooth height.

The tooth root bending stress σ_F , defined in [3.5.2], is not to exceed the permissible tooth root bending stress σ_{FP} defined in [3.5.8].

3.5.2 Tooth root bending stress σ_F

The tooth root bending stress σ_F is to be determined as follows:

$$\sigma_F = \frac{F_{mt}}{b \cdot m_{mn}} \cdot Y_{Fa} \cdot Y_{Sa} \cdot Y_\varepsilon \cdot Y_{LS} \cdot Y_K \cdot K_A \cdot K_\gamma \cdot K_V \cdot K_{F\beta} \cdot K_{F\alpha}$$

where:

Y_{Fa} : Tooth form factor, defined in [3.5.3]

Y_{Sa} : Stress correction factor, defined in [3.5.4]

Y_ε : Contact ratio factor, defined in [3.5.5]

Y_{LS} : Load sharing factor, defined in [3.5.6]

Y_K : Bevel gear factor, defined in [3.5.7]

K_A : Application factor (see [3.3.2])

K_γ : Load sharing factor (see [3.3.3])

K_V : Dynamic factor (see [3.3.4])

$K_{F\beta}$: Face load distribution factor (see [3.3.5])

$K_{F\alpha}$: Transverse load distribution factor (see [3.3.6]).

When a shot-peening treatment of the tooth root is applied according to a process agreed by the Society, a reduction of the bending stress σ_F (depending on the material category, but without being over 10%) could be taken in consideration only for carburized case-hardened steel gears.

3.5.3 Tooth form factor Y_{Fa}

The tooth form factor Y_{Fa} takes into account the effect of the tooth form on the nominal bending stress, assuming the load applied at the outer point of a single pair tooth contact of the virtual cylindrical gears in normal section.

Y_{Fa} is to be determined separately for the pinion and for the wheel, using the following formula:

$$Y_{Fa} = \frac{6 \cdot \dfrac{h_{Fa}}{m_{mn}} \cdot \cos\alpha_{Fan}}{\left(\dfrac{S_{Fn}}{m_{mn}}\right)^2 \cdot \cos\alpha_n}$$

where:

h_{Fa} : Bending moment arm, in mm:

$$\frac{h_{Fa}}{m_{mn}} = \frac{1}{2}\left[(\cos\gamma_a - \sin\gamma_a \cdot \tan\alpha_{Fan}) \cdot \frac{d_{van}}{m_{mn}} - z_{vn} \cdot \cos\left(\frac{\pi}{3} - \theta\right) - \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)\right]$$

s_{Fn} : Tooth root chord at the critical section, in mm:

$$\frac{s_{Fn}}{m_{mn}} = z_{vn} \cdot \sin\left(\frac{\pi}{3} - \theta\right) + \sqrt{3} \cdot \left(\frac{G}{\cos\theta} - \frac{\rho_{a0}}{m_{mn}}\right)$$

G : Parameter defined by:

$$G = \frac{\rho_{a0}}{m_{mn}} - \frac{h_{fP}}{m_{mn}} + x_h$$

θ : Parameter defined by:

$$\theta = \frac{2 \cdot G}{z_{vn}} \cdot \tan\theta - H$$

This transcendental equation is to be calculated by iteration

H : Parameter defined by:

$$H = \frac{2}{z_{vn}} \cdot \left(\frac{\pi}{2} - \frac{E}{m_{mn}}\right) - \frac{\pi}{3}$$

E : Parameter defined by:

$$E = \left(\frac{\pi}{4} - x_s\right) \cdot m_{mn} - h_{fP} \cdot \tan\alpha_n$$

$$+ \frac{s_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{a0}}{\cos\alpha_n}$$

s_{pr} : Residual fillet undercut, in mm:

$s_{pr} = pr - q$

The parameters of the virtual gears are defined as follows:

α_{Fan} : Load direction angle:

$\alpha_{Fan} = \alpha_{an} - \gamma_a$

γ_a : Parameter defined by:

$$\gamma_a = \frac{0,5 \cdot \pi + 2(\tan\alpha_n \cdot x_h + x_s)}{z_{vn}} + \mathrm{inv}\alpha_n - \mathrm{inv}\alpha_{an}$$

with inv, involute function, equal to:

inv α = $\tau\alpha\nu$ $\alpha - \alpha$

α_{an} : Form factor pressure angle:

$$\cos\alpha_{an} = \frac{d_{vbn}}{d_{van}}$$

3.5.4 Stress correction factor Y_{Sa}

The stress correction factor Y_{Sa} is used to convert the nominal bending stress to local tooth root stress.

Y_{Sa} is to be determined as follows:

$$Y_{Sa} = (1,2 + 0,13L_a) \cdot q_s^{\frac{1}{1,21 + (2,3)/L_a}}$$

where:

$$L_a = \frac{s_{Fn}}{h_{Fa}}$$

with s_{Fn} and h_{Fa} defined in [3.5.3]

q_s : Notch parameter:

$$q_s = \frac{s_{Fn}}{2\rho_F}$$

with s_{Fn} defined in [3.5.3]

Note 1: The notch parameter should be within the range:

$1 \leq q_s < 8$

ρ_F : Fillet radius at contact point of 30° tangent, in mm:

$$\frac{\rho_F}{m_{mn}} = \frac{\rho_{a0}}{m_{mn}} + \frac{2G^2}{\cos\theta \cdot (z_{vn} \cdot \cos^2\theta - 2G)}$$

3.5.5 Contact ratio factor Y_ε

The contact ratio factor Y_ε converts the load application at the tooth tip to the decisive point of load application.

Y_ε is to be determined as follows:

- if $\varepsilon_{v\beta} \leq 1$:

$$Y_\varepsilon = 0,25 + \frac{0,75}{\varepsilon_{v\alpha}} - \varepsilon_{v\beta} \cdot \left(\frac{0,75}{\varepsilon_{v\alpha}} - 0,375\right)$$

- if $\varepsilon_{v\beta} > 1$:

$Y_\varepsilon = 0,625$

Note 1: A minimum of 0,625 should always be taken for Y_ε.

3.5.6 Load sharing factor Y_{LS}

The load sharing factor Y_{LS} accounts for load sharing between two or more pairs of teeth.

Y_{LS} is to be determined as follows:

$$Y_{LS} = Z_{LS}^2$$

3.5.7 Bevel gear factor Y_K

The bevel gear factor Y_K accounts for the difference between bevel and cylindrical gears loading.

Y_K is to be determined as follows:

$$Y_K = \left(\frac{1}{2} + \frac{\ell'_{bm}}{2b}\right)^2 \cdot \frac{b}{\ell'_{bm}}$$

3.5.8 Permissible tooth root bending stress σ_{FP}

The permissible tooth root bending stress σ_{FP} is to be determined separately for pinion and for wheel, using the following formula:

$$\sigma_{FP} = \frac{\sigma_{FE}}{S_F} \cdot Y_d \cdot Y_{NT} \cdot Y_{\delta relT} \cdot Y_{RrelT} \cdot Y_X$$

where:

σ_{FE}	:	Endurance limit for tooth root bending stress, defined in [3.5.9]
Ψ_{δ}	:	Design factor, defined in [3.5.10]
Ψ_{NT}	:	Life factor for tooth root bending stress, defined in [3.5.11]
$\Psi_{\delta relT}$	:	Relative notch sensitivity factor, defined in [3.5.12]
$\Psi_{P\rho\varepsilon lT}$	:	Relative surface factor, defined in [3.5.13]
Ψ_{Ξ}	:	Size factor for tooth root bending stress, defined in [3.5.14]
Σ_{Φ}	:	Safety factor for tooth root bending stress, defined in [3.5.15].

3.5.9 Endurance limit for tooth root bending stress σ_{FE}

The endurance limit for tooth root bending stress σ_{FE} is the local tooth root stress which can be permanently endured.

The values to be adopted for σ_{FE} are given in [2.5.9]] in relation to the type of steel employed and the heat treatment performed.

3.5.10 Design factor Y_d

The design factor Y_d takes into account the influence of load reversing and shrink fit pre-stressing on the tooth root strength.

Y_d is defined in [2.5.10].

3.5.11 Life factor Y_{NT}

The life factor Y_{NT} accounts for the influence of limited service life on the permissible tooth root bending stress.

Some values of Y_{NT} are given in Tab 20 for information.

The value Y_{NT} to be used will be given special consideration by the Society depending on the equipment's arrangement and use.

3.5.12 Relative notch sensitivity factor $\Psi_{\delta relT}$

The relative notch sensitivity factor $\Psi_{\delta relT}$ indicates the extent to which the theoretically concentrated stress lies above the fatigue endurance limit.

$\Psi_{\delta relT}$ is to be determined according to [2.5.12].

3.5.13 Relative surface factor $\Psi_{P\rho\varepsilon lT}$

The relative surface factor $\Psi_{P\rho\varepsilon lT}$ takes into account the dependence of the root strength on the surface condition on the tooth root fillet (roughness).

The values to be adopted for $\Psi_{P\rho\varepsilon lT}$ are given in Tab 22 in relation to the type of steel employed.

They are valid only when scratches or similar defects deeper than 12 R_a are not present.

3.5.14 Size factor Y_X

The size factor Y_X takes into account the decrease of the strength with increasing size.

The values to be adopted for Y_X are given in Tab 23 in relation to the type of steel employed and the value of normal module m_{mn}.

3.5.15 Safety factor for tooth root bending stress S_F

The values to be adopted for the safety factor for tooth root bending stress S_F are given in Tab 24.

3.6 Calculation of scuffing resistance

3.6.1 General

The following calculations are requested for equipment running in supercritical domain i.e. when N > 1,5 (see [3.3.4]).

The criterion for scuffing resistance is based on the calculation of the flash temperature method. According to this method, the risk of scuffing is assessed as a function of the properties of gear material, the lubricant characteristics, the surface roughness of tooth flanks, the sliding velocities and the load.

The interfacial contact temperatures are calculated as the sum of the interfacial bulk temperature of the moving interface and the fluctuating flash temperature of the moving faces in contact.

The maximum value of the interfacial contact temperature reduced by oil temperature is not to exceed 0,8 times the scuffing temperature reduced by oil temperature:

$(\Theta_{B,Max} - \Theta_{o\iota\lambda}) \leq 0{,}8\ (\Theta_{\sigma} - \Theta_{o\iota\lambda})$

where:

$\Theta_{B,Max}$: Maximum contact temperature along the path of contact, in °C, defined in [3.6.2]

$\Theta_{o\iota\lambda}$: Oil temperature, in °C

Θ_{Σ} : Scuffing temperature, in °C, defined in [3.6.11].

Additionally, the difference between the scuffing temperature and the contact temperature along the path is not to be below 30°C:

$(\Theta_{\sigma} - \Theta_{B,Max}) \geq 30°C$

Other methods of determination of the scuffing resistance could be accepted by the Society.

3.6.2 Contact temperature Θ_B

The maximum contact temperature $\Theta_{B,Max}$ along the path of contact, in °C, is calculated as follows:

$\Theta_{B,Max} = \Theta_{Mi} + \Theta_{fl,Max}$

where:

$\Theta_{M\iota}$: Interfacial bulk temperature, in °C, defined in [3.6.10]

$\Theta_{fl,Max}$: Maximum flash temperature along the path of contact, in °C, defined in [3.6.3].

The flash temperature is to be calculated on at least ten points along the path of contact and the maximum of these values has to be used for the calculation of maximum contact temperature.

3.6.3 Flash temperature Θ_{fl}

The flash temperature Θ_{fl} at any point along the path of contact, in °C, is calculated with the following formula:

$$\Theta_{fl} = \mu_m \cdot X_M \cdot X_J \cdot X_G (X_\Gamma \cdot w_{Bt})^{0,75} \cdot \frac{v_{mt}^{0,5}}{r_m^{0,25}}$$

where:

μ_m : Mean coefficient of friction, defined in [3.6.4]

Ξ_M : Thermo-elastic factor, in $K \cdot N^{-3/4} \cdot s^{-1/2} \cdot m^{-1/2} \cdot mm$, defined in [3.6.5]

Ξ_J : Approach factor, defined in [3.6.6]

Ξ_G : Geometry factor, defined in [3.6.7]

Ξ_Γ : Load sharing factor, defined in [3.6.8]]

ω_{Bt} : Transverse unit load, in N/mm, defined in [3.6.9].

3.6.4 Mean coefficient of friction μ_m

An estimation of the mean coefficient of friction μ_m of common working conditions could be used with the following formula:

$$\mu_m = 0,06 \cdot \left(\frac{w_{Bt}}{v_{g\Sigma C} \cdot \rho_{relC}}\right)^{0,2} \cdot X_L \cdot X_R$$

where:

w_{Bt} : Transverse unit load, in N/mm (see [2.6.9])

$v_{g\Sigma C}$: Sum of tangential velocities in pitch point, in m/s:

$v_{g\Sigma C} = 2\ v_{mt} \sin \alpha_{vt}$

with the maximum value of v_{mt} equal to 50 m/s

ρ_{relC} : Transverse relative radius of curvature, in mm:

$$\rho_{relC} = \frac{u \cdot \tan\delta_1 \cdot \tan\delta_2}{\tan\delta_1 + u \cdot \tan\delta_2} \cdot r_m \cdot \sin\alpha_{vt}$$

X_L : Lubricant factor, given in Tab 25

X_R : Roughness factor:

$$X_R = \left(\frac{R_{zf1} + R_{zf2}}{2}\right)^{0,25}$$

3.6.5 Thermo-elastic factor X_M

The thermo-elastic factor X_M accounts for the influence of the material properties of pinion and wheel.

The values to be adopted for X_M are given in [2.6.5] in relation to the gear material characteristics.

3.6.6 Approach factor X_J

The approach factor X_J takes empirically into account an increased scuffing risk in the beginning of the approach path, due to mesh starting without any previously built up oil film.

The values to be adopted for X_J are given in [2.6.6] in relation to the gear material characteristics.

3.6.7 Geometry factor X_G

The geometry factor X_G is calculated according to the following formula:

$$X_G = 0,51 X_{\alpha\beta}\left(\frac{1}{\tan\delta_1} + \frac{1}{\tan\delta_2}\right)^{0,25} \frac{\left|(1+\Gamma)^{0,5} - \left(1 + \Gamma\dfrac{\tan\delta_1}{\tan\delta_2}\right)^{0,5}\right|}{(1+\Gamma)^{0,25} \cdot \left(1 - \Gamma\dfrac{\tan\delta_1}{\tan\delta_2}\right)^{0,25}}$$

where:

$X_{\alpha\beta}$: Angle factor, equal to:

$X_{\alpha\beta} = 1,22\ (\sin\alpha_{vt})^{0,25} \cdot (\cos\alpha_{vt})^{-0,5} \cdot (\cos\beta_{vb})^{0,25}$

Γ : Parameter of the point on the line of action, defined in Tab 32.

3.6.8 Load sharing factor X_Γ

The load sharing factor X_Γ accounts for the load sharing of succeeding pairs of meshing teeth. It is defined as a function of the value of the parameter in the line of action, increasing at the approach path of transverse double contact.

The values to be adopted for X_Γ are given in [2.6.8].

The parameter of the line of action Γ to be used is given in Tab 32.

Table 32 : Parameter Γ on the line of action

Point	Γ
A : Lower end point of the path of contact	$\Gamma_A = -\dfrac{\tan\delta_2}{\tan\delta_1}\left(\dfrac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right)$
AU : Lower end point of buttressing effect	$\Gamma_{AU} = \Gamma_A + 0,2 \sin\beta_{vb}$
AB : Intermediate point between A and B	$\Gamma_{AB} = 0,5\ (\Gamma_A + \Gamma_B)$
B : Lower point of single pair tooth contact	$\Gamma_B = \dfrac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1 - \dfrac{2\pi \cdot \cos\delta_1}{z_1 \tan\alpha_{vt}}$
C : Point with parameter equal to 0	$\Gamma_C = 0$
M : Intermediate point between A and E	$\Gamma_M = 0,5\ (\Gamma_A + \Gamma_E)$
D : Upper point of single pair tooth contact	$\Gamma_D = -\dfrac{\tan\delta_2}{\tan\delta_1}\left(\dfrac{\tan\alpha_{a2}}{\tan\alpha_{vt}} - 1\right) + \dfrac{2\pi \cdot \cos\delta_1}{z_1 \tan\alpha_{vt}}$
DE : Intermediate point between D and E	$\Gamma_{DE} = 0,5\ (\Gamma_D + \Gamma_E)$
EU : Upper end point of buttressing effect	$\Gamma_{EU} = \Gamma_E - 0,2 \sin\beta_{vb}$
E : Upper end point of the path of contact	$\Gamma_E = \dfrac{\tan\alpha_{a1}}{\tan\alpha_{vt}} - 1$
Note 1: $\alpha_{\alpha i}$: Transverse tip pressure angle of pinion and wheel, in rad: $\cos\alpha_{ai} = \dfrac{\cos\alpha_{vt}}{1 + 2h_{f0i} \cdot (\cos\delta_i)/d_{mi}}$	

3.6.9 Transverse unit load w_{Bt}

The transverse unit load w_{Bt} is calculated according to the following formula:

$$w_{Bt} = K_A \cdot K_V \cdot K_{H\beta} \cdot K_{H\alpha} \cdot K_\gamma \cdot \frac{F_{mt}}{b}$$

where:

K_A : Application factor (see [3.3.2])

K_V : Dynamic factor (see [3.3.4])
$K_{H\beta}$: Face load distribution factor (see [3.3.5])
$K_{H\alpha}$: Transverse load distribution factor (see [3.3.6])
K_γ : Load sharing factor (see [3.3.3]).

3.6.10 Interfacial bulk temperature Θ_{Mi}

The interfacial bulk temperature Θ_{Mi} may be suitably averaged from the two overall bulk temperatures of the teeth in contact, Θ_{M1} and Θ_{M2}. An estimation of Θ_{Mi} , given in [2.6.10], could be used in general configurations.

3.6.11 Scuffing temperature Θ_σ

The scuffing temperature Θ_S may be determined according to the following formula:

$$\Theta_S = 80 + (0,85 + 1,4\ X_W) \cdot X_L \cdot (S_{FZG} - 1)^2$$

where:

X_W : Structural factor given in Tab 27
X_L : Lubricant factor given in Tab 25
S_{FZG} : Load stage where scuffing occurs, according to gear tests, such as Ryder, FZG-Ryder, FZG L-42 or FZG A/8 3/90.

4 Design and construction - except tooth load capacity

4.1 Materials

4.1.1 General

a) Forged, rolled and cast materials used in the manufacturing of shafts, couplings, pinions and wheels are to comply with the requirements of NR216 Materials and Welding.
b) Materials other than steels will be given special consideration by the Society.

4.1.2 Steels for pinions and wheel rims

a) Steels intended for pinions and wheels are to be selected considering their compatibility in service. In particular, for through-hardened pinion / wheel pairs, the hardness of the pinion teeth is to exceed that of the corresponding wheel. For this purpose, the minimum tensile strength of the pinion material is to exceed that of the wheel by at least 15%.
b) The minimum tensile strength of the core is not to be less than:
   - 750 N/mm^2 for case-hardened teeth
   - 800 N/mm^2 for induction-hardened or nitrided teeth.

4.2 Teeth

4.2.1 Manufacturing accuracy

a) The teeth design flank tolerance class of propulsion machinery gearing, as defined by ISO 1328-1:2013, is not to exceed 4. A lower tolerance class (i.e. ISO 1328-1:2013 class higher than 4) may be accepted for auxiliary machinery gearing and for particular cases of propulsion machinery gearing of auxiliary ships subject to special consideration by the owner.
b) Where the quality class of the gear is indicated by the gear Manufacturer according to another Standard accepted by the Society, the corresponding accuracy of teeth is to be to the satisfaction of the Society.
c) Mean roughness (R_a) of shaved or ground teeth is not to exceed 0,7 μm.
d) Wheels are to be cut by cutters with a method suitable for the expected type and quality. Whenever necessary, the cutting and grinding is to be carried out in a temperature controlled environment.

4.2.2 Tooth root

Teeth are to be well faired and rounded at the root. The fillet radius at the root of the teeth, within a plane normal to the teeth, is to be not less than 0,25 m_n.

Profile-grinding of gear teeth is to be performed in such a way that no notches are left in the fillet.

4.2.3 Tooth tips and ends

a) All sharp edges on the tips and ends of gear teeth are to be removed after cutting and finishing of teeth.
b) Where the ratio b/d exceeds 0,3, the ends of pinion and wheel are to be chamfered to an angle between 45 and 60 degrees. The chamfering depth is to be at least equal to 1,5 m_n.

4.2.4 Surface treatment

a) The hardened layer on surface-hardened gear teeth is to be uniform and extended over the whole tooth flank and fillet.
b) Where the pinions and the toothed portions of the wheels are case-hardened and tempered, the teeth flanks are to be ground while the bottom lands of the teeth remain only case-hardened. The superficial hardness of the case-hardened zone is to be at least equal to 56 C Rockwell units.

c) Where the pinions and the toothed part of the wheel are case hardened, the thickness of the hardened layer after finish grinding is to be at least equal to the following value:

$$T = \sqrt{0,5 \cdot m_n + 1,1} - (0,7)$$

Thickness of the hardened layer for case hardening is the depth, measured normally to the tooth flank surface, where the local hardness falls below the value of 52,5 HRC (550 HV).

d) Where the pinions and the toothed portions of the wheels are nitrided, the hardened layer is to comply with Tab 33.

e) The use of other processes of superficial hardening of the teeth, such as flame hardening, will be given special consideration, in particular as regards the values to be adopted for $\sigma_{H,lim}$ and σ_{FE}.

Table 33 : Characteristics of the hardened layer for nitrided gears

Type of steel	Minimum thickness of hardened layer (mm)**(1)**	Minimum hardness (HV)
Nitriding steel	0,6	500 (at 0,25 mm depth)
Other steels	0,3	450 (surface)

(1) Depth of the hardened layer to core hardness.
When the grinding of nitrided teeth is performed, the depth of the hardened layer to be taken into account is the depth after grinding.

4.3 Wheels and pinions

4.3.1 General

Wheel bodies are to be so designed that radial deflections and distorsions under load are prevented, so as to ensure a satisfactory meshing of teeth.

4.3.2 Welding

a) Where welding is employed for the construction of wheels, the welding procedure is to be submitted to the Society for approval. Welding processes and their qualification are to comply with NR216 Materials and Welding.

b) Stress relieving treatment is to be performed after welding.

c) Examination of the welded joints is to be performed by means of magnetic particle or dye penetrant tests to the satisfaction of the Surveyor. Suitable arrangements are to be made to permit the examination of the internal side of the welded joints.

4.3.3 Shrink-fits

a) The shrink fit assembly of wheel body and shaft is to be designed with a safety factor against slippage of not less than $2,8 \cdot K_a$.
For different type of drives the value to be adopted will be specially considered.

b) The shrink fit assembly of wheel rim and body is to be designed with a safety factor against slippage of not less than 5.

Note 1: The manufacturer is to ensure that the maximum torque transmitted during the clutch engagement does not exceed the nominal torque by more than 20%.

c) The shrink-fit assembly is to take into account the thermal expansion differential between the shrunk-on parts in the service conditions.

4.3.4 Bolting

The bolting assembly of:

- rim and wheel body
- wheel body and shaft,

is to be designed according to Ch 1, Sec 7, [2.5.1].

The nuts are to be suitably locked by means other than welding.

4.4 Shafts and bearings

4.4.1 General

Shafts and their connections, in particular flange couplings and shrink-fits connections, are to comply with the provisions of Ch 1, Sec 7.

4.4.2 Pinion and wheel shafts

The minimum diameter of pinion and gear wheel shafts is not to be less than the value d_S, in mm, given by the following formula:

$$d_S = \left\{ \left[\left(10,2 + \frac{28000}{R_{S,min}} \right) T \right]^2 + \left[\frac{170000}{412 + R_{s,min}} M \right]^2 \right\}^{\frac{1}{6}} \left(\frac{1}{1 - K_d{}^4} \right)^{\frac{1}{3}}$$

where:

$R_{S,min}$: Minimum yield strength of the shaft material, in N/mm^2

T : Nominal torque transmitted by the shaft, in Nm

M : Bending moment on the shaft, in Nm

K_d : Coefficient having the following values:

- for solid shafts: $K_d = 0$
- for hollow shafts, K_d is equal to the ratio of the hole diameter to the outer shaft diameter.

  Where $K_d \le 0,3$: $K_d = 0$ may be taken.

Note 1: The values of d_S, T and M refer to the cross-section of the shaft concerned.

Note 2: In correspondence of keyways d_S shall be increased by 10%.

As an alternative to the above given formula, the Society may accept direct strength calculations showing that the equivalent stress represented in a diagram average stress vs. alternate stress falls below the lines defined by the points having coordinates:

$(R_m;0), (0;\sigma_{fa}/1,5)$

and

$(0,8 \cdot R_s;0), (0;0,8 \cdot R_s)$

where σ_{fa} is the pure alternate bending fatigue limit for a survival probability not less than 80%.

4.4.3 Quill shafts

The minimum diameter of quill shafts subject to torque only is not to be less than the value d_{QS}, in mm, given by the following formula:

$$d_{QS} = \left[\left(7,65 + \frac{27000}{R_{S,min}}\right) \cdot \frac{T}{1 - K_d^{\,4}}\right]^{\frac{1}{3}}$$

$R_{S,min}$ and K_d being defined in [4.4.2].

4.4.4 Bearings

a) Thrust bearings and their supports are to be so designed as to avoid detrimental deflections under load.

b) Life duration of bearings L_{10h} calculated according to ISO 281-1, is not be less than 40000 hours. Shorter durations may be accepted on the basis of the actual load time distribution, and subject to the agreement of the owner.

4.5 Casings

4.5.1 General

Gear casings are to be of sufficient stiffness such that misalignment, external loads and thermal effects in all service conditions do not adversely affect the overall tooth contact.

4.5.2 Welded casings

a) Carbon content of steels used for the construction of welded casings is to comply with the provisions of NR216 Materials and Welding.

b) The welded joints are to be so arranged that welding and inspection can be performed satisfactorily. They are to be of the full penetration type.

c) Welded casings are to be stress-relieved after welding.

4.5.3 Openings

Access or inspection openings of sufficient size are to be provided to permit the examination of the teeth and the structure of the wheels.

4.6 Lubrication

4.6.1 General

a) Manufacturers are to take care of the following points:

- reliable lubrication of gear meshes and bearings is ensured:
  - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
  - for all angles stated in Ch 1, Sec 1, [2.4]
- in multi-propellers plants and a transient black-out, provision is to be made to ensure lubrication of gears likely to be affected by windmilling.

b) Lubrication by means other than oil circulation under pressure will be given special consideration.

4.6.2 Pumps

a) Gears intended for propulsion or other essential services independent gearbox are to be provided with at least 2 lubricating pumps, so arranged as to maintain a sufficient lubrication of the gearbox in the whole speed range in case of failure of one pump. At least one of the pumps is not to be mechanically driven by the gearbox.

One of the two lubricating pumps could be a common one for the two gearboxes if they are located in the same compartment.

b) In the case of gears having a transmitted power not exceeding 375 kW one of the pumps mentioned in a) may be a spare pump ready to be connected to the reduction gear lubricating oil system, provided disassembling and reassembling operations can be carried out on board in a short time.

c) Provisions are to be made to maintain a sufficient lubrication of the gearbox in:

- black-out conditions, and
- in any operating conditions mentioned in the ship specification.

4.6.3 Filtration

a) Forced lubrication systems are to be fitted with a device which efficiently filters the oil in the circuit.

b) When fitted to gears intended for propulsion machinery or machinery driving electric propulsion generators, such filters are to be so arranged that they can be easily cleaned without stopping the lubrication of the machines.

4.7 Control and monitoring

4.7.1 Gears are to be provided with the alarms and safeguards listed in Tab 34.

Table 34 : Reduction gears / reversing gears

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by start	Stop
Lubricating oil temperature		local					
Lubricating oil pressure		local					
	L **(1)**			x			
Oil tank level		local					
(1) May be omitted in case of restricted navigation notation							

5 Installation

5.1 General

5.1.1 Manufacturers and shipyards are to take care directly that stiffness of gear seating and alignment conditions of gears are such as not to adversely affect the overall tooth contact and the bearing loads under all operating conditions of the ship.

5.2 Fitting of gears

5.2.1 Means such as stoppers or fitted bolts are to be arranged in the case of gears subject to propeller thrust. However, where the thrust is transmitted by friction and the relevant safety factor is not less than 2, such means may be omitted.

6 Certification, inspection and testing

6.1 General

6.1.1

a) Inspection and testing of shafts and their connections (flange couplings, hubs, bolts, pins) are to be carried out in accordance with the provisions of Ch 1, Sec 7.

b) For inspection of welded joints of wheels, refer to [4.3.2].

6.2 Workshop inspection and testing

6.2.1 Testing of materials

Chemical composition and mechanical properties are to be tested in accordance with the applicable requirements of NR216 Materials and Welding, Chapter 5 for the following items:

- pinions and wheel bodies
- rims
- plates and other elements intended for propulsion gear casings of welded construction.

6.2.2 Testing of pinion and wheel forgings

a) Mechanical tests of pinions and wheels are to be carried out in accordance with:
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.6] for normalised and tempered or quenched and tempered forgings
   - NR216 Materials and Welding, Ch 5, Sec 5, [1.7] for surface-hardened forgings.

b) Non-destructive examination of pinion and wheel forgings is to be performed in accordance with NR216 Materials and Welding, Ch 5, Sec 5, [1.8].

6.2.3 Balancing test

Rotating components, in particular gear wheel and pinion shaft assemblies with the coupling part attached, are to undergo a static balancing test.

Propulsion gear wheels and pinion shaft assemblies having a speed in excess of 150 rpm are also to undergo a dynamic balancing test after finish machining; the residual imbalance shall be as small as possible and anyway, is not exceed the Grade 2,5 according to ISO 1940.

Auxiliary gear wheels and pinion shaft assemblies are also to undergo a dynamic balancing test after finish machining, when

$n^2 \cdot d > 1,5 \,.\, 10^9$

the residual imbalance shall not exceed the Grade 2,5 according to ISO 1940.

6.2.4 Verification of cutting accuracy

Examination of the accuracy of tooth cutting is to be performed in the presence of the Surveyor. Records of measurements of errors, tolerances and clearances of teeth are to be submitted at the request of the Surveyor.

6.2.5 Meshing test

a) A tooth meshing test is to be performed in the presence of the Surveyor. This test is to be carried out at a load sufficient to ensure tooth contact, with the journals located in the bearings according to the normal running conditions. Before the test, the tooth surface is to be coated with a thin layer of suitable coloured compound.

b) The results of such test are to demonstrate that the tooth contact is adequately distributed on the length of the teeth. Strong contact marks at the end of the teeth are not acceptable. In case the test is carried out at full load, the contact pattern shall meet with the one requested under Ch 1, Sec 16, Tab 1.

c) In case of helix modification or crowning the tooth meshing test is to be performed before these corrections will be carried out.

d) A permanent record of the tooth contact is to be made for the purpose of subsequent checking of alignment following installation on board.

6.2.6 Hydrostatic tests

a) Hydraulic or pneumatic clutches are to be hydrostatically tested before assembly to 1,5 times the maximum working pressure.

b) Pressure piping, pumps casings, valves and other fittings are to be hydrostatically tested in accordance with the requirements of Ch 1, Sec 10, [19].

Section 7 Main Propulsion Shafting

1 General

1.1 Application

1.1.1 This Section applies to shafts, couplings, clutches and other shafting components transmitting power for main propulsion. In addition, main propulsion machinery components are to comply with the requirements listed in Tab 1.

Table 1 : Rule requirements for main propulsion component

Item		Reference
Power transmission equipment	Diesel engines	Ch 1, Sec 2
	Turbines	Ch 1, Sec 4 Ch 1, Sec 5
	Propellers	Ch 1, Sec 8
	Gear	Ch 1, Sec 6
	Thrusters	Ch 1, Sec 13
Shaft line analysis	Shaft alignment	Ch 1, Sec 7
	Torsional vibration	Ch 1, Sec 9

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 2 for approval.

Plans of power transmitting parts and shaft liners listed in Tab 2 are to include the relevant material specifications.

Table 2 : Documentation to be submitted

No.	Document (drawings, calculations, etc.)
1	Shafting arrangement **(1)**
2	Thrust shaft
3	Intermediate shafts
4	Propeller shaft
5	Shaft liners, relevant manufacture and welding procedures, if any
6	Couplings and coupling bolts
7	Flexible couplings **(2)**
8	Sterntube
9	Details of sterntube glands
10	Oil piping diagram for oil lubricated propeller shaft bearings
11	Shaft alignment calculation, see also [3.3]

(1) This drawing is to show the entire shafting, from the main engine coupling flange to the propeller. The location of the thrust block, and the location and number of shafting bearings (type of material and length) are also to be shown.

(2) The Manufacturer of the elastic coupling is also to submit the following data:
- allowable mean transmitted torque (static) for continuous operation
- maximum allowable shock torque
- maximum allowable speed of rotation
- maximum allowable values for radial, axial and angular misalignment

In addition, when the torsional vibration calculation of main propulsion system is required (see Ch 1, Sec 9), the following data are also to be submitted:
- allowable alternating torque amplitude and power loss for continuous operation, as a function of frequency and/or mean transmitted torque
- static and dynamic stiffness, as a function of frequency and/or mean transmitted torque
- moments of inertia of the primary and secondary halves of the coupling
- damping coefficient or damping capability
- properties of rubber components
- for steel springs of couplings: chemical composition and mechanical properties of steel employed.

2 Design and construction

2.1 Materials

2.1.1 General

The use of other materials or steels having values of tensile strength exceeding the limits given in [2.1.2], [2.1.3] and [2.1.4] will be considered by the Society in each case.

2.1.2 Shaft materials

Where shafts may experience vibratory stresses close permissible stresses for transient operation (see Ch 1, Sec 9), the materials are to have a specified minimum ultimate tensile strength Rm of 500 N/mm^2. Otherwise materials having a specified minimum ultimate tensile strength Rm of 400 N/mm^2 may be used.

For use in the following formulae in this Section, Rm is limited as follows:

- for carbon and carbon manganese steels, Rm is not exceed 760 N/mm^2
- for alloy steels, Rm is not to exceed 800 N/mm^2
- for propeller shafts, Rm is not to exceed 600 N/mm^2 (for carbon, carbon manganese and alloy steels).

Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions are not acceptable when derived from the formulae given in this Section unless the Society verifies that the materials exhibit similar fatigue life as conventional steels (see Ch 1, App 4).

2.1.3 Couplings, flexible couplings, hydraulic couplings

Non-solid-forged couplings and stiff parts of elastic couplings subjected to torque are to be of forged or cast steel, or nodular cast iron.

Rotating parts of hydraulic couplings may be of grey cast iron, provided that the peripheral speed does not exceed 40m/s.

2.1.4 Coupling bolts

Coupling bolts are to be of forged, rolled or drawn steel.

In general, the value of the tensile strength of the bolt material R_{mB} is to comply with the following requirements:

- $R_m \leq R_{mB} \leq 1,7\ R_m$
- $R_{mB} \leq 1000$ N/mm^2.

2.1.5 Shaft liners

Liners are to be of metallic corrosion resistant material complying with the applicable requirements of NR216 Materials and Welding with the approved specification, if any; in the case of liners fabricated in welded lengths, the material is to be recognised as suitable for welding.

In general, they are to be manufactured from castings.

For small shafts, the use of liners manufactured from pipes instead of castings may be considered.

Where shafts are protected against contact with seawater not by metal liners but by other protective coatings, the coating procedure is to be approved by the Society.

2.1.6 Sterntubes

Sterntubes are to comply with the requirements of Pt B, Ch 8, Sec 2, [6.7].

2.2 Shafts - Scantling

2.2.1 General

The provisions of this sub-article apply to propulsion shafts such as an intermediate and propeller shafts of traditional straight forged design and which are driven by rotating machines such as diesel engines, turbines or electric motors.

For shafts that are integral to equipment, such as for gear boxes, podded drives, electrical motors and/or generators, thrusters, turbines and which in general incorporate particular design features, additional criteria in relation to acceptable dimensions have to be taken into account. For the shafts in such equipment, the provisions of this sub-article apply only to shafts subject mainly to torsion and having traditional design features. Other shafts will be given special consideration by the Society.

2.2.2 Alternative calculation methods

Alternative calculation methods may be considered by the Society. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections.

Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions.

2.2.3 Shaft diameters

The diameter of intermediate shafts, thrust shafts and propellers shafts is not to be less than that determined from the following formula:

$$d = F \cdot k \cdot \left[\frac{P}{n \cdot (1 - Q^4)} \cdot \frac{560}{R_m + 160}\right]^{1/3}$$

where:

d : Minimum required diameter in mm

Q : Factor equal to d_i / d_o , where:

d_i : Actual diameter of the shaft bore, in mm (to be taken as 0 for solid shafts)

d_o : Outside diameter of the shaft, in mm.

Note 1: Where $d_i \le 0{,}4\ d_o$, Q may be taken as 0.

F : Factor for type of propulsion installation equal to:

- 95 for intermediate and thrusts shafts in turbine installations, diesel installations with hydraulic (slip type) couplings and electric propulsion installations
- 100 for all other diesel installation and all propeller shafts.

k : Factor for the particular shaft design features, see Tab 3

n : Speed of rotation of the shaft, in revolution per minute, corresponding to power P

P : Maximum continuous power of the propulsion machinery for which the classification is requested, in kW

R_m : Specified minimum tensile strength of the shaft material, in N/mm², see [2.1.2].

The diameter of the propeller shaft located forward of the inboard stern tube seal may be gradually reduced to the corresponding diameter required for the intermediate shaft using the minimum specified tensile strength of the propeller shaft in the formula and recognising any limitations given in [2.1.2].

Note 2: Transitions of diameters are to be designed with either a smooth taper or a blending radius equal to the change in diameter.

Table 3 : Values of factor k

For intermediate shafts with						For thrust shafts external to engines		propeller shafts		
straight sections and integral coupling flange**(1)**	shrink fit coupling**(2)**	keyway, tapered connection**(3)(4)**	keyway, cylindrical connection**(3)(4)**	radial hole**(5)**	longitudinal slots**(6)**	on both sides of thrust collar**(1)**	in way of bearing when a roller bearing is used	flange mounted or keyless taper fitted propellers**(7)**	key fitted propellers**(7)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	1,10	1,10	1,10	1,20	1,10	1,10	1,22	1,26	1,15

(1) The fillet radius is to be in accordance with the provisions of [2.5.1].

(2) k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in [2.2.3] Note 2.

(3) At a distance of not less than 0,2 d_o from the end of the keyway the shaft diameter may be reduced to the diameter calculated with k = 1,0.

(4) Keyways are to be in accordance with the provisions of [2.5.5].

(5) Diameter of the radial bore is not to exceed 0,3 d_o.

(6) Subject to limitations as $\ell/d_o < 0{,}8$ and $d_i/d_o < 0{,}7$ and $e/d_o > 0{,}15$, where:

ℓ : slot length in mm

e : slot width in mm

The end rounding of the slot is not to be less than e/2. an edge rounding should preferably be avoided as this increases the stress concentration slightly.

The k value is valid for 1, 2, 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(7) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2,5 times the required diameter.

2.3 Liners

2.3.1 General

Metal liners or other protective coatings approved by the Society are required where propeller shafts are not made of corrosion-resistant material.

Metal liners are generally to be continuous; however, discontinuous liners, i.e. liners consisting of two or more separate lengths, may be accepted by the Society on a case by case basis, provided that:

- they are fitted in way of all supports
- the shaft portion between liners, likely to come into contact with sea water, is protected with a coating of suitable material with characteristics, fitting method and thickness approved by the Society.

2.3.2 Scantling

The thickness of metal liners fitted on propeller shafts or on intermediate shafts inside sterntubes is to be not less than the value t, in mm, given by the following formula:

$$t = \frac{d + 230}{32}$$

where:

d : Actual diameter of the shaft, in mm.

Between the sternbushes, the above thickness t may be reduced by 25%.

The shrinkage induced equivalent stress in the liner is not exceed 70% of liner yield strength; a calculation in this respect is to be submitted.

2.4 Aft bearings

2.4.1 General

The bearings are to be so designed and lubricated as to withstand the continuous operation of the propulsion plant at the minimum rotating speed mentioned in the ship specification.

2.4.2 Oil lubricated aft bearings of antifriction metal

a) The length of the two aft most bearings lined with white metal or other antifriction metal and with oil glands of a type approved by the Society is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above, provided the nominal bearing pressure is not more than 0,8 N/mm^2, as determined by static bearing reaction calculations taking into account shaft and propeller weight, as exerting solely on the aft bearing, divided by the projected area of the shaft.

   However, the minimum bearing length is to be not less than 1,5 times its actual inner diameter.

2.4.3 Oil lubricated aft bearings of synthetic rubber, reinforced resin or plastic material

a) For bearings of synthetic rubber, reinforced resin or plastic material which are approved by the Society for use as oil lubricated sternbush bearings, the length of the two aft most bearings is to be not less than twice the rule diameter of the shaft in way of the bearing.

b) The length of the bearing may be less than that given in (a) above provided the nominal bearing pressure is not more than 0,6 N/mm^2, as determined according to [2.4.2], item b).

   However, the minimum length of the bearing is to be not less than 1,5 times its actual inner diameter.

   Where the material has proven satisfactory testing and operating experience, consideration may be given to an increased bearing pressure.

c) Synthetic materials for application as oil lubricated stern tube bearings are to be of an approved type.

2.4.4 Water lubricated aft bearings

a) The length of the two aft most bearings is to be not less than 4 times the rule diameter of the shaft in way of the bearing.

b) For a bearing of synthetic material, consideration may be given to a bearing length less than 4 times, but in no case less than 2 times, the rule diameter of the shaft in way of the bearing, provided the bearing design and material is substantiated by experiments to the satisfaction of the Society.

c) Synthetic materials for application as water lubricated stern tube bearings are to be type approved by the Society.

2.4.5 Water circulation system

For water lubricated bearings, means are to be provided to ensure efficient water circulation. In case of open loop systems, the sea water suction is normally to be from a sea chest.

The water grooves on the bearings are to be of ample section such as to ensure efficient water circulation and be scarcely affected by wear-down, particularly for bearings of the plastic type.

The shut-off valve or cock controlling the water supply is to be fitted direct to the stuffing box bulkhead or in way of the water inlet to the sterntube, when this is fitted forward of such bulkhead.

2.5 Couplings

2.5.1 Flange couplings

a) Flange couplings of intermediate and thrust shafts and the flange of the forward coupling of the propeller shaft are to have a thickness not less than 0,2 times the rule diameter of the solid intermediate shaft and not less than the coupling bolt diameter calculated for a tensile strength equal to that of the corresponding shaft.

The fillet radius at the base of solid forged flanges is to be not less than 0,08 times the actual shaft diameter.

The fillet may be formed of multi-radii in such a way that the stress concentration factor will not be greater than that for a circular fillet with radius 0,08 times the actual shaft diameter.

For non-solid forged flange couplings, the above fillet radius is not to cause a stress in the fillet higher than that caused in the solid forged flange as above.

Fillets are to have a smooth finish and are not to be recessed in way of nuts and bolt heads.

b) Where the propeller is connected to an integral propeller shaft flange, the thickness of the flange is to be not less than 0,25 times the rule diameter of the aft part of the propeller shaft. The fillet radius at the base of the flange is to be not less than 0,125 times the actual diameter.

The strength of coupling bolts of the propeller boss to the flange is to be equivalent to that of the aft part of the propeller shaft.

c) Non-solid forged flange couplings and associated keys are to be of a strength equivalent to that of the shaft.

They are to be carefully fitted and shrunk on to the shafts, and the connection is to be such as to reliably resist the vibratory torque and astern pull.

d) For couplings of intermediate and thrust shafts and for the forward coupling of the propeller shaft having all fitted coupling bolts, the coupling bolt diameter in way of the joining faces of flanges is not to be less than the value d_B, in mm, given by the following formula:

$$d_B = 0,65 \cdot \left[\frac{d^3 \cdot (R_m + 160)}{n_B \cdot D_C \cdot R_{mB}}\right]^{0,5}$$

where:

d	:	Rule diameter of solid intermediate shaft, in mm
n_B	:	Number of fitted coupling bolts
D_C	:	Pitch circle diameter of coupling bolts, in mm
R_m	:	Value of the minimum tensile strength of intermediate shaft material taken for calculation of d, in N/mm^2
R_{mB}	:	Value of the minimum tensile strength of coupling bolt material, in N/mm^2. Where, in compliance with [2.1.1], the use of a steel having R_{mB} in excess of the limits specified in [2.1.4] is allowed for coupling bolts, the value of R_{mB} to be introduced in the formula is not exceed the above limits.

e) Flange couplings with non-fitted coupling bolts may be accepted on the basis of the calculation of bolt tightening, bolt stress due to tightening, and assembly instructions.

To this end, the torque based on friction between the mating surfaces of flanges is not to be less than 2,8 times the transmitted torque, assuming a friction coefficient for steel on steel of 0,18. In addition, the bolt stress due to tightening in way of the minimum cross-section is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2 proof stress ($R_{p\,0,2}$), of the bolt material.

Transmitted torque has the following meanings:

- For main propulsion systems powered by diesel engines fitted with slip type or high elasticity couplings, by turbines or by electric motors: the mean transmitted torque corresponding to the maximum continuous power P and the relevant speed of rotation n, as defined under [2.2.3].
- For main propulsion systems powered by diesel engines fitted with couplings other than those mentioned in (a): the mean torque above increased by 20% or by the torque due to torsional vibrations, whichever is the greater.

The value 2,8 above may be reduced to 2,5 in the following cases:

- ships having two or more main propulsion shafts
- when the transmitted torque is obtained, for the whole functioning rotational speed range, as the sum of the nominal torque and the alternate torque due to the torsional vibrations, calculated as required in Ch 1, Sec 9.

2.5.2 Shrunk couplings

Non-integral couplings which are shrunk on the shaft by means of the oil pressure injection method or by other means may be accepted on the basis of the calculation of shrinking and induced stresses, and assembly instructions.

To this end, the force due to friction between the mating surfaces is not to be less than 2,8 times the total force due to the transmitted torque and thrust.

The value of 2,8 above may be reduced to 2,5 in the cases specified under [2.5.1], item e)

The values of 0,14 and 0,18 will be taken for the friction coefficient in the case of shrinking under oil pressure and dry shrink fitting, respectively.

In addition, the equivalent stress due to shrinkage determined by means of the von Mises-Hencky criterion in the points of maximum stress of the coupling is not to exceed 0,8 times the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the material of the part concerned.

The transmitted torque is that defined under item e) of [2.5.1].

For the determination of the thrust, see Ch 1, Sec 8, [3.1.2].

2.5.3 Other couplings

Types of couplings other than those mentioned in [2.5.1] and [2.5.2] above will be specially considered by the Society.

2.5.4 Flexible couplings

a) The scantlings of stiff parts of flexible couplings subjected to torque are to be in compliance with the requirements of Article [2].

b) For flexible components, the limits specified by the Manufacturer relevant to static and dynamic torque, speed of rotation and dissipated power are not to be exceeded.

c) Where all the engine power is transmitted through one flexible component only (ships with one propulsion engine and one shafting only), the flexible coupling is to be fitted with a torsional limit device or other suitable means to lock the coupling should the flexible component break.

   In stiff transmission conditions with the above locking device, a sufficiently wide speed range is to be provided, free from excessive torsional vibrations, such as to enable safe navigation and steering of the ship. As an alternative, a spare flexible element is to be provided on board.

2.5.5 Propeller shaft keys and keyways

a) Keyed connections are in general not to be used in installations with a barred speed range.

b) Keyways

   Keyways on the propeller shaft cone are to comply with the following requirements (see Fig 1).

   Keyways are to have well rounded corners, with the forward end faired and preferably spooned, so as to minimize notch effects and stress concentrations.

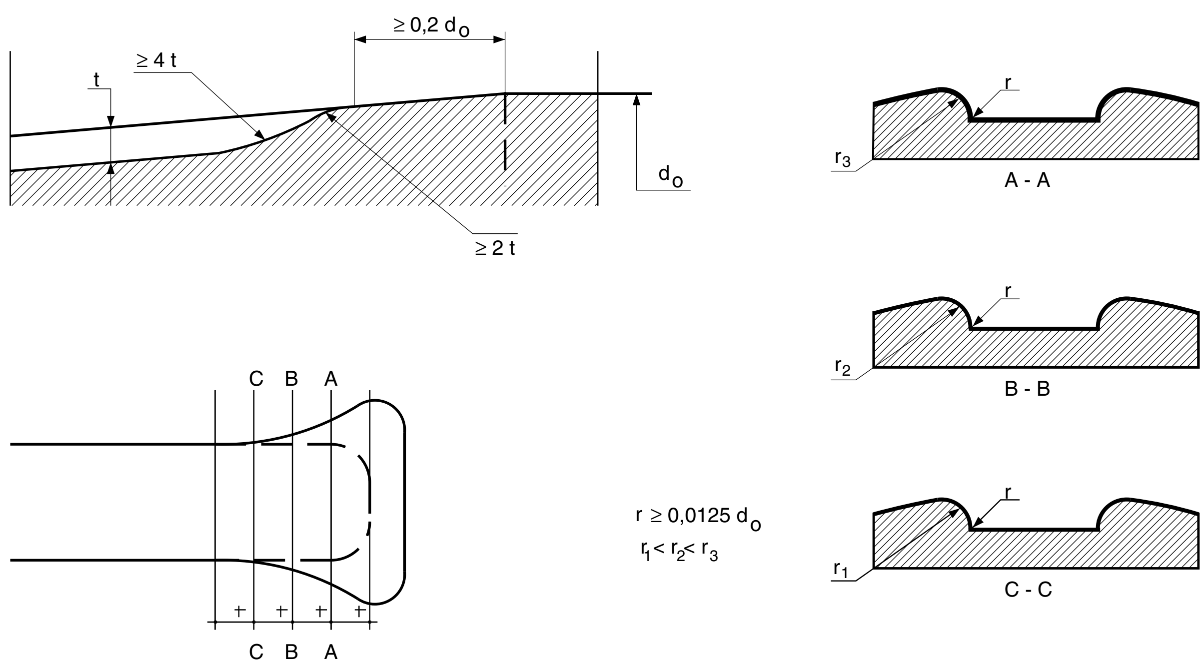
   The fillet radius at the bottom of the keyway is to be not less than 1,25% of the actual propeller shaft diameter at the large end of the cone.

   The distance from the large end of the propeller shaft cone to the forward end of the key is to be not less than 20% of the actual propeller shaft diameter in way of the large end of the cone.

   Key securing screws are not to be located within the first one-third of the cone length from its large end; the edges of the holes are to be carefully faired.

Note 1: Different scantlings may be accepted, provided that at least the same reduction in stress concentration is ensured.

Figure 1 : Details of forward end of propeller shaft keyway



c) Keys

The sectional area of the key subject to shear stress is to be not less than the value A, in mm², given by the following formula:

$$A = 0{,}4 \cdot \frac{d^3}{d_{PM}}$$

where:

d : Rule diameter, in mm, of the intermediate shaft calculated in compliance with the requirements of [2.2.3], assuming:

$R_m = 400\ N/mm^2$

d_{PM} : Actual diameter of propeller shaft at mid-length of the key, in mm.

The edges of the key are to be rounded.

2.6 Design of oil control systems for clutches

2.6.1 Separate oil systems intended for the control of clutches are to include at least two power pumps, of such a capacity as to maintain normal control with any one pump out of action.

2.6.2 In the case of propulsion plants comprising:

- more than one shaft line with the clutches fitted with their own control system, or
- one engine with an output not exceeding 220 kW

one of the pumps mentioned in [2.6.1] may be a spare pump ready to be connected to the oil control system, provided disassembling and reassembling operations can be carried out on board in a short time.

2.6.3 However, when the propulsion plant comprises one or more engines, each with an output not exceeding 220 kW, the standby or spare pump may be omitted for the clutches provided that they are so designed as to be fixed mechanically in the "clutched" position and that the capacity of the starting means ensures the number of starts required in such conditions.

2.7 Monitoring

2.7.1 General

In addition to those given in this item, the requirements of Part C, Chapter 3 apply.

2.7.2 Propeller shaft monitoring

For the assignment of the propeller shaft monitoring system notation, see Pt E, Ch 5, Sec 2.

2.7.3 Indicators

The local indicators for main propulsion shafting to be installed on ships of 500 gross tonnage and upwards without automation notations are given in Tab 4. For monitoring of engines, turbines, gears, controllable pitch propellers and thrusters, see Ch 1, Sec 2, Ch 1, Sec 4, Ch 1, Sec 6, Ch 1, Sec 8 and Ch 1, Sec 13, respectively.

The indicators listed in Tab 4 are to be fitted at a normally attended position.

Table 4 : Shafting and clutches of propulsion machinery

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Temperature of each shaft thrust bearing (non applicable for ball or roller bearings)	H		X				
Stern tube bush oil gravity tank level	L						
Clutches lubricating oil temperature	H		X				
Clutches oil tank level	L						

3 Arrangement and installation

3.1 General

3.1.1 The installation is to be carried out according to the instructions of the component Manufacturer or approved documents, when required.

3.1.2 The installation of sterntubes and/or associated non-shrunk bearings is subject to approval of procedures and materials used.

3.1.3 The joints between liner parts are not to be located in way of supports and sealing glands.

Metal liners are to be shrunk on to the shafts by pre-heating or forced on by hydraulic pressure with adequate interference; dowels, screws or other means of securing the liners to the shafts are not acceptable.

3.1.4 When shaft line is crossing bulkheads, crossing devices are to be fitted enabling to keep characteristics of bulkhead regarding watertightness and fire integrity with a motionless shaft line. Design of these devices is to be submitted to the Society.

Fire integrity of the crossing may be achieved by fitting of local water spraying system on each side of the bulkhead.

Automatised systems are to be provided with additional manual control.

Controls for systems involved in achieving watertightness and fire integrity are to be operable from outside the impacted compartments.

3.2 Protection of propeller shaft against corrosion

3.2.1 The propeller shaft surface between the propeller and the sterntube, and in way of propeller nut, is to be suitably protected in order to prevent any entry of sea water, unless the shaft is made of austenitic stainless steel.

3.3 Shaft alignment

3.3.1 General

Shaft alignment procedures are to be submitted for review in the following cases:

a) Propulsion shafting installations, where the shaft diameter is 350 mm or greater in way of the aftermost stern tube bearing.

b) Propulsion shafting installations, incorporating two or more engines.

c) Propulsion shafting installations, with one or even no shaft line bearing, inboard of the forward stern tube bearing, where the shaft diameter is 200 mm or greater in way of the aftermost stern tube bearing.

d) Propulsion shafting installations, incorporating power take-off or power take-in units.

e) Propulsion shafting installations, where a slope boring should be introduced at the aft stern tube bearing.

f) Propulsion shafting installations, with bearings with offsets from a reference line.

g) Propulsion shafting installations with turbines.

The Society may also require the above calculation in the case of special arrangements.

3.3.2 Shaft alignment calculations

a) Scope of the calculations

The shaft alignment calculations are to be carried out in the following conditions:

1) alignment conditions during the shafting installation (ship in dry dock or afloat with propeller partly immersed)
2) cold, static, afloat conditions
3) hot, static, afloat conditions
4) hot, running conditions.

Note 1: Vertical and horizontal calculations are to carried out, as deemed relevant.

b) Information to be submitted

The shaft alignment calculation report should contain the following information:

1) Description of the shaftline model:
   - length, diameters and density of material for each shaft
   - definition of the reference line
   - longitudinal, vertical and horizontal position of the bearing with respect to the reference line
   - bearings characteristics: material, length, clearance.

2) Input parameters
   - hydrodynamic propeller loads (horizontal and vertical forces and moments)
   - weight and buoyancy effect of the propeller, depending on the propeller immersion corresponding to the different loading cases of the ship
   - engine power and rotational speed of the propeller (for calculations in running conditions)
   - machining data of aft bush slope boring
   - for slow speed engines, equivalent model of the crankshaft, with indication of the input loads
   - for geared installation, gear tooth forces and moments
   - thermal expansion of the gearbox or of the main engine between cold and hot conditions
   - jack-up location.
3) Limits
   - limits specified by engine or gearbox manufacturer (such as allowable bearing loads, allowable moments and forces at the shaft couplings)
   - allowable loads specified by bearing manufacturer.
4) Results
   - bearings influence coefficients table
   - expected bearing reactions, for the different calculation conditions
   - expected shaft deflections, shear forces and bending moments alongside the shaftline, for the different calculation conditions
   - gap and sag values (depending on the alignment method)
   - jack-up correction factors.

c) Acceptability criteria for the calculations

The results of the shaft alignment calculations are to comply with the following acceptability criteria:
- relative slope between propeller shaft and aftermost boring axis is not to exceed 0,3 mm/m
- all bearings are to remain loaded
- loads on intermediate shaft bearings are not to exceed 80% of the maximum permissible load specified by the manufacturer
- stern tube bearing loads are not to exceed the limits stated in [2.4].

Note 2: Relative slope between propeller shaft and aftermost boring axis exceeding 0,3mm/m may be accepted according to the bearing manufacturer's specification provided it is also demonstrated that a higher slope is not detrimental to the lubrication.

3.3.3 Shaft alignment procedure

The shaft alignment procedure is to be submitted for review and is to be consistent with the shaft alignment calculations.

The shaft alignment procedure should include at least the following:
- Ship conditions in which the alignment is to be carried out (drafts, propeller immersion, engine room temperature)
- Method used for establishing the reference line (using laser or optical instruments or piano wire)
- Description of the different steps of the shafting installation:
  - bearing slope boring
  - setting of the bearing offset and installation of the temporary shaft support (where relevant) in accordance with the results of the shaft alignment calculation
  - flange coupling parameter setting (gap and sag)
  - bearing load test (jack-up test).

3.3.4 Verification of the alignment procedure

The purpose of the verification procedure is to ensure that the alignment measurements comply with the calculated values. The shaft alignment verification procedure is described in Ch 1, Sec 16, [3.7.1].

The shaft alignment verification is to be carried out by the shipyard in presence of the Surveyor and submitted to the Society.

The criteria for acceptability of the alignment conditions include the following:
- the position of the two aftermost bearings should not differ from the specified offsets by more than ± 0,1 mm.
- gap and sag values should not differ from the calculated values by more than ± 0,1 mm.
- bearing loads should not differ from the calculated values by more than ± 20%.

The tolerance values given in the above list are guidance values provided to designers and shipyards.

4 Material tests, workshop inspection and testing, certification

4.1 Material and non-destructive tests, workshop inspections and testing

4.1.1 Material tests

Shafting components are to be tested in accordance with Tab 5 and in compliance with the requirements of NR216 Materials and Welding.

Magnetic particle or liquid penetrant tests are required for the parts listed in Tab 5 and are to be effected in positions mutually agreed upon by the Manufacturer and the Surveyor, where experience shows defects are most likely to occur.

Ultrasonic testing requires the Manufacturer's signed certificate.

4.1.2 Hydrostatic tests

Parts of hydraulic couplings, clutches of hydraulic reverse gears and control units, hubs and hydraulic cylinders of controllable pitch propellers, including piping systems and associated fittings, are to be hydrostatically tested to 1,5 times the maximum working pressure.

Sterntubes, when machine-finished, and propeller shaft liners, when machine-finished on the inside and with an overthickness not exceeding 3 mm on the outside, are to be hydrostatically tested to 0,2 N/mm^2.

4.2 Certification

4.2.1 Testing certification

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for material tests of components in items 1 to 5 of Tab 5.

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for hydrostatic tests of components indicated in [4.1.2] and for material and non-destructive tests of components in items of Tab 5 other than those for which Society's certificates (C) are required.

Table 5 : Material and non-destructive tests

Shafting component	Material tests (Mechanical properties and chemical composition)	Non-destructive tests	
		Magnetic particle or liquid penetrant	Ultrasonic
1) Coupling (separate from shafts)	all	all	all
2) Propeller shafts	all	all	all
3) Intermediate shafts	all	all	all
4) Thrust shafts	all	all	all
5) Cardan shafts (flanges, crosses, shafts, yokes)	all	all	all
6) Sterntubes	all	–	–
7) Sterntube bushes and other shaft bearings	all	–	–
8) Shaft liners	all	all	–
9) Coupling bolts or studs	all	if diameter ≥ 40 mm	–
10) Flexible couplings (metallic parts only)	all	–	–
11) Thrust sliding-blocks (frame only)	all	–	–

Section 8 Propellers

1 General

1.1 Application

1.1.1 Propulsion propellers

The requirements of this Section apply to propellers of any size and type intended for propulsion. They include fixed and controllable pitch propellers, including those ducted in fixed nozzles.

1.1.2 Exclusions

The requirements of this Section do not apply to propellers and impellers in rotating or bow and stern thrusters, which are covered in Ch 1, Sec 13.

1.2 Definitions

1.2.1 Solid propeller

A solid propeller is a propeller (including hub and blades) cast in one piece.

1.2.2 Built-up propeller

A built-up propeller is a propeller cast in more than one piece. In general, built up propellers have the blades cast separately and fixed to the hub by a system of bolts and studs.

1.2.3 Controllable pitch propellers

Controllable pitch propellers are built-up propellers which include in the hub a mechanism to rotate the blades in order to have the possibility of controlling the propeller pitch in different service conditions.

1.2.4 Nozzle

A nozzle is a circular structural casing enclosing the propeller.

1.2.5 Ducted propeller

A ducted propeller is a propeller installed in a nozzle.

1.2.6 Geometry of propeller

For all the geometrical definitions of propeller, see Fig 1.

1.2.7 Blade areas and area ratio

- The projected blade area A_P is the projection of the blade area in the direction of the propeller shaft.
- The developed blade area A_D is the area enclosed by the connection line between the end points of the cylindrical profile sections turned in the propeller plane.
- The expanded blade area A_E is the area enclosed by the connection line between the end points of the developed and additionally straightened sections.

A_O : Disc area calculated by means of the propeller diameter

B : Developed area ratio equal to: $B = A_D / A_O$.

1.2.8 Rake and rake angle

- The rake h is the horizontal distance between the line connecting the blade tip to the blade root and the vertical line crossing the propeller axis in the same point where the prolongation of the first line crosses it, taken in correspondence of the blade tip. Aft rakes are considered positive, fore rakes are considered negative.
- The rake angle is the angle at any point between the tangent to the generating line of the blade at that point and a vertical line passing at the same point. If the blade generating line is straight, there is only one rake angle; if it is curved there are an infinite number of rake angles.

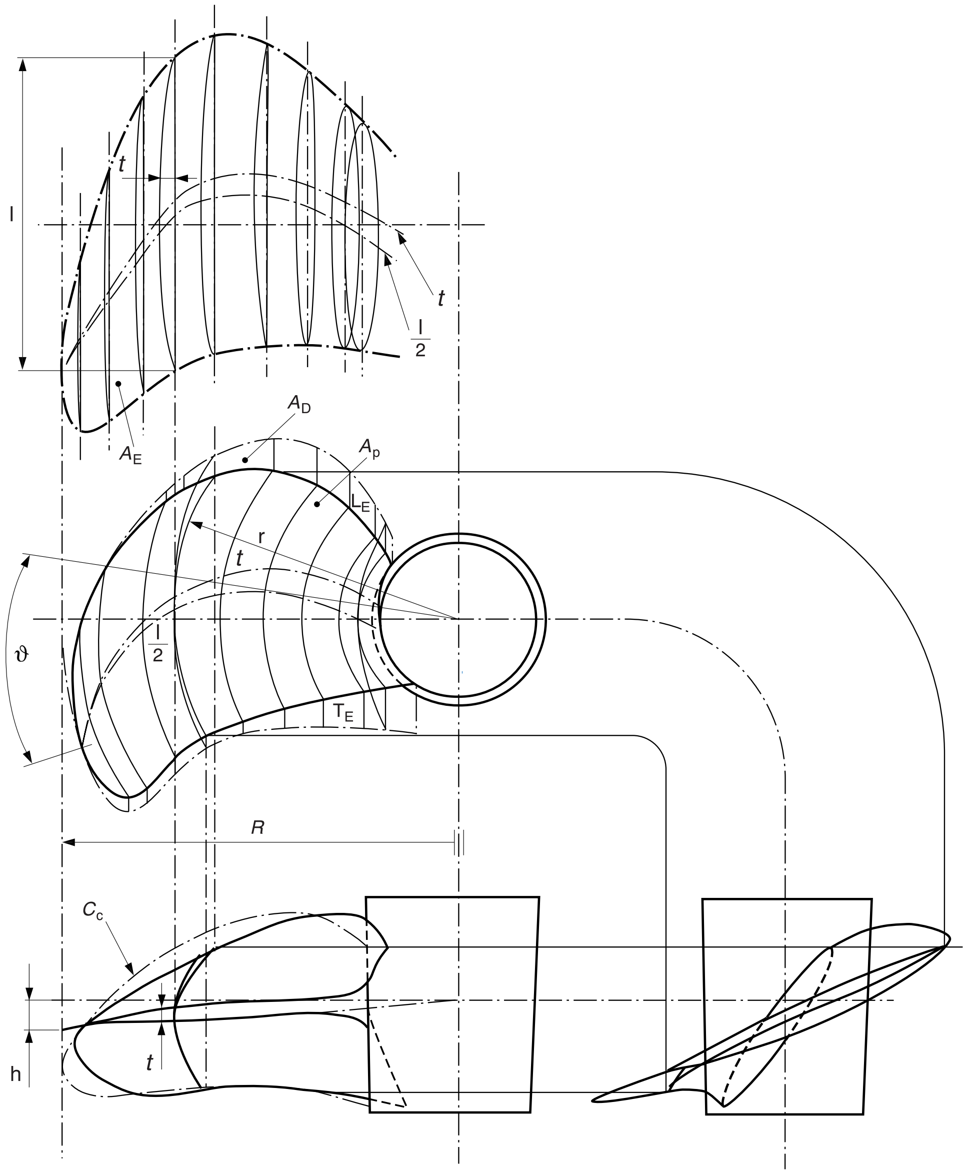
1.2.9 Skew angle at tip of blade

The skew angle ϑ at the tip of blade is the angle on the projected blade plane between a line starting at the centre of the propeller axis and tangent to the blade midchord line and a line also starting at the centre of the propeller axis and passing at the outer end of this midchord line as measured.

1.2.10 Skewed propellers

The skewed propellers are propellers whose blades have a skew angle other than 0.

Figure 1 : Description of propeller



1.2.11 Highly skewed propellers and very highly skewed propellers

The highly skewed propellers are propellers having blades with skew angle between 25° and 50°. The very highly skewed propellers are propellers having blades with skew angle exceeding 50°.

1.2.12 Leading and trailing edges

The leading edge LE of a propeller blade is the edge of the blade at side entering the water while the propeller rotates.

The trailing edge TE of a propeller blade is the edge of the blade opposite the leading edge.

1.3 Documentation to be submitted

1.3.1 Solid propellers

The documents listed in Tab 1 are to be submitted for solid propellers intended for propulsion.

All listed plans are to be constructional plans complete with all dimensions and are to contain full indication of types of materials employed.

1.3.2 Built-up and controllable pitch propellers

The documents listed in Tab 2, as applicable, are to be submitted for built-up and controllable pitch propellers intended for propulsion.

1.3.3 Very highly skewed propellers and propellers of unusual design

For very highly skewed propellers and propellers of unusual design, in addition to the documents listed in Tab 1 and Tab 2, as applicable, a detailed hydrodynamic load and stress analysis is to be submitted (see [2.4.2]).

Table 1 : Documents to be submitted for solid propellers

No.	A/I **(1)**	ITEM
1	A	Sectional assembly
2	A	Blade and hub details
3	I	Rating (power, rpm, etc.)
4	A	Data and procedures for fitting propeller to the shaft
(1) A = to be submitted for approval I = to be submitted for information.		

Table 2 : Documents to be submitted for built-up and controllable pitch propellers

No.	A/I **(1)**	ITEM
1	A/I	Same documents as requested for solid propellers
2	A	Blade bolts and pre-tensioning procedures
3	I	Pitch corresponding to maximum propeller thrust and to normal service condition
4	A	Pitch control mechanism
5	A	Pitch control hydraulic system
(1) A = to be submitted for approval I = to be submitted for information.		

2 Design and construction

2.1 Materials

2.1.1 Normally used materials for propeller hubs and blades

a) Tab 3 indicates the minimum tensile strength R_m (in N/mm²), the density δ (in kg/dm³) and the material factor f of normally used materials.

b) Common bronze, special types of bronze and cast steel used for the construction of propeller hubs and blades are to have a minimum tensile strength of 400 N/mm².

c) Other materials are subject of special consideration by the Society following submission of full material specification.

Table 3 : Normally used materialsfor propeller blades and hub

Material	R_m	δ	f
Common brass	400	8,3	7,6
Manganese brass (Cu1)	440	8,3	7,6
Nickel-manganese brass (Cu2)	440	8,3	7,9
Aluminium bronze (Cu3 and Cu4)	590	7,6	8,3
Steel	440	7,9	9,0

2.1.2 Materials for studs

In general, steel (preferably nickel-steel) is to be used for manufacturing the studs connecting steel blades to the hub of built-up or controllable pitch propellers, and high tensile brass or stainless steel is to be used for studs connecting bronze blades.

2.2 Solid propellers - Blade thickness

2.2.1

a) The maximum thickness $t_{0,25}$, in mm, of the solid propeller blade at the section at 0,25 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,25} = 3,2\left[f\cdot\frac{1,5.10^6.\rho.M_T + 51.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l\cdot z\cdot R_m}\right]^{0,5}$$

where:

f : Material factor as indicated in Tab 3

$\rho = D / H$

H : Mean pitch of propeller, in m. When H is not known, the pitch $H_{0.7}$ at 0,7 radius from the propeller axis, may be used instead of H.

D : Propeller diameter, in m

M_T : Continuous transmitted torque, in kN.m; where not indicated, the value given by the following formula may be assumed for M_T:

$$M_T = 9{,}55 \cdot \left(\frac{P}{N}\right)$$

P : Maximum continuous power of propulsion machinery, in kW

N : Rotational speed of the propeller, in rev/min

δ : Density of blade material, in kg/dm³, as indicated in Tab 3

B : Expanded area ratio

h : Rake, in mm

l : Developed width of blade section at 0,25 radius from propeller axis, in mm

z : Number of blades

R_m : Minimum tensile strength of blade material, in N/mm²

$R = D / 2$

b) The maximum thickness $t_{0,6}$, in mm, of the solid propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,6} = 1{,}9\left[f\,\frac{1{,}5.10^6.\rho_{0,6}.M_T + 18{,}4.\delta.\left(\frac{D}{100}\right)^3.B.l.N^2.h}{l_{0,6} \cdot z \cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,6} = D / H_{0.6}$

$H_{0.6}$: Pitch at 0,6 radius from the propeller axis, in m

$l_{0.6}$: Developed width of blade section at 0,6 radius from propeller axis, in mm.

c) The radius at the blade root is to be at least ¾ of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account. If the propeller hub extends over 0,25 radius, the thickness calculated by the formula in a) is to be compared with the thickness obtained by linear interpolation of the actual blade thickness up to 0,25 radius.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.3 Built-up propellers and controllable pitch propellers

2.3.1 Blade thickness

a) The maximum thickness $t_{0.35}$, in mm, of the blade at the section at 0,35 radius from the propeller axis is not to be less than that obtained from the following formula:

$$t_{0,35} = 2{,}7\left[f\,\frac{1{,}5.10^6.\rho_{0,7}.M_T + 41.\delta\left(\frac{D}{100}\right)^3 B.l_{0,35}.N^2 h}{l_{0,35} \cdot z \cdot R_m}\right]^{0,5}$$

where:

$\rho_{0,7}$: $D/H_{0.7}$

$H_{0.7}$: Pitch at 0,7 radius from the propeller axis, in m. The pitch to be used in the formula is the actual pitch of the propeller when the propeller develops the maximum thrust.

$l_{0.35}$: Developed width of blade section at 0,35 radius from propeller axis, in mm.

b) The maximum thickness $t_{0.6}$, in mm, of the propeller blade at the section at 0,6 radius from the propeller axis is not to be less than that obtained from the formula in [2.2.1], item b), using the value of $l_{0,35}$ in lieu of l.

c) The radius at the blade root is to be at least 3/4 of the minimum thickness required in that position. As an alternative, constant stress fillets may also be considered. When measuring the thickness of the blade, the increased thickness due to the radius of the fillet at the root of the blade is not to be taken into account.

d) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). For stress analysis the blade is to be modelled as a cantilever subject to centrifugal and hydrodynamic forces; more complex blade models are also accepted. The safety factor resulting form such calculation is not to be less than 7,5 with respect to the minimum ultimate tensile strength of the propeller material R_m. Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:
   - full load end of life displacement
   - sea state
   - hull fouling
   - doubts on ship resistance and global propulsion efficiency.

   A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.3.2 Flanges for connection of blades to hubs

a) The diameter D_F, in mm, of the flange for connection to the propeller hub is not to be less than that obtained from the following formula:

   $D_F = D_C + 1,8\ d_{PR}$

   where:

   D_C : Stud pitch circle diameter, in mm

   d_{PR} : Nominal stud diameter.

b) The thickness of the flange is not to be less than 1/10 of the diameter D_F.

2.3.3 Connecting studs

a) The diameter d_{PR}, in mm, at the bottom of the thread of the studs is not to be less than obtained from the following formula:

$$d_{PR} = \left(\frac{4,6 \cdot 10^7 \cdot \rho_{0,7} \cdot M_T + 0,88 \cdot \delta \cdot \left(\frac{D}{10}\right)^3 \cdot B \cdot l_{0,35} \cdot N^2 \cdot h_1}{n_{PR} \cdot z \cdot D_C \cdot R_{m,PR}}\right)^{0,5}$$

   where:

   $h_1 = h + 1,125\ D$

   n_{PR} : Total number of studs in each blade

   $R_{m,PR}$: Minimum tensile strength of stud material, in N/mm².

b) The studs are to be tightened in a controlled manner such that the tension on the studs is approximately 60-70% of their yield strength.

c) The shank of studs may be designed with a minimum diameter equal to 0,9 times the root diameter of the thread.

d) The studs are to be properly secured against unintentional loosening.

2.4 Skewed propellers

2.4.1 Skewed propellers

The thickness of skewed propeller blades may be obtained by the formulae in [2.2] and [2.3.1], as applicable, provided the skew angle is less than 25°.

2.4.2 Highly skewed propellers

a) For solid and controllable pitch propellers having skew angles between 25° and 50°, the blade thickness, in mm, is not to be less than that obtained from the following formulae:

   1) For solid propellers:

      $t_{S-0,25} = t_{0,25}\ (0,92 + 0,0032\ \vartheta)$

2) For built-up and controllable pitch propellers:

$t_{S-0,35} = t_{0,35}\ (0,90 + 0,0040\ \vartheta)$

3) For all propellers:

$t_{S-0,6} = t_{0,6}\ (0,74 + 0,0129\ \vartheta - 0,0001\ \vartheta^2)$

$t_{S-0,9} = t_{0,6}\ (0,35 + 0,0015\ \vartheta)$

where:

$t_{S-0,25}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,25 radius from the propeller axis

$t_{0,25}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,25 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,35}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,35 radius from the propeller axis

$t_{0,35}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,35 radius from the propeller axis, obtained by the formula in [2.3.1]

$t_{S-0,6}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,6 radius from the propeller axis

$t_{0,6}$: Maximum thickness, in mm, of normal shape propeller blade at the section at 0,6 radius from the propeller axis, obtained by the formula in [2.2.1]

$t_{S-0,9}$: Maximum thickness, in mm, of skewed propeller blade at the section at 0,9 radius from the propeller axis

ϑ : Skew angle.

b) As an alternative, a detailed hydrodynamic load and stress analysis carried out by the propeller designer may be considered by the Society. The hydrodynamic analysis is to be carried out according to recognized techniques (e.g. lifting line, lifting surface, panel methods). The stress analysis is to be carried out by a FEM method. The safety factor resulting form such calculation is not to be less than 8 with respect to the minimum ultimate tensile strength of the propeller material R_m.

Lower values, up to a minimum of 6,5 may be considered, when the load hypothesis for the calculation take in account margin for:

- full load end of life displacement
- sea state
- hull fouling
- doubts on ship resistance and global propulsion efficiency.

A fatigue strength analysis of the propeller is to be carried out. It should take in account the stress variation in the blade during rotation.

2.4.3 Very highly skewed propellers

For very highly skewed propellers, the blade thickness is to be obtained by a stress analysis according to a calculation criteria accepted by the Society. The safety factor to be used in this direct analysis is not to be less than 8 with respect to the ultimate tensile strength of the propeller blade material, R_m.

2.5 Ducted propellers

2.5.1 The minimum blade thickness of propellers with wide tip blades running in nozzles is not to be less than the values obtained by the applicable formula in [2.2] or [2.3.1], increased by 10%.

2.6 Features

2.6.1 Blades and hubs

a) All parts of propellers are to be free of defects and are to be built and installed with clearances and tolerances in accordance with sound marine practice.

b) Particular care is to be given to the surface of blades to comply with the specified class of ISO 484-1 and 484-2.

c) In case of direct calculation the class to be specified is to take in account the safety factor resulting of the fatigue strength calculation.

d) Where the mean load of the propeller, computed on the basis of the developed blades surface, exceeds 50 kN/m², the hydrodynamic characteristics of the propeller are to be verified with tests of properly scaled model performed in a cavitation tunnel to evaluate the risk of erosive cavitation in the whole operating speed range.

Table 4 : Controllable pitch propeller monitoring

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Main Engine			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Oil tank level	L	local					
Pitch position **(1)**	H**(2)(3)**	R					
Control oil pressure	L	local				x	

(1) Local manual control is to be available
(2) High difference from set point
(3) For feathering propellers, too high pitch value is also to give an alarm

2.6.2 Controllable pitch propellers pitch control system

a) Where the pitch control mechanism is operated hydraulically, two independent, power-driven pump sets are to be fitted. Hydraulic actuating system of controllable pitch propellers are also to comply with relevant requirements of Ch 1, Sec 10, [13].

b) Pitch control systems are to be provided with an engine room indicator showing the actual setting of the blades. Further blade position indicators are to be mounted on the bridge and in the engine control room, if any.

c) Suitable devices are to be fitted to ensure that an alteration of the blade setting cannot overload the propulsion plant or cause it to stall.

d) Steps are to be taken to ensure that, in the event of failure of the control system, the setting of the blades

- does not change, or
- assumes a final position slowly enough to allow the emergency control system to be put into operation.

e) Controllable pitch propeller systems are to be equipped with means of emergency control enabling the controllable pitch propeller to operate should the remote control system fail. This requirement may be complied with by means of a device which locks the propeller blades in the "ahead" setting.

f) Tab 4 indicates the monitoring requirements to be displayed at the control console.

3 Arrangement and installation

3.1 Fitting of propeller on the propeller shaft

3.1.1 General

a) Screw propeller hubs are to be properly adjusted and fitted on the propeller shaft cone. The contacts are to be checked to be not less than 70% of the theoretical contact area. Non-contact bands extending circumferentially around the boss (excluding the center shanked part), or over the full length of the boss are not acceptable.

b) The forward end of the hole in the hub is to have the edge rounded to a radius of approximately 6 mm.

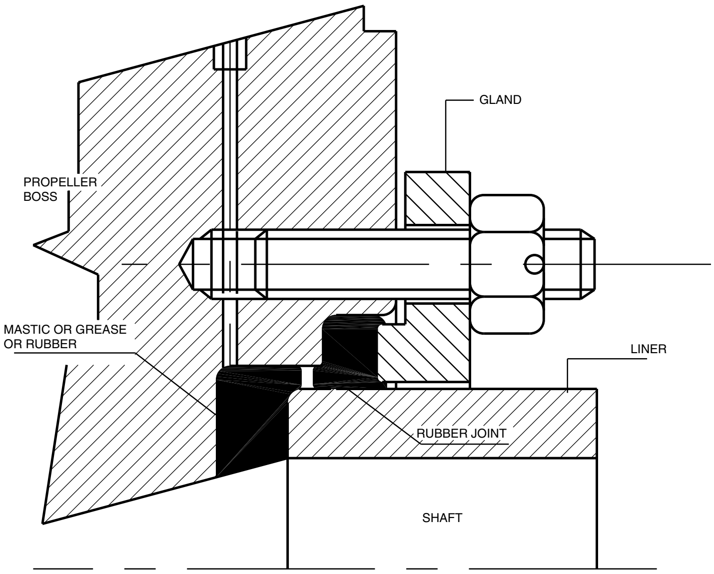
c) In order to prevent any entry of sea water under the liner and onto the end of the propeller shaft, the arrangement of Fig 2 is generally to be adopted for assembling the liner and propeller boss.

d) The external stuffing gland is to be provided with a seawater resistant rubber ring preferably without joints. The clearance between the liner and the internal air space of the boss is to be as small as possible. The internal air space is to be filled with an appropriate protective material which is insoluble in sea water and non-corrodible or fitted with a rubber ring.

e) All free spaces between the propeller shaft cone, propeller boss, nut and propeller cap are to be filled with a material which is insoluble in sea water and non-corrodible. Arrangements are to be made to allow any air present in these spaces to withdraw at the moment of filling. It is recommended that these spaces be tested under a pressure at least equal to that corresponding to the immersion of the propeller in order to check the tightness obtained after filling.

f) For propeller keys and key area, see Ch 1, Sec 7, [2.5.5].

Figure 2 : Example of sealing arrangement



3.1.2 Shrinkage of keyless propellers

In the case of keyless shrinking of propellers, the following requirements apply:

a) The meaning of the symbols used in the subparagraphs below is as follows:

A	:	100% theoretical contact area between propeller boss and shaft, as read from plans and disregarding oil grooves, in mm²
d_{PM}	:	Diameter of propeller shaft at the mid-point of the taper in the axial direction, in mm
d_H	:	Mean outer diameter of propeller hub at the axial position corresponding to d_{PM}, in mm
K	:	$K = d_H / d_{PM}$
F	:	Tangential force at interface, in N
M_T	:	Continuous torque transmitted; in N.m, where not indicated, M_T may be assumed as indicated in [2.2.1]
C	:	• C = 1,0 for turbines, geared diesel engines, electrical drives and direct-drive reciprocating internal combustion engines with a hydraulic, electromagnetic or high elasticity coupling • C = 1,2 for diesel engines having couplings other than those specified above. The Society reserves the right to increase the value of C if the shrinkage needs to absorb an extremely high pulsating torque,
T	:	Temperature of hub and propeller shaft material, in °C, assumed for calculation of pull-up length and push-up load
V	:	Ship speed at P power, in knots
S	:	Continuous thrust developed for free running ship, in N
s_F	:	Safety factor against friction slip at 35°C
θ	:	Half taper of propeller shaft (for instance: taper = 1/15, θ = 1/30)
μ	:	Coefficient of friction between mating surfaces
p_{35}	:	Surface pressure between mating surfaces, in N/mm², at 35°C
p_T	:	Surface pressure, in N/mm², between mating surfaces at temperature T
p_0	:	Surface pressure between mating surfaces, in N/mm², at 0°C
p_{MAX}	:	Maximum permissible surface pressure, in N/mm², at 0°C
d_{35}	:	Push-up length, in mm, at 35°C
d_T	:	Push-up length, in mm, at temperature T
d_{MAX}	:	Maximum permissible pull-up length, in mm, at 0°C
W_T	:	Push-up load, in N, at temperature T
σ_{ID}	:	Equivalent uni-axial stress in the boss according to the von Mises-Hencky criterion, in N/mm²
α_P	:	Coefficient of linear expansion of shaft material, in mm/(mm°C)
α_M	:	Coefficient of linear expansion of boss material, in mm/(mm°C)
E_P	:	Value of the modulus of elasticity of shaft material, in N/ mm²
E_M	:	Value of the modulus of elasticity of boss material, in N/ mm²
ν_P	:	Poisson's ratio for shaft material
ν_M	:	Poisson's ratio for boss material

$R_{S,MIN}$: Value of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of propeller boss material, in N/mm².

For other symbols not defined above, see [2.2].

b) The manufacturer is to submit together with the required constructional plans specifications containing all elements necessary for verifying the shrinkage. Tests and checks deemed necessary for verifying the characteristics and integrity of the propeller material are also to be specified.

c) Moreover, the manufacturer is to submit an instruction handbook, in which all operations and any precautions necessary for assembling and disassembling the propeller, as well as the values of all relevant parameters, are to be specified. A copy, endorsed by the Society, is to be kept on board each ship where the propeller is installed.

d) The formulae and other provisions below do not apply to propellers where a sleeve is introduced between shaft and boss or in the case of hollow propeller shafts. In such cases, a direct shrinkage calculation is to be submitted to the Society.

e) The taper of the propeller shaft cone is not to exceed 1/15.

f) Prior to final pull-up, the contact area between the mating surfaces is to be checked according to general requirements of [3.1.1] item a).

g) After final push-up, the propeller is to be secured by a nut on the propeller shaft. The nut is to be secured to the shaft.

h) The safety factor s_F against friction slip at 35°C is not to be less than 2,5, under the combined action of torque and propeller thrust, based on the maximum continuous power P for which classification is requested at the corresponding speed of rotation N of the propeller, plus pulsating torque due to torsionals.

i) For the oil injection method, the coefficient of friction μ is to be 0,13 in the case of bosses made of copper-based alloy and steel. For other methods, the coefficient of friction will be considered in each case by the Society.

j) The maximum equivalent uni-axial stress in the boss at 0°C, based on the von Mises-Hencky criterion, is not to exceed 70% of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p0,2}$), of the propeller material, based on the test piece value. For cast iron, the value of the above stress is not to exceed 30% of the nominal tensile strength.

k) For the formulae given below, the material properties indicated in the following items are to be assumed:

- Modulus of elasticity, in N/mm²:

  Cast and forged steel: E = 206000

  Cast iron: E = 98000

  Type Cu1 and Cu2 brass: E = 108000

  Type Cu3 and Cu4 brass: E = 118000

- Poisson's ratio:

  Cast and forged steel: ν = 0,29

  Cast iron: ν = 0,26

  All copper based alloys: ν = 0,33

- Coefficient of linear expansion in mm/(mm°C):

  Cast and forged steel and cast iron: $\alpha = 12{,}0\ 10^{-6}$

  All copper based alloys: $\alpha = 17{,}5\ 10^{-6}$

l) For shrinkage calculation the formulae in the following items, which are valid for the ahead condition, are to be applied. They will also provide a sufficient margin of safety in the astern condition.

- Minimum required surface pressure at 35°C:

$$p_{35} = \frac{s_F S}{AB} \cdot \left[- s_F \theta + \left(\mu^2 + B \cdot \frac{F^2}{S^2} \right)^{0,5} \right]$$

  where:

  $B = \mu^2 - s_F^2\, \theta^2$

- Corresponding minimum pull-up length at 35°C:

$$d_{35} = \frac{p_{35} d_{PM}}{2\theta} \cdot \left[\frac{1}{E_M} \cdot \left(\frac{K^2+1}{K^2-1} + \nu_M \right) + \frac{1-\nu_P}{E_P} \right]$$

- Minimum pull-up length at temperature T (T<35°C):

$$d_T = d_{35} + \frac{d_{PM}}{2\theta} \cdot (\alpha_M - \alpha_P) \cdot (35 - T)$$

- Corresponding minimum surface pressure at temperature T:

$$p_T = p_{35} \cdot \frac{d_T}{d_{35}}$$

- Minimum push-up load temperature T:

$$W_T = A p_T \cdot (\mu + \theta)$$

- Maximum permissible surface pressure at 0°C:

$$p_{MAX} = \frac{0{,}7 R_{S,MIN} \cdot (K^2 - 1)}{(3K^4 + 1)^{0,5}}$$

- Corresponding maximum permissible pull-up length at 0°C:

$$d_{MAX} = d_{35} \cdot \frac{p_{MAX}}{p_{35}}$$

- Tangential force at interface:

$$F = \frac{2000 C M_T}{d_{PM}}$$

- Continuous thrust developed for free running ship; if the actual value is not given, the value, in N, calculated by one of the following formulae may be considered:

$$S = 1760 \cdot \frac{P}{V}$$

$$S = 57{,}3 \cdot 10^3 \cdot \frac{P}{H \cdot N}$$

3.1.3 Circulating currents

Means are to be provided to prevent circulating electric currents from developing between the propeller and the hull. A description of the type of protection provided and its maintenance is to be kept on board.

4 Testing and certification

4.1 Material tests

4.1.1 Solid propellers

Material used for the construction of solid propellers is to be tested in accordance with the requirements of NR216 Materials and Welding in the presence of the Surveyor.

4.1.2 Built-up propellers and controllable pitch propellers

In addition to the requirement in [4.1.1], materials for studs and for all other parts of the mechanism transmitting torque are to be tested in the presence of the Surveyor.

4.2 Testing and inspection

4.2.1 Inspection of finished propeller

Finished propellers are to be inspected at the manufacturer's plant by the Surveyor. At least the following checks are to be carried out:

- visual examination of the entire surface of the propeller blades
- conformity to approved plans of blade profile
- liquid penetrant examination of suspected and critical parts of the propeller blade, to the satisfaction of the Surveyor.

Repair of defective casting is not allowed without the previous agreement of the Owner; where agreed, it is to be carried out according to the requirements of NR216 Materials and Welding, Ch 6, Sec 8 [1.12] or NR216 Materials and Welding, Ch 8, Sec 3 [1.12], as applicable.

4.2.2 Controllable pitch propellers

The complete hydraulic system for the control of the controllable pitch propeller mechanism is to be hydrotested at a pressure equal to 1,5 times the design pressure. The proper operation of the safety valve is to be tested in the presence of the Surveyor.

4.2.3 Balancing

Finished propellers are to be statically balanced as required by the relevant class according to ISO 484. For built-up and controllable pitch propellers, the required static balancing of the complete propeller may be replaced by an individual check of blade weight and gravity centre position. Refer also to:

- NR216 Materials and Welding, Ch 6, Sec 8 [1.9.3] for stainless steel propeller blades and
- NR216 Materials and Welding, Ch 8, Sec 3, [1.9.4] for copper alloy propeller blades.

4.3 Certification

4.3.1 Certification of propellers

Propellers in general are to be individually tested and certified by the Society.

4.3.2 Mass produced propellers

Mass produced propellers may be accepted within the framework of the type approval program of the Society.

Section 9 Shaft Vibrations

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the shafting of the following installations:

- propulsion systems with prime movers developing 220 kW or more
- other systems with internal combustion engines developing 110 kW or more and driving auxiliary machinery intended for essential services.

1.1.2 Exemptions

The requirements of this Section may be waived in cases where satisfactory service operation of similar installations is demonstrated.

2 Design of systems in respect of vibrations

2.1 Principle

2.1.1 General

a) Special consideration shall be given by Manufacturers to the design, construction and installation of propulsion machinery systems so that any mode of their vibrations shall not cause undue stresses in these systems in the normal operating ranges.

b) Calculations are to be carried out for the configurations of the system likely to have influence on the torsional vibrations.

c) Where torsional and axial vibrations may be coupled (e.g. due to helical gears), the effect of such vibrations is to be investigated.

2.1.2 Vibration levels

Systems are to have torsional, bending and axial vibrations both in continuous and in transient running acceptable to the Manufacturers, and in accordance with the requirements of this section.

Where vibrations are found to exceed the limits stated in this Section, the builder of the plant is to propose corrective actions, such as:

- operating restrictions, provided that the owner is informed, or
- modification of the plant.

2.1.3 Condition of components

Systems are to be designed considering the following conditions, as deemed necessary by the Manufacturer:

- engine: cylinder malfunction
- flexible coupling: possible variation of the stiffness or damping characteristics due to heating or ageing
- vibration damper: possible variation of the damping coefficient.

2.2 Modifications of existing plants

2.2.1 Where substantial modifications of existing plants, such as:

- change of the running speed or power of the engine
- replacement of an important component of the system (propeller, flexible coupling, damper) by one of different characteristics, or
- connection of a new component

are carried out, new vibration analysis is to be submitted for approval.

3 Torsional vibrations

3.1 Documentation to be submitted

3.1.1 Calculations

Torsional vibration calculations are to be submitted for the various configurations of the plants, showing:

- the equivalent dynamic system used for the modelling of the plant, with indication of:
  - inertia and stiffness values for all the components of the system
  - outer and inner diameters and material properties of the shafts
- the natural frequencies
- the values of the vibratory torques or stresses in the components of the system for the most significant critical speeds and their analysis in respect of the Rules and other acceptance criteria
- the possible restrictions of operation of the plant.

3.1.2 Particulars to be submitted

The following particulars are to be submitted with the torsional vibration calculations:

a) for turbines, multi-engine installations or installations with power take-off systems:
   - description of the operating configurations
   - load sharing law between the various components for each configuration

b) for installations with controllable pitch propellers, the power/rotational speed values resulting from the combinator operation

c) for prime movers, the service speed range and the minimum speed at no load

d) for internal combustion engines:
   - manufacturer and type
   - nominal output and rotational speed
   - mean indicated pressure
   - number of cylinders
   - “V” angle
   - firing angles
   - bore and stroke
   - excitation data, such as the polynomial law of harmonic components of excitations
   - nominal alternating torsional stress considered for crankpin and journal

Note 1: The nominal alternating torsional stress is part of the basic data to be considered for the assessment of the crankshaft. It is defined in Ch 1, App 1.

e) for turbines:
   - nominal output and rotational speed
   - power/speed curve and range of operation
   - number of stages, and load sharing between the stages
   - main excitation orders for each rotating disc
   - structural damping of shafts
   - external damping on discs (due to the fluid)

f) for reduction or step-up gears, the speed ratio for each step

g) for flexible couplings:
   - the maximum torque
   - the nominal torque
   - the permissible vibratory torque
   - the permissible heat dissipation
   - the relative damping
   - the torsional dynamic stiffness / transmitted torque relation where relevant

h) for torsional vibration dampers:
   - the manufacturer and type
   - the permissible heat dissipation
   - the damping coefficient
   - the inertial and stiffness properties, as applicable

i) for propellers:
   - the type of propeller: ducted or not ducted
   - the number of propellers of the ship
   - the number of blades
   - the excitation and damping data, if available

j) for electric motors, generators and pumps, the drawing of the rotating parts, with their mass moment of inertia and main dimensions.

3.2 Definitions, symbols and units

3.2.1 Definitions

a) Torsional vibration stresses referred to in this Article are the stresses resulting from the alternating torque corresponding to the synthesis of the harmonic orders concerned.

b) The misfiring condition of an engine is the malfunction of one cylinder due to the absence of fuel injection (which results in a pure compression or expansion in the cylinder).

3.2.2 Symbols, units

The main symbols used in this Article are defined as follows:

τ : Torsional vibration stress, as defined in [3.2.1], in N/mm^2

τ_1 : Permissible stress due to torsional vibrations for continuous operation, in N/mm^2

τ_2 : Permissible stress due to torsional vibrations for transient running, in N/mm^2

R_m : Tensile strength of the shaft material, as defined in Ch 1, Sec 7, [2.1.2], in N/mm^2.

C_R : Material factor, equal to:

$$\frac{R_m + 160}{18}$$

d : Minimum diameter of the shaft, in mm

C_D : Size factor of the shaft, equal to:

$0{,}35 + 0{,}93\ d^{-0{,}2}$

N : Speed of the shaft for which the check is carried out, in rev/min

N_n : Nominal speed of the shaft, in rev/min

N_c : Critical speed, in rev/min

λ : Speed ratio, equal to N/N_n

C_λ : Speed ratio factor, equal to:

- $3 - 2\,\lambda^2$ for $\lambda < 0{,}9$
- 1,38 for $0{,}9 \le \lambda < 1{,}05$

C_k : Factor depending on the stress concentration factor of the shaft design features given in Tab 1.

Table 1 : Values of C_k factors

Intermediate shafts with							Thrust shafts external to engines		Propeller shafts		
straight sections and integral coupling flanges	shrink-fit couplings **(1)**	keyways, tapered connection **(2)**	keyways, cylindrical connection **(2)**	radial hole	longitudinal slot **(3)**	splined shafts	on both sides of thrust collar	in way of axial bearing where a roller bearing is used as a thrust bearing	flange mounted or keyless fitted propellers **(4)**	key fitted propellers **(4)**	between forward end of aft most bearing and forward stern tube seal
1,00	1,00	0,60	0.45	0.50	0.30	0,80	0,85	0,85	0,55	0,55	0.80

(1) C_k values refer to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2% and a blending radius as described in Ch 1, Sec 7, [2.5.1]

(2) Keyways are to be in accordance with the provisions of Ch 1, Sec 7, [2.5.5].

(3) Subject to limitations as $\ell/d_o < 0{,}8$ and $d_i/d_o < 0{,}7$ and $e/d_o > 0{,}15$, where:

ℓ : Slot length in mm

e : Slot width in mm

d_i, d_o : As per Sec 7, [2.2.3]

The C_k value is valid for 1, 2 and 3 slots, i.e. with slots at 360 respectively 180 and respectively 120 degrees apart.

(4) Applicable to the portion of the propeller shaft between the forward edge of the aftermost shaft bearing and the forward face of the propeller hub (or shaft flange), but not less than 2.5 times the required diameter.

Note 1: Higher values of C_k factors based on direct calculations may also be considered.

Note 2: The determination of C_k factors for shafts other than those given in this table will be given special consideration by the Society.

3.3 Calculation principles

3.3.1 Method

a) Torsional vibration calculations are to be carried out using a recognised method.

b) Where the calculation method does not include harmonic synthesis, attention is to be paid to the possible superimposition of two or more harmonic orders of different vibration modes which may be present in some restricted ranges.

3.3.2 Scope of the calculations

a) Torsional vibration calculations are to be carried out considering:
- normal firing of all cylinders, and
- misfiring of one cylinder.

b) Where the torsional dynamic stiffness of the coupling depends on the transmitted torque, two calculations are to be carried out:
- one at full load
- one at the minimum load expected in service.

c) For installations with controllable pitch propellers, two calculations are to be carried out:
- one for full pitch condition
- one for zero pitch condition.

d) The calculations are to take into account other possible sources of excitation, as deemed necessary by the Manufacturer. Electrical sources of excitations, such as static frequency converters, are to be detailed. The same applies to transient conditions such as engine start up, reversing, clutching in, as necessary.

e) The natural frequencies are to be considered up to a value corresponding to 15 times the maximum service speed. Therefore, the excitations are to include harmonic orders up to the fifteenth.

3.3.3 Criteria for acceptance of the torsional vibration loads under normal firing conditions

a) Torsional vibration stresses in the various shafts are not to exceed the limits defined in [3.4]. Higher limits calculated by an alternative method may be considered, subject to special examination by the Society.

Auxiliary machinery is to be capable of running continuously without restrictions at least within the range between 0,95 N_n and 1,1 N_n. Transient running may be considered only in restricted speed ranges for speed ratios $\lambda \leq 0,95$.

b) Torsional vibration levels in other components are to comply with the provisions of [3.5].

c) The generating set is to show torsional vibration levels which are compatible with the allowable limits for the alternator, shafts, coupling and damper.

d) Propulsion systems are to be capable of running continuously without restrictions, and therefore are to respect the limits given in a) and b) in the whole operating speed range.

3.3.4 Criteria for acceptance of torsional vibration loads under misfiring conditions

The provisions of [3.3.3] related to normal firing conditions also apply to misfiring conditions.

3.4 Permissible limits for torsional vibration stresses in crankshaft, propulsion shafting and other transmission shafting

3.4.1 General

a) The limits provided below apply to steel shafts. For shafts made of other material, the permissible limits for torsional vibration stresses will be determined by the Society after examination of the results of fatigue tests carried out on the material concerned.

b) These limits apply to the torsional vibration stresses as defined in [3.2.1]. They relate to the shaft minimum section, without taking account of the possible stress concentrations.

3.4.2 Crankshaft

a) Where the crankshaft has been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
- $\tau_1 = \tau_N$ for continuous running
- $\tau_2 = 1,7\ \tau_N$ for transient running,

where τ_N is the nominal alternating torsional stress on which the crankshaft scantling is based (see Note 1 in [3.1.2]).

b) Where the crankshaft has not been designed in accordance with Ch 1, App 1, the torsional vibration stresses in any point of the crankshaft are not to exceed the following limits:
- $\tau_1 = 0,55 \cdot C_R \cdot C_D \cdot C_\lambda$ for continuous running
- $\tau_2 = 2,3\ \tau_1$ for transient running.

3.4.3 Intermediate shafts, thrust shafts and propeller shafts

The torsional vibration stresses in any intermediate, thrust and propeller shafts are not to exceed the following limits:

- $\tau_1 = C_R . C_k . C_D . C_\lambda$ for continuous running
- $\tau_2 = 1{,}7\ \tau_1 . C_k^{-0{,}5}$ for transient running.

3.4.4 Transmission shafting for generating sets and other auxiliary machinery

The torsional vibration stresses in the transmission shafting for generating sets and other auxiliary machinery, such as pumps or compressors, are not to exceed the following limits:

- $\tau_1 = 0{,}90 . C_R . C_D$ for continuous running
- $\tau_2 = 5{,}4\ \tau_1$ for transient running.

3.4.5 Restricted speed ranges

Restricted speed ranges in normal firing condition are acceptable only for auxiliary machinery:

a) Where the torsional vibration stresses exceed the limit τ_1 for continuous running, restricted speed ranges are to be imposed which are to be passed through rapidly.

b) The limits of the restricted speed range related to a critical speed N_c are to be calculated in accordance with the following formula:

$$\frac{16 \cdot N_c}{18-\lambda} \le N \le \frac{(18-\lambda) \cdot N_c}{16}$$

c) Where the resonance curve of a critical speed is obtained from torsional vibration measurements, the restricted speed range may be established considering the speeds for which the stress limit for continuous running τ_1 is exceeded.

d) Where restricted speed ranges are imposed, they are to be crossed out on the tachometers and an instruction plate is to be fitted at the control stations indicating that:
   - the continuous operation of the engine within the considered speed range is not permitted
   - this speed range is to be passed through rapidly.

e) When restricted speed ranges are imposed, the accuracy of the tachometers is to be checked in such ranges as well as in their vicinity.

3.5 Permissible vibration levels in components other than shafts

3.5.1 Gears

a) The torsional vibration torque in any gear step is not to exceed 30% of the torque corresponding to the approved rating throughout the service speed range.

   Where the torque transmitted at nominal speed is less than that corresponding to the approved rating, higher torsional vibration torques may be accepted, subject to special consideration by the Society.

b) Gear hammering induced by torsional vibration torque reversal is not permitted throughout the service speed range.

3.5.2 Generators

a) In the case of alternating current generators, the torsional vibration amplitude at the rotor is not to exceed ± 2,5 electrical degrees at service rotational speed under full load working conditions.

b) Vibratory inertia torques due to torsional vibrations and imposed on the rotating parts of the generator are not to exceed the values M_A, in N.m, calculated by the following formulae, as appropriate:
   - for $0{,}95 \le \lambda \le 1{,}1$: $M_A = \pm 2{,}5\ M_T$
   - for $\lambda \le 0{,}95$: $M_A = \pm 6\ M_T$

   where:

   M_T : Mean torque transmitted by the engine under full load running conditions, in N.m

   Note 1: In the case of two or more generators driven by the same engine, the portion of M_T transmitted to each generator is to be considered.

   λ : Speed ratio defined in [3.2.2].

3.5.3 Flexible couplings

a) Flexible couplings are to be capable of withstanding the mean transmitted torque and the torsional vibration torque throughout the service speed range, without exceeding the limits for continuous operation imposed by the manufacturer (permissible vibratory torque and power loss).

   Where such limits are exceeded under misfiring conditions of auxiliary machines, appropriate restrictions of power or speed are to be established.

b) The coupling selection for the generating set is to take into account the stresses and torques imposed on it by the torsional vibration of the system.

c) Flexible couplings fitted in generating sets are also to be capable of withstanding the torques and twist angles arising from transient criticals and short-circuit currents. Start up conditions are also to be checked.

3.5.4 Dampers

a) Torsional vibration dampers are to be such that the permissible power loss recommended by the manufacturer is not exceeded throughout the service speed range.

b) Dampers for which a failure may lead to a significant vibration overload of the installation will be the subject of special consideration.

3.6 Torsional vibration measurements

3.6.1 General

a) The Society may require torsional vibration measurements to be carried out under its attendance in the following cases:
   - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
   - where doubts arise as to the actual stress amplitudes or critical speed location, or
   - where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

3.6.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

4 Bending vibrations

4.1 General

4.1.1 The provisions of this Article apply to the bending vibrations of propulsion systems having a transmitted power in excess of 1000 KW:

- having a l/D ratio exceeding the following value:

$$10\left(\ln\frac{2}{D}\right)+D^2$$

  where:

  l : Span between the aft bearings of the propeller shaft, in m

  D : Diameter of the propeller shaft, in m

  or

- fitted with bearings located outboard the hull (brackets), or
- fitted with cardan shafts.

4.2 Documentation to be submitted

4.2.1 Calculations

Bending vibration calculations are to show:

- the equivalent dynamic system used for the modelling of the plant, with indication of the mass of the shafts, propeller and other rotating components, and the lateral stiffness of the bearings, including that of the oil film and that of the seating
- the natural bending frequencies
- the values of the vibratory amplitudes and bending moments in the shafting for the most significant critical speeds
- the possible restrictions of operation of the plant.

4.2.2 Particulars to be submitted

The following particulars are to be submitted with the bending vibration calculations:

a) shafting arrangement with indication of:
   - the diameter and length of the shafts
   - the position of the bearings
   - the mounting characteristics of the cardan shafts

b) detailed drawings of the bearings and their seating

c) details of the bearing lubrication, including the oil viscosity

d) for the propeller:
   - the diametral and polar moments of inertia of the propeller in air and water
   - excitations (bending moments and bending forces).

4.3 Calculation principles

4.3.1 Scope of the calculations

a) Bending vibration calculations are to take into account:
- the stiffness of the bearings and their seatings and, where applicable, that of the lubricating oil film
- the excitations due to the propeller and cardan shafts.

b) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy, parametric studies are to be carried out.

4.3.2 Criteria for acceptance of the bending vibration levels

The first shafting vibration mode is not to be excited by the first propeller blade excitation order, in the speed range between 80% and 110% of nominal speed.

Furthermore vibration induced stresses should not exceed 1,5 times the one indicated in [3.4.3] in the whole speed range.

In case the shafting is checked by means of direct calculation the allowable stresses will be established on a case by case.

4.4 Bending vibration measurements

4.4.1 General

a) The Society may require bending vibration measurements in the following cases:
- where the calculations indicate the possibility of dangerous critical speeds in or near the operating speed range
- where the accuracy of some data is not deemed sufficient
- where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

4.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

5 Axial vibrations

5.1 General

5.1.1 The provisions of this Article apply to the axial vibrations of propulsion systems fitted with:
- an internal combustion engine having a power exceeding 2000 kW and a running speed of less than 200 RPM, or
- a shaft line where the power transmitted exceeds 375 kW and the L/D ratio exceeds 50,

  where:

  L : Total length of the shaft line between the propeller and the thrust bearing

  D : Minimum diameter of the shaft line.

5.2 Documentation to be submitted

5.2.1 Calculations

Axial vibration calculations are to show:
- the equivalent dynamic system used for the modelling of the plant, with indication of the masses and axial stiffnesses for all the components of the system
- the natural frequencies
- the axial vibration amplitude in way of the sterntube sealing gland for the most significant critical speeds
- for engines directly connected to the shaftline, the axial vibration amplitude at the free end of the crankshaft for the most significant critical speeds
- the possible restrictions of operation of the plant.

5.2.2 Particulars to be submitted

The following particulars are to be submitted with the axial vibration calculations:

a) detailed drawing of the thrust bearing and its supporting structure with indication of their flexibility

b) for the propeller:
- the thrust
- the excitations (axial forces)
- the damping characteristics

c) for the engine:
  - the axial excitations
  - the permissible axial amplitude at the free end of the crankshaft

d) the characteristics of the axial vibration damper or detuner.

5.3 Calculation principles

5.3.1 Scope of the calculations

a) Axial vibration calculations are to take into account:
  - the flexibility of the thrust bearing and its supporting structure
  - the excitations due to the engine and to the propeller.

b) Where data having a significant influence on the vibration levels cannot be determined with a sufficient degree of accuracy (e.g. the flexibility of the thrust bearing and its supporting structure), parametric studies are to be carried out.

c) Where the plant includes an axial vibration damper or detuner, a calculation is to be carried out assuming a malfunction of the damper or detuner.

5.3.2 Criteria for acceptance of the axial vibration levels

a) The axial vibration force acting on the thrust bearing is not to exceed 30% of the nominal thrust.

b) The axial vibration amplitude is not to exceed:
  - at the free end of the crankshaft, the limit recommended by the engine manufacturer
  - in way of the sterntube sealing gland, the limit recommended by the sealing gland manufacturer, if any.

c) Where the calculations show that in the continuous operation speed range the above limits may be exceeded in the event of malfunction of the axial vibration damper or detuner, a suitable device is to be fitted to indicate the occurrence of such conditions.

Note 1: When detuners or dampers of satisfactorily proven design are used, this requirement may be waived.

5.4 Axial vibration measurements

5.4.1 General

a) The Society may require axial vibration measurements in the following cases:
  - where the calculations indicate the possibility of dangerous critical speeds in the operating speed range
  - where the accuracy of some data is not deemed sufficient, or
  - where restricted speed ranges need to be verified.

b) Where measurements are required, a comprehensive report including the analysis of the results is to be submitted to the Society.

5.4.2 Method of measurement

When measurements are required, the method of measurement is to be submitted to the Society for approval. The type of measuring equipment and the location of the measurement points are to be specified.

Section 10 Piping Systems

1 General

1.1 Application

1.1.1

a) General requirements applying to all piping systems are contained in:
- Article [2] for their design and construction
- Article [3] for the welding of steel pipes
- Article [4] for the bending of pipes
- Article [5] for their arrangement and installation
- Article [19] for their certification, inspection and testing.

b) Specific requirements for ship piping systems and machinery piping systems are given in Articles [6] to [18].

1.2 Documentation to be submitted

1.2.1 Documents

The documents listed in Tab 1 are to be submitted.

1.2.2 Additional information

The information listed in Tab 2 is also to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Drawing showing the arrangement of the sea chests and ship side valves
2	A	Diagram of the bilge and ballast systems (in and outside machinery spaces)
3	A	Specification of the central priming system intended for bilge pumps, when provided
4	A	Diagram of the scuppers and sanitary discharge systems
5	A	Diagram of the air, sounding and overflow systems
6	A	Diagram of cooling systems (sea water and fresh water)
7	A	Diagram of fuel oil system and of JP5-NATO (F44) system
8	A	Drawings of the fuel oil and of JP5-NATO (F44) tanks not forming part of the ship's structure
9	A	Diagram of the lubricating oil system
10	A	Diagram of the thermal oil system
11	A	Diagram of the hydraulic systems intended for essential services or located in machinery spaces
12	A	Diagram of steam system, including safety valve exhaust and drain pipes
13		For high temperature steam pipes:
	A	• stress calculation note
	I	• drawing showing the actual arrangement of the piping in three dimensions
14	A	Diagram of the boiler feed water and condensate system
15	A	Diagram of the compressed air system
16	A	Diagram of the hydraulic and pneumatic remote control systems
17	A	Diagram of the remote level gauging system
18	I	Diagram of the exhaust gas system
19	A	Diagram of drip trays and gutterway draining system
20	I	Arrangement of the ventilation system
21	A	Diagram of the oxyacetylene welding system
22	A	Drawings and specification of valves and accessories, where required in [2.7]

(1) A = to be submitted for approval ; I = to be submitted for information.
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems.

Table 2 : Information to be submitted

No.	I/A **(1)**	Document
1	I	Nature, service temperature and pressure of the fluids
2	A	Material, external diameter and wall thickness of the pipes
3	A	Type of connections between pipe lengths, including details of the weldings, where provided
4	A	Material, type and size of the accessories
5	A	Capacity, prime mover and, when requested, location of the pumps
6	A	For plastic pipes: • the chemical composition • the physical and mechanical characteristics in function of temperature • the characteristics of inflammability and fire resistance • the resistance to the products intended to be conveyed.
(1) A = to be submitted for approval ; I = to be submitted for information.		

1.3 Definitions

1.3.1 Piping and piping systems

a) Piping includes pipes and their connections, flexible hoses and expansion joints, valves and their actuating systems, other accessories (filters, level gauges, etc.) and pump casings.

b) Piping systems include piping and all the interfacing equipment such as tanks, pressure vessels, heat exchangers, pumps and centrifugal purifiers, but do not include boilers, turbines, internal combustion engines and reduction gears.

Note 1: The equipment other than piping is to be designed in accordance with the relevant Sections of Part C, Chapter 1.

1.3.2 Design pressure

a) The design pressure of a piping system is the pressure considered by the manufacturer to determine the scantling of the system components. It is not to be taken less than the maximum working pressure expected in this system or the highest setting pressure of any safety valve or relief device, whichever is the greater.

b) The design pressure of a boiler feed system is not to be less than 1,25 times the design pressure of the boiler or the maximum pressure expected in the feed piping, whichever is the greater.

c) The design pressure of steam piping located upstream of pressure reducing valves (high pressure side) is not to be less than the setting pressure of the boiler or superheater safety valves.

d) The design pressure of a piping system located on the low pressure side of a pressure reducing valve where no safety valve is provided is not to be less than the maximum pressure on the high pressure side of the pressure reducing valve.

e) The design pressure of a piping system located on the delivery side of a pump or a compressor is not to be less than the setting pressure of the safety valve for displacement pumps or the maximum pressure resulting from the operating (head-capacity) curve for centrifugal pumps, whichever is the greater.

1.3.3 Design temperature

The design temperature of a piping system is the maximum temperature of the medium inside the system.

1.3.4 Flammable oils

Flammable oils include fuel oils, lubricating oils, thermal oils, hydraulic oils and JP5-NATO (F44).

1.4 Symbols and units

1.4.1 The following symbols and related units are commonly used in this Section. Additional symbols, related to some formulae indicated in this Section, are listed wherever it is necessary.

p : Design pressure, in MPa

T : Design temperature, in °C

t : Rule required minimum thickness, in mm

D : Pipe external diameter, in mm.

1.5 Class of piping systems

1.5.1 Purpose of the classes of piping systems

Piping systems are subdivided into three classes, denoted as class I, class II and class III, for the purpose of acceptance of materials, selection of joints, heat treatment, welding, pressure testing and certification of fittings.

1.5.2 Definitions of the classes of piping systems

a) Classes I, II and III are defined in Tab 3.

b) Fluids for refrigerating plants are not covered by Tab 3 (see Ch 1, Sec 14).

Table 3 : Class of piping systems

Media conveyed by the piping system	CLASS I	CLASS II	CLASS III
Fuel oil and JP5-NATO (F44)**(1)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Thermal oil	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 150
Flammable Hydraulic oil **(5)**	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Lubricating oil	p > 1,6 or T > 150	other **(2)**	p ≤ 0,7 and T ≤ 60
Other flammable media: • heated above flashpoint, or • having flashpoint <60°C and liquefied gas	without special safeguards**(3)**	with special safeguards**(3)**	
Oxygen and acetylene • upstream the pressure reduction valve • downstream the pressure reduction valve	irrespective of p		
Toxic media	irrespective of p, T		
Corrosive media	without special safeguards**(3)**	with special safeguards**(3)**	
Steam	p > 1,6 or T > 300	other **(2)**	p ≤ 0,7 and T ≤ 170
Air, gases, water, non-flammable hydraulic oil**(4)**	p > 4 or T > 300	other **(2)**	p ≤ 1,6 and T ≤ 200
Open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes)			irrespective of T

(1) Valves under static pressure on fuel oil and on JP5-NATO (F44) tanks belong to class II.
(2) Pressure and temperature conditions other than those required for class I and class III.
(3) Safeguards for reducing the possibility of leakage and limiting its consequences, to the Society's satisfaction.
(4) Valves and fittings fitted on the ship side and collision bulkhead belong to class II.
(5) Steering gear piping belongs to class I irrespective of p and T
Note 1: p : Design pressure, as defined in [1.3.2], in MPa.
Note 2: T : Design temperature, as defined in [1.3.3], in °C.

2 General requirements for design and construction

2.1 Materials

2.1.1 General

Materials to be used in piping systems are to be suitable for the medium and the service for which the piping is intended.

2.1.2 Use of metallic materials

a) Metallic materials are to be used in accordance with Tab 4.

b) Materials for class I and class II piping systems are to be manufactured and tested in accordance with the appropriate requirements of NR216 Materials and Welding.

c) Materials for class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national or international standards or specifications.

d) Mechanical characteristics required for metallic materials are specified in NR216 Materials and Welding.

2.1.3 Use of plastics

a) Plastics, FRP and GRP may be used for piping systems belonging to class III in accordance with Ch 1, App 2. The use of plastics for other systems or in other conditions will be given special consideration.

b) Plastics intended for piping systems dealt with in this Section are to be of a type approved by the Society.

c) Installation of plastic pipes shall be avoided if not agreed by the Society and the Naval Authority.

Table 4 : Conditions of use of metallic materials in piping systems

Material	Allowable classes	Maximum design temperature, in °C **(1)**	Particular conditions of use
Carbon and carbon-manganese steels	III, II, I	400 **(2)**	Class I and II pipes are to be seamless drawn pipes **(3)**
Copper and aluminium brass	III, II, I	200	• Not to be used in fuel oil and JP5-NATO(F44) systems, except for class III pipes of a diameter not exceeding 25 mm not passing through fuel oil or JP5-NATO(F44) tanks • Not to be used for boiler blow-down valves and pieces for connection to the shell plating **(4)**
Copper-nickel	III, II, I	300	
Special high temperature resistant bronze	III, II, I	260	
Stainless steel	III, II, I	300	Except for system fittings, an austenitic stainless steel is not to be used for sea water systems
Spheroidal graphite cast iron	III, II	350	• Spheroidal cast iron of the ferritic type according to the material rules of the Society may be accepted for bilge and ballast piping within double bottom tanks, or other locations to the Society's satisfaction • The use of this material for pipes, valves and fittings for other services, in principle Classes II and III, will be subject to special consideration • Spheroidal cast iron pipes and valves fitted on ship's side should have specified properties to the Society's satisfaction • Minimum elongation is not to be less than 12% on a gauge length of $5,65 \cdot S^{0,5}$, where S is the actual cross-sectional area of the test piece • Not to be used for boiler blow-down valves and pieces for connection to the shell plating
Grey cast iron	III, II **(5)**	220	Grey cast iron is not to be used for the following systems: • boiler blow-down systems and other piping systems subject to shocks, high stresses and vibrations • bilge lines in tanks • parts of scuppers and sanitary discharge systems located next to the hull below the maximum ship draft • ship side valves and fittings • valves fitted on the collision bulkhead • valves fitted to fuel oil and lubricating oil tanks under static pressure head • class II fuel oil and JP5-NATO(F44) systems
Aluminium and aluminium alloys	III, II **(6)**	200	Aluminium and aluminium alloys are not to be used on the following systems: • flammable oil systems • sounding and air pipes of fuel oil tanks and of JP5-NATO(F44) tanks • fire-extinguishing systems • bilge system in boiler or machinery spaces or in spaces containing fuel oil tanks, JP5-NATO(F44) tanks or pumping units • scuppers and overboard discharges except for pipes led to the bottoms or to the shell above the watertight deck or fitted at their upper end with closing means operated from a position above the watertight deck • boiler blow-down valves and pieces for connection to the shell plating

(1) Maximum design temperature is not to exceed that assigned to the class of piping.
(2) Higher temperatures may be accepted if metallurgical behaviour and time dependent strength (ultimate tensile strength after 100 000 hours) are in accordance with national or international standards or specifications and if such values are guaranteed by the steel manufacturer.
(3) Pipes fabricated by a welding procedure approved by the Society may also be used.
(4) Pipes made of copper and copper alloys are to be seamless.
(5) Use of grey cast iron is not allowed when the design pressure exceeds 1,3 MPa.
(6) Accessories of aluminium or aluminium alloys intended for flammable oil systems may be accepted subject to the satisfactory result of an endurance flame test to be carried out according to the "Rules for the type approval of flexible hoses and expansion joints" issued by the Society.

2.2 Thickness of pressure piping

2.2.1 Calculation of the thickness of pressure pipes

a) The thickness t, in mm, of pressure pipes is to be determined by the following formula but, in any case, is not to be less than the minimum thickness given in Tab 5 to Tab 8.

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}}$$

where:

t_0 : Coefficient, in mm, equal to

$$t_0 = \frac{p \cdot D}{2Ke + p}$$

with:

p and D : As defined in [1.4.1]

K : Permissible stress defined in [2.2.2]

e : Weld efficiency factor to be:

- equal to 1 for seamless pipes and pipes fabricated according to a welding procedure approved by the Society
- specially considered by the Society for other welded pipes, depending on the service and the manufacture procedure

b : Thickness reduction due to bending defined in [2.2.3], in mm

c : Corrosion allowance defined in [2.2.4], in mm

a : Negative manufacturing tolerance percentage equal to:

- 7,0 for copper and copper alloy pipes
- 10,0 for cold drawn seamless steel pipes fabricated according to a welding procedure approved by the Society
- 12,5 for hot laminated seamless steel pipes.

b) The thickness thus determined does not take into account the particular loads to which pipes may be subjected. Attention is to be drawn in particular to the case of high temperature and low temperature pipes.

Table 5 : Minimum wall thickness for steel pipes

External diameter, in mm	Minimum nominal wall thickness, in mm			Minimum reinforced wall thickness, in mm **(2)**	Minimum extra reinforced wall thickness, in mm **(3) (4)**
	Sea water pipes, bilge and ballast systems **(1)**		Other piping systems **(1) (4)**		
	normally full **(4)**	normally empty			
10,2 - 12,0	–	–	1,6	–	–
13,5 - 19,3	–	–	1,8	–	–
20,0	–	–	2,0	–	–
21,3 - 25,0	3,2	2,4	2,0	–	–
26,7 - 33,7	3,2	2,4	2,0	–	–
38,0 - 44,5	3,6	2,6	2,0	4,8	7,1
48,3	3,6	2,6	2,3	5,0	7,1
51,0 - 63,5	4,0	2,9	2,3	5,0	7,6
70,0	4,0	2,9	2,6	5,0	7,6
76,1 - 82,5	4,5	2,9	2,6	5,0	7,6
88,9 - 108,0	4,5	3,2	2,9	5,4	7,8
114,3 - 127,0	4,5	3,6	3,2	6,0	8,8
133,0 - 139,7	4,5	4,0	3,6	6,3	9,5
152,4 - 168,3	4,5		4,0	7,1	11,0
177,8	5,0		4,0	8,1	12,7
193,7	5,4		4,0	8,1	12,7
219,1	5,9		4,0	8,1	12,7
244,5 - 273,0	6,3		4,0	8,8	12,7
298,5 - 368,0	6,3		4,5	8,8	12,7
406,4 - 457,2	6,3		5,6	8,8	12,7

<table>
<tr><td rowspan="3">External diameter, in mm</td><td colspan="3">Minimum nominal wall thickness, in mm</td><td rowspan="3">Minimum reinforced wall thickness, in mm (2)</td><td rowspan="3">Minimum extra reinforced wall thickness, in mm (3) (4)</td></tr>
<tr><td colspan="2">Sea water pipes, bilge and ballast systems (1)</td><td rowspan="2">Other piping systems (1) (4)</td></tr>
<tr><td>normally full (4)</td><td>normally empty</td></tr>
<tr><td colspan="6">(1) Attention is drawn to the special requirements regarding:
• bilge and ballast systems
• scupper and discharge pipes
• sounding, air and overflow pipes
• ventilation systems
• oxyacetylene welding systems
• CO_2 fire-extinguishing systems (see Ch 4, Sec 13)
(2) Reinforced wall thickness applies to pipes passing through tanks containing a fluid distinct from that conveyed by the pipe, however the pipe thickness may not be greater than the tank plating.
(3) Extra-reinforced wall thickness applies to pipes connected to the shell, however the pipe thickness may not be greater than what required by these Rules for shell.
(4) For pipes efficiently protected against corrosion, the thickness may be reduced by an amount up to than 1 mm.
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.
Note 2: The thickness of threaded pipes is to be measured at the bottom of the thread.
Note 3: The minimum thickness listed in this table is the nominal wall thickness and no allowance is required for negative tolerance or reduction in thickness due to bending.
Note 4: For larger diameters, the minimum wall thickness will be specially considered by the Society.</td></tr>
</table>

Table 6 : Minimum wall thickness for copper and copper alloy pipes

External diameter, in mm	Minimum wall thickness, in mm	
	Copper	Copper alloy
8 - 10	1,0	0,8
12 - 20	1,2	1,0
25 - 44,5	1,5	1,2
50 - 76,1	2,0	1,5
88,9 - 108	2,5	2,0
133 - 159	3,0	2,5
193,7 - 267	3,5	3,0
273 - 457,2	4,0	3,5
470	4,0	3,5
508	4,5	4,0
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.		

Table 7 : Minimum wall thickness for stainless steel pipes

External diameter, in mm	Minimum wall thickness,in mm
up to 17,2	1,0
up to 48,3	1,6
up to 88,9	2,0
up to 168,3	2,3
up to 219,1	2,6
up to 273,0	2,9
up to 406,4	3,6
over 406,4	4
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards.	

Table 8 : Minimum wall thickness for aluminium and aluminium alloy pipes

External diameter, in mm	Minimum wall thickness,in mm
0 - 10	1,5
12 - 38	2,0
43 - 57	2,5
76 - 89	3,0
108 - 133	4,0
159 - 194	4,5
219 - 273	5,0
above 273	5,5
Note 1: A different thickness may be considered by the Society on a case by case basis, provided that it complies with recognized standards. **Note 2:** For sea water pipes, the minimum thickness is not to be less than 5 mm.	

2.2.2 Permissible stress

a) For carbon steel and alloy steel pipes with a design temperature equal to or less than 300 °C, the value of the permissible stress K is to be taken equal to the lowest of the following values:

- $R_{m,20}$ / 2,4 or R_e / 1,5 when the materials tests are carried out under the supervision of the Society
- $R_{m,20}$ / 2,7 or R_e / 1,8 when the materials tests are not carried out under the supervision of the Society

where:

$R_{m,20}$: Minimum tensile strength of the material at ambient temperature (20°C), in N/mm²

R_e : Minimum yield strength or 0,2% proof stress at the design temperature, in N/mm²

b) For carbon steel and alloy steel pipes with a design temperature above 300 °C and for copper and copper alloy pipes, the permissible stress K is given in:

- Tab 9 for carbon and carbon-manganese steel pipes
- Tab 10 for alloy steel pipes, and
- Tab 11 for copper and copper alloy pipes,

as a function of the temperature. Intermediate values may be obtained by interpolation.

c) The permissible stress values adopted for materials other than carbon steel, alloy steel, copper and copper alloy will be specially considered by the Society.

2.2.3 Thickness reduction due to bending

a) Unless otherwise justified, the thickness reduction b due to bending is to be determined by the following formula:

$$b = \frac{Dt_0}{2{,}5\rho}$$

where:

ρ : Bending radius measured on the centre line of the pipe, in mm

D : As defined in [1.4.1]

t_0 : As defined in [2.2.1].

b) When the bending radius is not given, the thickness reduction is to be taken equal to:

t_0 / 10

c) For straight pipes, the thickness reduction is to be taken equal to 0.

Table 9 : Permissible stresses for carbon and carbon-manganese steel pipes

Specified minimum tensile strength, in N/mm²	Design temperature, in °C							
	300	350	400	410	420	430	440	450
320	62	57	55	55	54	54	54	49
360	76	69	68	68	68	64	56	49
410	93	86	84	79	71	64	56	49
460	111	101	99	98	85	73	62	53
490	121	111	109	98	85	73	62	53

Table 10 : Permissible stresses for alloy steel pipes

Type of steel	Specified minimum tensile strength, in N/mm²	Design temperature, in °C						
		300	350	400	440	450	460	470
1Cr1/2Mo	440	114	106	102	101	101	100	99
2 1/4Cr1Mo annealed	410	50	47	45	44	43	43	42
2 1/4Cr1Mo normalized and tempered below 750°C	490	144	140	136	130	128	127	116
2 1/4Cr1Mo normalized and tempered above 750°C	490	144	140	136	130	122	114	105
1/2Cr 1/2Mo 1/4V	460	120	115	111	106	105	103	102

Type of steel	Specified minimum tensile strength, in N/mm²	Design temperature, in °C									
		480	490	500	510	520	530	540	550	560	570
1Cr1/2Mo	440	98	97	91	76	62	51	42	34	27	22
2 1/4Cr1Mo annealed	410	42	42	41	41	41	40	40	40	37	32
2 1/4Cr1Mo normalized and tempered below 750°C	490	106	96	86	79	67	58	49	43	37	32
2 1/4Cr1Mo normalized and tempered above 750°C	490	96	88	79	72	64	56	49	43	37	32
1/2Cr 1/2Mo 1/4V	460	101	99	97	94	82	72	62	53	45	37

Table 11 : Permissible stresses for copper and copper alloy pipes

Material (annealed)	Specified minimum tensile strength, in N/mm²	Design temperature, in °C										
		≤ 50	75	100	125	150	175	200	225	250	275	300
Copper	215	41	41	40	40	34	27,5	18,5				
Aluminium brass	325	78	78	78	78	78	51	24,5				
Copper-nickel 95/5 and 90/10	275	68	68	67	65,5	64	62	59	56	52	48	44
Copper-nickel 70/30	365	81	79	77	75	73	71	69	67	65,5	64	62

2.2.4 Corrosion allowance

The values of corrosion allowance c are given for steel pipes in Tab 12 and for non-ferrous metallic pipes in Tab 13.

2.2.5 Tees

As well as complying with the provisions of [2.2.1] to [2.2.4], the thickness t_T of pipes on which a branch is welded to form a Tee is not to be less than that given by the following formula:

$$t_T = \left(1 + \frac{D_1}{D}\right) \cdot t_0$$

where:

D_1 : External diameter of the branch pipe

D : As defined in [1.4.1]

t_0 : As defined in [2.2.1].

Note 1: This requirement may be dispensed with for Tees provided with a reinforcement or extruded.

Table 12 : Corrosion allowance for steel pipes

Piping system		Corrosion allowance, in mm
Superheated steam		0,3
Saturated steam		0,8
Steam coils in liquid fuel tanks		2,0
Feed water for boilers in open circuit systems		1,5
Feed water for boilers in closed circuit systems		0,5
Blow-down systems for boilers		1,5
Compressed air		1,0
Hydraulic oil		0,3
Lubricating oil		0,3
Fuel oil and JP5-NATO(F44)		1,0
Thermal oil		1,0
Fresh water		0,8
Sea water	normally full normally empty **(1)**	3,0 2,0
Refrigerants referred to in Section 13		0,3

(1) Assuming that arrangements are made to allow complete drainage of the pipe.
Note 1: For pipes passing through tanks, an additional corrosion allowance is to be considered in order to account for the external corrosion.
Note 2: The corrosion allowance of pipes efficiently protected against corrosion may be reduced by no more than 50%.
Note 3: When the corrosion resistance of alloy steels is adequately demonstrated, the corrosion allowance may be disregarded.

Table 13 : Corrosion allowance for non-ferrous metal pipes

Piping material **(1)**	Corrosion allowance, in mm**(2)**
Copper	0,8
Brass	0,8
Copper-tin alloys	0,8
Copper-nickel alloys with less than 10% of Ni	0,8
Copper-nickel alloys with at least 10% of Ni	0,5
Aluminium and aluminium alloys	0,5

(1) The corrosion allowance for other materials will be specially considered by the Society. Where their resistance to corrosion is adequately demonstrated, the corrosion allowance may be disregarded.
(2) In cases of media with high corrosive action, a higher corrosion allowance may be required by the Society.

2.3 Calculation of high temperature pipes

2.3.1 General

For main steam piping having a design temperature exceeding 400°C, calculations are to be submitted to the Society concerning the stresses due to internal pressure, piping weight and any other external load, and to thermal expansion, for all cases of actual operation and for all lengths of piping.

The calculations are to include, in particular:

- the components, along the three principal axes, of the forces and moments acting on each branch of piping
- the components of the displacements and rotations causing the above forces and moments
- all parameters necessary for the computation of forces, moments and stresses.

In way of bends, the calculations are to be carried out taking into account, where necessary, the pipe ovalisation and its effects on flexibility and stress increase.

A certain amount of cold springing, calculated on the basis of expected thermal expansion, is to be applied to the piping during installation. Such springing is to be neglected in stress calculations; it may, however, be taken into account in terms of its effect on thrusts on turbines and other parts.

2.3.2 Thermal stress

The combined stress σ_{ID}, in N/mm^2, due to thermal expansion, calculated by the following formula:

$$\sigma_{ID} = (\sigma^2 + 4\tau^2)^{0,5}$$

is to be such as to satisfy the following equation:

$$\sigma_{ID} \le 0,75K_{20} + 0,25K_T$$

where:

- σ : Value of the longitudinal stress due to bending moments caused by thermal expansion, increased, if necessary, by adequate factors for bends, in N/mm^2; in general it is not necessary to take account of the effect of axial force
- τ : Value of the tangential stress due to torque caused by thermal expansion, in N/mm^2; in general it is not necessary to take account of the effect of shear force
- K_{20} : Value of the permissible stress for the material employed, calculated according to [2.2.2], for a temperature of 20°C, in N/mm^2
- K_T : Value of the permissible stress for the material employed, calculated according to [2.2.2], for the design temperature T, in N/mm^2.

2.3.3 Longitudinal stresses

The sum of longitudinal stresses σ_L, in N/mm^2, due to pressure, piping weight and any other external loads is to be such as to satisfy the following equation:

$$\sigma_L \le K_T$$

where K_T is defined in [2.3.2].

2.3.4 Alternative limits for permissible stresses

Alternative limits for permissible stresses may be considered by the Society in special cases or when calculations have been carried out following a procedure based on hypotheses other than those considered above.

2.4 Junction of pipes

2.4.1 General

a) The junctions between metallic pipe lengths or between metallic pipe lengths and fittings are to be made by:
   - direct welding (butt-weld, socket-weld)
   - bolted flanges (welded-on or screwed-on)
   - threaded sleeve joints, or
   - mechanical joints (see [2.4.5]).

   The joints are to comply with a recognized standard or to be of a design proven to be suitable for the intended purpose and acceptable to the Society. See also [2.1.2].

   The expression “mechanical joints” means devices intended for direct connection of pipe lengths other than by welding, flanges or threaded joints described in [2.4.2], [2.4.3] and [2.4.4].

b) The number of joints in flammable oil piping systems is to be kept to the minimum necessary for mounting and dismantling purposes.

c) The gaskets and packings used for the joints are to suit the design pressure, the design temperature and the nature of the fluids conveyed.

d) The junction between plastic pipes is to comply with Ch 1, App 2.

2.4.2 Welded metallic joints

a) Welded joints are to be used in accordance with Tab 14. Welding and non destructive testing of welds are to be carried out in accordance with Article [3].

b) Butt-welded joints are to be of full penetration type, with or without special provision for a high quality of root side.

   The expression "special provision for a high quality of root side" means that butt welds were accomplished as double welded or by use of a backing ring or inert gas back-up on first pass, or other similar methods accepted by the Society.

c) Slip-on sleeve and socket welded joints are to have sleeves, sockets and weldments of adequate dimensions in compliance with a standard recognised by the Society.

2.4.3 Metallic flange connections

a) Flanges are to comply with a standard recognized by the Society. This standard is to cover the design pressure and design temperature of the piping system.

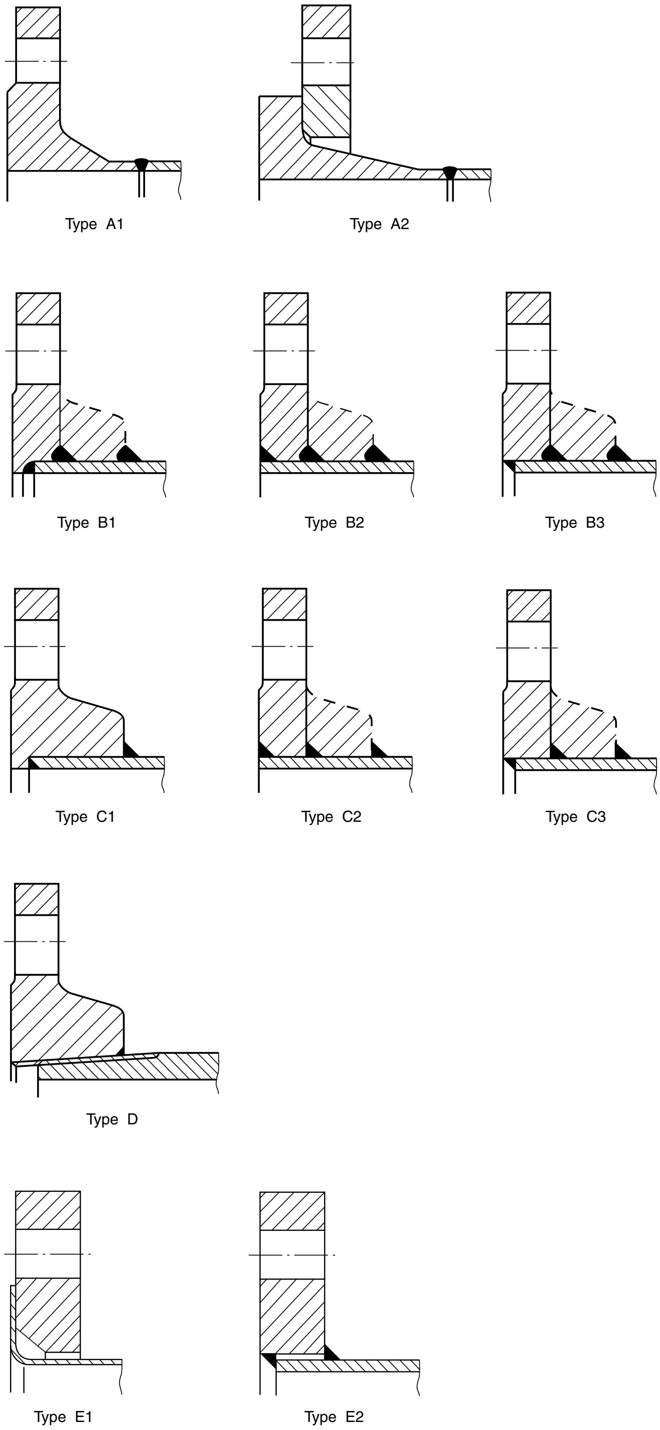
b) Flange material is to be suitable for the nature and temperature of the fluid, as well as for the material of the pipe on which the flange is to be attached.

c) Flanges are to be attached to the pipes by welding or screwing in accordance with one of the designs shown in Fig 1.

Permitted applications are indicated in Tab 15.

Alternative methods of attachment will be specially considered by the Society.

Figure 1 : Types of metallic flange connections



Note 1: For type D, the pipe and flange are to be screwed with a tapered thread and the diameter of the screw portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unthreaded pipe. For certain types of thread, after the flange has been screwed hard home, the pipe is to be expanded into the flange.

Note 2: The leg length of the fillet weld, as well as the dimension of the groove penetration in the flange, is to be in general equal to 1,5 times the pipe thickness but not less than 5 mm.

2.4.4 Slip-on threaded joints

a) Slip-on threaded joints having pipe threads where pressure-tight joints are made on the threads with parallel or tapered threads are to comply with requirements of a recognized national or international standard and are to be acceptable to the Society.

b) Slip-on threaded joints may be used for piping systems in accordance with Tab 14.

c) Threaded joints may be accepted also in CO_2 piping systems, provided that they are used only inside protected spaces and in CO_2 cylinder rooms.

Table 14 : Use of welded and threaded metallic joints in piping systems

Joints	Permitted classes of piping	Restrictions of use
Butt-welded, with special provision for a high quality of root side **(1)**	III, II, I	No restrictions
Butt-welded, without special provision for a high quality of root side **(1)**	III, II	No restrictions
Slip-on sleeve and socket welded **(2)**	III	no restrictions
Threaded sleeve joints with tapered thread **(3)**	I	Not allowed for: • pipes with outside diameter of more than 33,7 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
	III, II	Not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
Threaded sleeve joints with parallel thread **(3)**	III	Not allowed for: • pipes with outside diameter of more than 60,3 mm • pipes inside tanks • piping systems conveying toxic or flammable media or services where fatigue, severe erosion or crevice corrosion is expected to occur.

(1) For expression "special provision for a high quality of root side" see [2.4.2] item b).
(2) Particular cases may be allowed by the Society for piping systems of Class I and II having outside diameter ≤ 88,9 mm except for piping systems conveying toxic media or services where fatigue, severe erosion or crevice corrosion is expected to occur.
(3) In particular cases, sizes in excess of those mentioned above may be accepted by the Society if found in compliance with a recognised national and/or international standard.
Note 1: Other applications will be specially considered by the Society.

Table 15 : Use of metallic flange connections in piping systems (types as shown in Fig 1)

Type of media conveyed	Class of piping (see Tab 3)		
	I	II	III
Toxic or corrosive media Flammable liquids (where heated above flashpoint or having flashpoint < 60°C) Liquefied gases	A1, A2, B1, B2, B3 **(1) (2) (4)**	A1, A2, B1, B2, B3, C1, C2, C3 **(1) (4)**	not applicable
Fuel oil Lubricating oil	A1, A2, B1, B2, B3	A1, A2, B1, B2, B3, C1, C2, C3	A1, A2, B1, B2, B3, C1, C2, C3, E2
Steam Thermal oil	A1, A2, B1, B2, B3 **(2) (3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2
Other media as water, air, gases (refrigerants), non-flammable hydraulic oil, etc.	A1, A2, B1, B2, B3 **(3)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E2 **(6)**	A1, A2, B1, B2, B3, C1, C2, C3, D, E1, E2 **(5) (6) (7)**

(1) When design pressure p (see [1.3.2]) exceeds 1 MPa, types A1 and A2 only.
(2) For nominal diameter ND ≥ 150 mm, types A1 and A2 only.
(3) When design temperature T (see [1.3.3] exceeds 400°C, types A1 and A2 only.
(4) For cargo piping carrying chemical products covered by the IBC Code, IBC Code Ch. 5, 5.3 is to be applied. For cargo piping carrying gas products covered by the IGC Code, IGC Code Ch. 5, 5.4 is to be applied.
(5) Type E2 only, for design pressure p ≤ 1,6 Mpa and design temperature T ≤ 150°C.
(6) Types D and E1 only, for design temperature T ≤ 250°C.
(7) Type E1 only, for water pipelines and for open ended lines (e.g. drain, overflow, air vent piping, etc.).

2.4.5 Mechanical joints

Due to the great variations in design and configuration of mechanical joints, specific recommendation regarding calculation method for theoretical strength calculations is not specified. The Type Approval is to be based on the results of testing of the actual joints.

Below specified requirements are applicable to pipe unions, compression couplings, slip-on joints as shown in Fig 2. Similar joints complying with these requirements may be acceptable.

a) Mechanical joints including pipe unions, compression couplings, slip-on joints and similar joints are to be of approved type for the service conditions and the intended application.

b) Where the application of mechanical joints results in reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

c) Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

d) Material of mechanical joints is to be compatible with the piping material and internal and external media.

e) As far as applicable, the mechanical joints are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure is to be specially considered by the Society.

f) In general, mechanical joints are to be of fire resistant type as required by Tab 16.

g) Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the shell openings or tanks containing flammable fluids.

h) The mechanical joints are to be designed to withstand internal and external pressure as applicable and, where used in suction lines, are to be capable of operating under vacuum.

i) The number of mechanical joints in flammable liquid systems is to be kept to a minimum. In general, flanged joints conforming to recognised standards are to be used.

j) Piping in which a mechanical joint is fitted is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

k) Slip-on joints are not to be used in pipelines in tanks and other spaces which are not easily accessible (refer to IMO Circular MSC/Circ.734), except that these joints may be permitted in tanks that contain the same media as the pipe where the joint is fitted. Usage of slip type slip-on joints as the main means of pipe connection is not permitted except for cases where compensation of axial pipe deformation is necessary.

l) Application of mechanical joints and their acceptable use for each service is indicated in Tab 16; dependence upon the class of piping, pipe dimensions, working pressure and temperature is indicated in Tab 17.

m) In some particular cases, sizes in excess of those mentioned above may be accepted by the Society if they are in compliance with a recognised national and/or international standard.

n) Application of various mechanical joints may be accepted as indicated by Tab 16. However, in all cases, acceptance of the joint type is to be subject to approval for the intended application, and subject to conditions of the approval and applicable Rules.

o) Mechanical joints are to be tested in accordance with the provisions of Tab 37.

2.5 Protection against overpressure

2.5.1 General

a) These requirements deal with the protection of piping systems against overpressure, with the exception of heat exchangers and pressure vessels, which are dealt with in Ch 1, Sec 3, [2.4].

b) Safety valves are to be sealed after setting.

2.5.2 Protection of flammable oil systems

Provisions shall be made to prevent overpressure in any flammable oil tank or in any part of the flammable oil systems, including the filling pipes.

2.5.3 Protection of pump and compressor discharges

a) Provisions are to be made so that the discharge pressure of pumps and compressors cannot exceed the pressure for which the pipes located on the discharge of these pumps and compressors are designed.

b) When provided on the pump discharge for this purpose, safety valves are to lead back to the pump suction.

c) The discharge capacity of the safety valves installed on pumps and compressors is to be such that the pressure at the discharge side cannot exceed by more than 10% the design pressure of the discharge pipe in the event of operation with closed discharge.

2.5.4 Protection of pipes

a) Pipes likely to be subjected to a pressure exceeding their normal working pressure are to be provided with safety valves or equivalent overpressure protecting devices.

b) In particular, pipes located on the low pressure side of pressure reducing valves are to be provided with safety valves unless they are designed for the maximum pressure on the high pressure side of the pressure reducing valve. See also [1.3.2] and [2.9.1].

c) The discharge capacity of the devices fitted on pipes for preventing overpressure is to be such that the pressure in these pipes cannot exceed the design pressure by more than 10%.

Figure 2 : Examples of mechanical joints

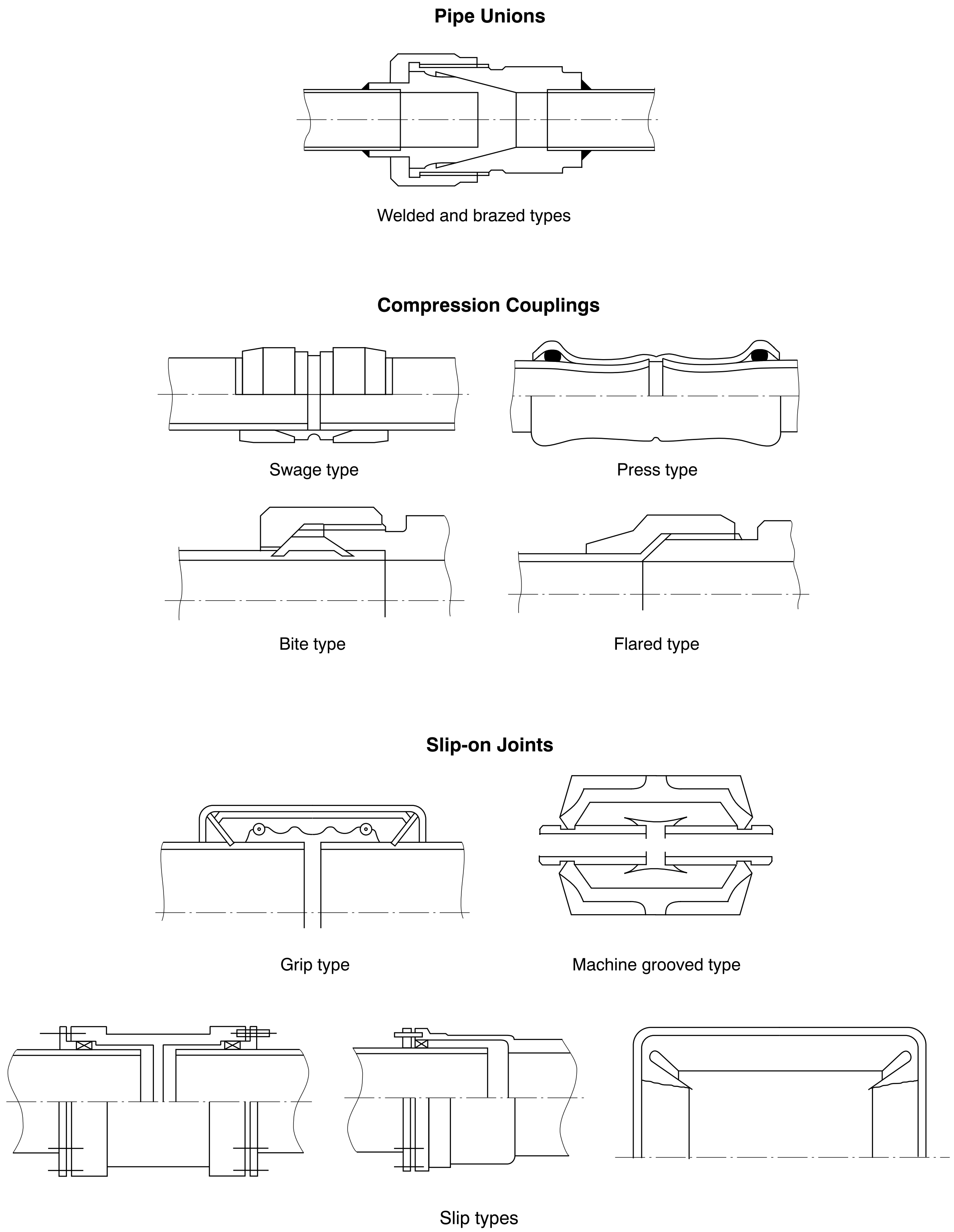


Table 16 : Application of mechanical joints

Systems		Kind of connections		
		Pipe unions	Compression couplings **(5)**	Slip-on joints
Flammable fluids (flash point > 60°C)				
1	JP5-NATO(F44) lines	+	+	+ **(2) (3)**
2	Fuel oil lines	+	+	+ **(2) (3)**
3	Lubricating oil lines	+	+	+ **(2) (3)**
4	Hydraulic oil	+	+	+ **(2) (3)**
5	Thermal oil	+	+	+ **(2) (3)**
Sea water				
6	Bilge lines	+	+	+ **(1)**
7	Fire main and water spray	+	+	+**(3)**
8	Foam system	+	+	+**(3)**
9	Sprinkler system	+	+	+ **(3)**
10	Ballast system	+	+	+ **(1)**
11	Cooling water system	+	+	+ **(1)**
12	Tank cleaning services	+	+	+
13	Non-essential systems	+	+	+
Fresh water				
14	Cooling water system	+	+	+ **(1)**
15	Condensate return	+	+	+ **(1)**
16	Non-essential systems	+	+	+
Sanitary/Drains/Scuppers				
17	Deck drains (internal)	+	+	+ **(4)**
18	Sanitary drains	+	+	+
19	Scuppers and discharge (overboard)	+	+	–
Sounding/Vent				
20	Water tanks/Dry spaces	+	+	+
21	Oil tanks (flash point > 60°C)	+	+	+ **(2) (3)**
Miscellaneous				
22	Starting/Control air **(1)**	+	+	–
23	Service air (non-essential)	+	+	+
24	Brine	+	+	+
24	CO_2 system **(1)**	+	+	–
25	Steam	+	+	–

Note 1:
+ : Application is allowed
– : Application is not allowed.
(1) Inside machinery spaces of category A - only approved fire resistant types.
(2) Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
(3) Approved fire resistant types.
(4) Above freeboard deck only.
(5) If compression couplings include any components which readily deteriorate in case of fire, they are to be of approved fire resistant type as required for slip-on joints.

Table 17 : Application of mechanical joints depending upon the class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe Unions			
Welded and brazed types	+ (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm)	+
Compression Couplings			
Swage type	+	+	+
Bite type Flared type	+ (OD ≤ 60,3 mm) + (OD ≤ 60,3 mm)	+ (OD ≤ 60,3 mm) + (OD ≤ 60,3 mm)	+ +
Press type	–	–	+
Slip-on Joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
Note 1: + : Application is allowed – : Application is not allowed.			

2.6 Flexible hoses and expansion joints

2.6.1 General

a) Definitions:
   - Flexible hose assembly: short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.
   - Expansion joint: an assembly designed to safely absorb the heat-induced expansion and contraction, mainly to allow axial relative movement between pipes and the ship's structure as required in [5.6].

b) Flexible hoses and expansion joints are to be of a type approved by the Society. Unless otherwise specified, they are to comply with the requirements of this sub-article.

c) The requirements of this sub-article apply to flexible hoses and expansion joints of metallic or non-metallic material intended for a permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporarily connected flexible hoses or hoses of portable equipment.

d) Unless otherwise specified, the requirements of this sub-article do not apply for flexible hose assemblies and expansion joints intended to be used in fire-extinguishing systems.

e) Flexible hose assemblies and expansion joints intended for piping systems with a design temperature below the ambient temperature are subject to special consideration by the Society.

2.6.2 General conditions of use applicable to flexible hoses and expansion joints

a) Unless otherwise specified, the Society may permit the use of flexible hoses and expansion joints, made of both metallic and non-metallic materials, provided they are approved for the intended service. They may be accepted for use in oil fuel, JP5-NATO (F44), lubricating, hydraulic and thermal oil systems, fresh water and sea water cooling systems, compressed air systems, bilge and ballast systems, Class III steam systems and exhaust gas systems where they comply with the requirements of this sub-article.

b) For steam systems, the flexible hose assemblies and expansion joints are to be of metallic construction.

c) The position of flexible hose assemblies and expansion joints is to be clearly shown on the drawings listed in [1.2.1] and [1.2.2] when submitted to the Society.

d) Flexible hose assembly or an expansion joint is to be selected for the intended location and application taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any requirements of the Society.

e) The arrangement and installation of the flexible hose assemblies and expansion joints are also to comply with [5.9.3].

f) The distance between pipe flanges is to be between the manufactured contraction length and extension length of relevant flexible hose.

2.6.3 Specific conditions of use applicable to flexible hoses

a) Flexible hose assembly is not accepted in high pressure fuel oil injection systems.

b) Flexible hose assemblies for essential services or containing either flammable or toxic media are not to exceed 1,5 m in length.

2.6.4 General requirements for the design of flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be designed and constructed in accordance with recognised National or International standards acceptable to the Society.

b) Acceptance of a flexible hose assembly or an expansion joint is subject to satisfactory prototype testing in accordance with the provisions of [19.2].

c) The material, design and construction are to be at least suitable for:
   - marine environment and external contact with hydrocarbons
   - internal contact and resistance to the fluid they are to convey
   - maximal pressure and temperature of fluid they are to convey
   - maximum expected forces due to vibrations
   - maximum expected impulse peak pressure.

   The metallic materials are to comply with [2.1.2].

d) Where rubber materials are intended for use in bilge, ballast, compressed air, oil fuel, JP5-NATO (F44), lubricating, hydraulic and thermal oil systems, the construction is to incorporate a single, double, or more, closely woven integral wire braid or other suitable material reinforcement acceptable to the Society.

   Flexible hoses and expansion joints of plastic materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid, are to have suitable material reinforcement, as far as practicable.

   Rubber or plastic material hoses and expansion joints used in oil supply lines to burners are to have external wire braid protection in addition to the reinforcement mentioned above.

e) Flexible hose assemblies and expansion joints constructed of non-metallic materials, which are intended for installation in piping systems for flammable media or in sea water systems where failure may result in flooding, are to be of fire-resistant type except in cases where such hoses are installed on open decks as defined in Ch 4, Sec 5, [1.2.3], item b) (5) and not used for fuel oil or JP5-NATO (F44) lines.

   Fire resistance is to be demonstrated by testing in accordance with standard specified in Tab 33 and Tab 35.

f) Flexible hoses and expansion joints are to be complete with approved end fittings in accordance with manufacturer's specification. The end connections that do not have a flange are to comply with [2.4.5] as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose or expansion joint with particular reference to pressure and impulse tests.

2.6.5 Specific requirements for the design of flexible hoses

The hose clamps and similar types of end attachments are not acceptable for use in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 0,5 MPa and provided that there are double clamps at each end connection.

2.6.6 Marking

Flexible hoses or expansion joints are to be permanently marked by the manufacturer with the following details:

- manufacturer's name or trademark
- date of manufacture (month/year)
- designation type reference
- nominal diameter
- pressure rating
- temperature rating.

Where a flexible hose assembly or an expansion joint is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

2.7 Valves and accessories

2.7.1 General

a) Valves and accessories are normally to be built in accordance with a recognized standard.

   Failing this, they are to be approved by the Society when they are fitted:
   - in a class I piping system, or
   - in a class II piping system with a diameter exceeding 100 mm, or
   - on the ship side, on the collision bulkhead or on fuel or JP5-NATO (F44) tanks under static pressure.

b) Shut-off valves are to be provided where necessary to isolate pumps, heat exchangers, pressure vessels, etc., from the rest of the piping system, and in particular:
   - to allow the isolation of duplicate components without interrupting the fluid circulation
   - for maintenance or repair purposes.

2.7.2 Design of valves and accessories

a) Materials of valve and accessory bodies are to comply with [2.1].

b) Connections of valves and accessories with pipes are to comply with [2.4].

c) All valves and accessories are to be so designed as to prevent the loosening of covers and glands when they are operated.

d) Valves are to be so designed as to shut with a right-hand (clockwise) motion of the wheels.

e) Valves are to be provided with local indicators showing whether they are open or shut, unless this is readily apparent.

2.7.3 Valves with remote control

a) All valves which are provided with remote control are also to be designed for local manual operation.

b) The remote control system and means of local operation are to be independent. In this respect, arrangement of the local operation by means of a fixed hand pump will be specially considered by the Society.

c) In the case of valves which are to be provided with remote control in accordance with the Rules, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

d) Power failure of the remote control system is not to cause an undesired change of the valve position.

2.8 Sea inlets and overboard discharges

2.8.1 General

Except where expressly stated in Article [8], the requirements of this sub-article do not apply to scuppers and sanitary discharges.

2.8.2 Design of sea inlets and overboard discharges

a) All inlets and discharges in the shell plating are to be fitted with efficient and accessible arrangements for preventing accidental ingress of water into the ship.

b) Sea inlets and overboard discharges are to be fitted with valves complying with [2.7] and [2.8.3].

c) Sea inlets and discharges related to the operation of main and auxiliary machinery are to be fitted with readily accessible valves between the pipes and the shell plating or between the pipes and fabricated boxes attached to the shell plating. The valves may be controlled locally and are to be provided with indicators showing whether they are open or closed.

d) Sea inlets are to be so designed and arranged as to limit turbulence and to avoid the ingress of air due to motion of the ship.

e) Sea inlets are to be fitted with gratings complying with [2.8.4].

f) Provisions are to be made for clearing sea inlet gratings.

g) Sea chests are to be suitably protected against corrosion.

2.8.3 Valves

a) Sea inlet and overboard discharge valves are to be secured:
   - directly on the shell plating, or
   - on sea chests built on the shell plating, with scantlings in compliance with Part B of the Rules, or
   - on extra-reinforced and short distance pieces attached to the shell (see Tab 5).

b) The bodies of the valves and distance pieces are to have a spigot passing through the plating without projecting beyond the external surface of such plating or of the doubling plates and stiffening rings, if any.

c) Valves are to be secured by means of:
   - bolts screwed through the plating with a countersunk head, or
   - studs screwed in heavy pads themselves secured to the hull or chest plating, without penetration of the plating by the stud holes.

d) The use of butterfly valves will be specially considered by the Society. In any event, butterfly valves not fitted with flanges are not to be used for water inlets or overboard discharges unless provisions are made to allow disassembling at sea of the pipes served by these valves without any risk of flooding.

e) The materials of the valve bodies and connecting pieces are to comply with Tab 4.

2.8.4 Gratings

a) Gratings are to have a free flow area not less than twice the total section of the pipes connected to the inlet.

b) When gratings are secured by means of screws with a countersunk head, the tapped holes provided for such screws are not to pass through the plating or doubling plates outside distance pieces or chests.

c) Screws used for fixing gratings are not to be located in the corners of openings in the hull or of doubling plates.

d) In the case of large sea inlets, the screws used for fixing the gratings are to be locked and protected from corrosion.

e) When gratings are cleared by use of compressed air or steam devices, the chests, distance pieces and valves of sea inlets and outlets thus arranged are to be so constructed as to withstand the maximum pressure to which they may be subjected when such devices are operating.

2.8.5 Ship side connections for blow-down of boilers

a) Blow-down pipes of boilers are to be provided with cocks or valves placed as near the end of the pipes as possible, while remaining readily accessible and located above the engine room floor.

b) Blow-down valves are to be so designed that it is easy to ascertain whether they are open or shut. Where cocks are used, the control keys are to be such that they cannot be taken off unless the cocks are shut. Where valves are used, the control-wheels are to be permanently fixed to the spindle.

c) A protection ring is to be fitted on the shell plating, outside, at the end of the blow-down pipes. The spigot of the valve referred to in [2.8.3], item b), is to pass through this ring.

2.9 Control and monitoring

2.9.1 General

a) Local indicators are to be provided for at least the following parameters:
   - pressure, in pressure vessels, at pump or compressor discharge, at the inlet of the equipment served, on the low pressure side of pressure reducing valves
   - temperatures, in tanks and vessels, at heat exchanger inlet and outlet
   - levels, in tanks and vessels containing liquids.

b) Safeguards are to be provided where an automatic action is necessary to restore acceptable values for a faulty parameter.

c) Automatic controls are to be provided where it is necessary to maintain parameters related to piping systems at a pre-set value.

2.9.2 Level gauges

Level gauges used in flammable oil systems are to be of a type approved by the Society and are not to require penetration below the top of the tank and their failure or overfilling of the tanks is not to permit release of fuel.

Level gauges, when allowed, are to be made of heat-resistant material and efficiently protected against shocks.

3 Welding of steel piping

3.1 Application

3.1.1

a) The following requirements apply to welded joints belonging to class I or II piping systems.
   At the discretion of the Society they may also be requested for class III piping systems.

b) This article does not apply to refrigerated spaces installation piping systems operating at temperatures lower than minus 40°C.

c) The requirements for qualification of welding procedures are given in NR216 Materials and Welding.

3.2 General

3.2.1 Welding processes

a) Welded joints of pipes are to be made by means of electric arc or oxyacetylene welding, or any other previously approved process.

b) When the design pressure exceeds 0,7 MPa, oxyacetylene welding is not permitted for pipes with an external diameter greater than 100 mm or a thickness exceeding 6 mm.

3.2.2 Location of joints

The location of welded joints is to be such that as many as possible can be made in a workshop. The location of welded joints to be made on board is to be so determined as to permit their joining and inspection in satisfactory conditions.

3.3 Design of welded joints

3.3.1 Types of joints

a) Except for the fixing of flanges on pipes in the cases mentioned in Fig 1 and for the fixing of branch pipes, joints between pipes and between pipes and fittings are to be of the butt-welded type. However, for class I pipes with internal diameter not exceeding 50 mm and for class II pipes, socket welded connections of approved types may be used.

b) For butt-welded joints between pipes or between pipes and flanges or other fittings, correctly adjusted backing rings may be used; such rings are to be either of the same grade of steel as the elements to be welded or of such a grade as not to adversely influence the weld; if the backing ring cannot be removed after welding, it is to be correctly profiled.

3.3.2 Assembly of pipes of unequal thickness

If the difference of thickness between pipes to be butt-welded exceeds 10% of the thickness of the thinner pipe plus 1 mm, subject to a maximum of 4 mm, the thicker pipe is to be thinned down to the thickness of the thinner pipe on a length at least equal to 4 times the offset, including the width of the weld if so desired.

3.3.3 Accessories

a) When accessories such as valves are connected by welding to pipes, they are to be provided with necks of sufficient length to prevent abnormal deformations during the execution of welding or heat treatment.

b) For the fixing by welding of branch pipes on pipes, it is necessary to provide either a thickness increase as indicated in [2.2.5] or a reinforcement by doubling plate or equivalent.

3.4 Preparation of elements to be welded and execution of welding

3.4.1 General

Attention is drawn to the provisions of Ch 1, Sec 3, which apply to the welding of pressure pipes.

3.4.2 Edge preparation for welded joints

The preparation of the edges is preferably to be carried out by mechanical means. When flame cutting is used, care is to be taken to remove the oxide scales and any notch due to irregular cutting by matching, grinding or chipping back to sound metal.

3.4.3 Abutting of parts to be welded

a) The elements to be welded are to be so abutted that surface misalignments are as small as possible.

b) As a general rule, for elements which are butt-welded without a backing ring the misalignment between internal walls is not to exceed the lesser of:

- the value given in Tab 18 as a function of thickness t and internal diameter d of these elements, and
- t / 4.

Where necessary, the pipe ends are to be bored or slightly expanded so as to comply with these values; the thickness obtained is not to be less than the Rule thickness.

c) In the case of welding with a backing ring, smaller values of misalignment are to be obtained so that the space between the backing ring and the internal walls of the two elements to be assembled is as small as possible; normally this space is not to exceed 0,5 mm.

d) The elements to be welded are to be adequately secured so as to prevent modifications of their relative position and deformations during welding.

e) Tack welds should be made with an electrode suitable for the base metal; tack welds which form part of the finished weld should be made using approved procedures.

When welding materials requiring preheating are employed, the same preheating should be applied during tack welding.

3.4.4 Protection against adverse weather conditions

a) Pressure pipes are to be welded, both on board and in the shop, away from draughts and sudden temperature variations.

b) Unless special justification is given, no welding is to be performed if the temperature of the base metal is lower than 0°C.

3.4.5 Preheating

a) Preheating is to be performed as indicated in Tab 19, depending on the type of steel, the chemical composition and the pipe thickness.

b) The temperatures given in Tab 19 are based on the use of low hydrogen processes. Where low hydrogen processes are not used, the Society reserves the right to require higher preheating temperatures.

3.5 Post-weld heat treatment

3.5.1 General

a) As far as practicable, the heat treatment is to be carried out in a furnace. Where this is impracticable, and more particularly in the case of welding on board, the treatment is to be performed locally by heating uniformly a circular strip, extending on at least 75 mm on both sides of the welded joint; all precautions are to be taken to permit accurate checking of the temperature and slow cooling after treatment.

b) For austenitic and austenitic ferritic steels, post-weld head treatment is generally not required.

3.5.2 Heat treatment after welding other than oxyacetylene welding

a) Stress relieving heat treatment after welding other than oxyacetylene welding is to be performed as indicated in Tab 20, depending on the type of steel and thickness of the pipes.

b) The stress relieving heat treatment is to consist in heating slowly and uniformly to a temperature within the range indicated in the Table, soaking at this temperature for a suitable period, normally 2 min. per mm of thickness with a minimum of half an hour, cooling slowly and uniformly in the furnace to a temperature not exceeding 400°C and subsequently cooling in still atmosphere.

c) In any event, the heat treatment temperature is not to be higher than $(T_T - 20)$°C, where T_T is the temperature of the final tempering treatment of the material.

3.5.3 Heat treatment after oxyacetylene welding

Stress relieving heat treatment after oxyacetylene welding is to be performed as indicated in Tab 21, depending on the type of steel.

Table 18 : Maximum value of misalignment

d, in mm	t, in mm		
	$t \leq 6$	$6 < t \leq 10$	$10 < t$
$d < 150$	1,0	1,0	1,0
$150 \leq d < 300$	1,0	1,5	1,5
$300 \leq d$	1,0	1,5	2,0

Table 19 : Preheating temperature

Type of steel		Thickness of thicker part, in mm	Minimum preheating temperature, in °C
C and C-Mn steels	$C + \frac{Mn}{6} \leq 0,40$	$t \geq 20$**(2)**	50
	$C + \frac{Mn}{6} > 0,40$	$t \geq 20$ **(2)**	100
0,3 Mo		$t \geq 13$ **(2)**	100
1 Cr 0,5 Mo		$t < 13$ $t \geq 13$	100 150
2,25 Cr 1 Mo **(1)**		$t < 13$ $t \geq 13$	150 200
0,5 Cr 0,5 Mo V **(1)**		$t < 13$ $t \geq 13$	150 200

(1) For 2,25 Cr 1 Mo and 0,5 Cr 0,5 Mo V grades with thicknesses up to 6 mm, preheating may be omitted if the results of hardness tests carried out on welding procedure qualification are considered acceptable by the Society.
(2) For welding in ambient temperature below 0°C, the minimum preheating temperature is required independent of the thickness unless specially approved by the Society.

Table 20 : Heat treatment temperature

Type of steel	Thickness of thicker part, in mm	Stress relief treatment temperature, in °C
C and C-Mn steels	$t \geq 15$ **(1)** **(3)**	550 to 620
0,3 Mo	$t \geq 15$ **(1)**	580 to 640
1 Cr 0,5 Mo	$t \geq 8$	620 to 680
2,25 Cr 1 Mo 0,5 Cr 0,5 Mo V	any **(2)**	650 to 720

(1) Where steels with specified Charpy V notch impact properties at low temperature are used, the thickness above which post-weld heat treatment is to be applied may be increased, subject to the special agreement of the Society.
(2) For 2,25Cr 1Mo and 0,5Cr 0,5Mo V grade steels, heat treatment may be omitted for pipes having thickness lower than 8 mm, diameter not exceeding 100 mm and service temperature not exceeding 450°C.
(3) For C and C-Mn steels, stress relieving heat treatment may be omitted up to 30 mm thickness, subject to the special agreement of the Society.

Table 21 : Heat treatment after oxyacetylene welding

Type of steel	Heat treatment and temperature, in °C
C and C-Mn	Normalizing 880 to 940
0,3 Mo	Normalizing 900 to 940
1Cr-0,5Mo	Normalizing 900 to 960 Tempering 640 to 720
2,25Cr-1Mo	Normalizing 900 to 960 Tempering 650 to 780
0,5Cr-0,5Mo-0,25V	Normalizing 930 to 980 Tempering 670 to 720

3.6 Inspection of welded joints

3.6.1 General

a) The inspection of pressure pipe welded joints is to be performed at the various stages of the fabrication further to the qualifications defined in [3.1.1], item c).

b) The examination mainly concerns those parts to be welded further to their preparation, the welded joints once they have been made and the conditions for carrying out possible heat treatments.

c) The required examinations are to be carried out by qualified operators in accordance with procedures and techniques to the Surveyor's satisfaction.

3.6.2 Visual examination

Welded joints, including the inside wherever possible, are to be visually examined.

3.6.3 Non-destructive examinations

a) Non-destructive tests for class I pipes are to be performed as follows:
   - butt-welded joints of pipes with an external diameter exceeding 75 mm are to be subjected to full X-ray examination or equivalent
   - welded joints other than butt-welded joints and which cannot be radiographed are to be examined by magnetic particle or liquid penetrant tests
   - fillet welds of flange connections are to be examined by magnetic particle tests or by other appropriate non-destructive tests.

b) Non-destructive tests for class II pipes are to be performed as follows:
   - butt-welded joints of pipes with an external diameter exceeding 100 mm are to be subjected to at least 10% random radiographic examination or equivalent
   - welded joints other than butt-welded joints are to be examined by magnetic particle tests or by other appropriate non-destructive tests
   - fillet welds of flange connections may be required to be examined by magnetic particle tests or by other appropriate non-destructive tests, at the discretion of the Surveyor.

3.6.4 Defects and acceptance criteria

a) Joints for which non-destructive examinations reveal unacceptable defects are to be re-welded and subsequently to undergo a new non-destructive examination. The Surveyor may require that the number of joints to be subjected to non-destructive examination is larger than that resulting from the provisions of [3.6.3].

b) The acceptance criteria of defects are:
   - for class I pipes, those defined in NR216 Materials and Welding for the special quality level
   - for class II pipes, those defined in NR216 Materials and Welding for the normal quality level.

4 Bending of pipes

4.1 Application

4.1.1 This Article applies to pipes made of:

- alloy or non-alloy steels
- copper and copper alloys
- stainless steel.

4.2 Bending process

4.2.1 General

The bending process is to be such as not to have a detrimental influence on the characteristics of the materials or on the strength of the pipes.

4.2.2 Bending radius

Unless otherwise justified, the bending radius measured on the centreline of the pipe is not to be less than:

- twice the external diameter for copper and copper alloy, C steel and stainless steel pipes
- 3 times the external diameter for cold bent steel pipes.

4.2.3 Acceptance criteria

a) The pipes are to be bent in such a way that, in each transverse section, the difference between the maximum and minimum diameters after bending does not exceed 10% of the mean diameter; higher values, but not exceeding 15%, may be allowed in the case of pipes which are not subjected in service to appreciable bending stresses due to thermal expansion or contraction.

b) The bending is to be such that the depth of the corrugations is as small as possible and does not exceed:
- 5% of the corrugation length for class I and class II piping systems
- 9% of the corrugation length for class III piping system.

4.2.4 Hot bending

a) In the case of hot bending, all arrangements are to be made to permit careful checking of the metal temperature and to prevent rapid cooling, especially for alloy steels.

b) Hot bending is to be generally carried out in the temperature range 850°C-1000°C for all steel grades; however, a decreased temperature down to 750°C may be accepted during the forming process.

4.3 Heat treatment after bending

4.3.1 Copper and copper alloy

Copper and copper alloy pipes are to be suitably annealed after cold bending if their external diameter exceeds 50 mm.

4.3.2 Steel

a) After hot bending carried out within the temperature range specified in [4.2.4], the following applies:
- for C, C-Mn and C-Mo steels, no subsequent heat treatment is required,
- for Cr-Mo and Cr-Mo-V steels, a subsequent stress relieving heat treatment in accordance with Tab 20 is required.

b) After hot bending performed outside the temperature range specified in [4.2.4], a subsequent new heat treatment in accordance with Tab 21 is required for all grades.

c) Unless otherwise agreed, after cold bending at a radius lower than 4 times the external diameter of the pipe, a heat treatment in accordance with Tab 21 is required.

5 Arrangement and installation of piping systems

5.1 General

5.1.1 Unless otherwise specified, piping and pumping systems covered by the Rules are to be permanently fixed on board ship.

5.2 Location of tanks and piping system components

5.2.1 Flammable oil systems

Location of tanks and piping system components conveying flammable fluids under pressure is to comply with [5.10].

5.2.2 Piping systems with open ends

Attention is to be paid to the requirements for the location of open-ended pipes on board ships having to comply with the provisions of [5.5].

5.2.3 Pipe lines located inside tanks

a) The passage of pipes through tanks, when permitted, normally requires special arrangements such as reinforced thickness or tunnels, in particular for:
- bilge pipes
- ballast pipes
- scuppers and sanitary discharges
- air, sounding and overflow pipes
- fuel oil and JP5-NATO (F44) pipes.

b) Junctions of pipes inside tanks are to be made by welding or welded flange connections. See also [2.4.3].

5.2.4 Overboard discharges

Overboard discharges are to be so located as to prevent any discharge of water into the lifeboats while they are being lowered.

5.2.5 Piping and electrical apparatus

As far as possible, pipes are not to pass near switchboards or other electrical apparatus. If this requirement is impossible to satisfy, gutterways or masks are to be provided wherever deemed necessary to prevent projections of liquid or steam on live parts.

5.3 Passage through watertight bulkheads or decks

5.3.1 Penetration of watertight bulkheads and decks

a) Where penetrations of watertight bulkheads and internal decks are necessary for piping, arrangements are to be made to maintain the watertight integrity.

b) Lead or other heat sensitive materials are not to be used in piping systems which penetrate watertight subdivision bulkheads or decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the bulkhead or decks.

This applies in particular to the following systems:

- bilge system
- ballast system
- scuppers and sanitary discharge systems.

c) Where bolted connections are used when passing through watertight bulkheads or decks, the bolts are not to be screwed through the plating. Where welded connections are used, they are to be welded on both sides of the bulkhead or deck.

d) In case of penetrations of watertight bulkheads or decks by plastic pipes, case by case considerations will be made by the Society in agreement with the Naval Authority and based on Ch 1, App 2, [4.7.2].

5.3.2 Passage through the collision bulkhead

a) A maximum of two pipes may pass through the collision bulkhead below the bulkhead deck, unless otherwise justified. Such pipes are to be fitted with suitable valves operable from above the bulkhead deck and the valve chest is to be secured at the bulkhead inside the fore peak. Such valves may be fitted on the after side of the collision bulkhead provided that they are readily accessible under all service conditions and the space in which they are located is not a cargo space or similar space. All valves are to be of steel, bronze or other approved ductile material. Valves of ordinary cast iron or similar material are not acceptable.

b) The remote operation device of the valve referred to in a) is to include an indicator to show whether the valve is open or shut.

5.4 Independence of lines

5.4.1 As a general rule, bilge and ballast lines are to be entirely independent and distinct from lines conveying lubricating oil, fuel oil and JP5-NATO(F44), with the exception of:

- pipes located between collecting boxes and pump suctions
- pipes located between pumps and overboard discharges
- pipes supplying compartments likely to be used alternatively for ballast or fuel oil, provided such pipes are fitted with blind flanges or other appropriate change-over devices, in order to avoid any mishandling.

5.5 Prevention of progressive flooding

5.5.1 Principle

a) In order to comply with the subdivision and damage stability requirements of Pt B, Ch 3, Sec 3, provision is to be made to prevent any progressive flooding of a dry compartment served by any open-ended pipe, in the event that such pipe is damaged or broken in any other compartment by collision or grounding.

b) For this purpose, if pipes are situated within assumed flooded compartments, arrangements are to be made to ensure that progressive flooding cannot thereby extend to compartments other than those assumed to be flooded for each case of damage. However, the Society may permit minor progressive flooding if it is demonstrated that its effects can be easily controlled and the safety of the ship is not impaired. Refer to Pt B, Ch 3, Sec 3.

5.5.2 Extent of damage

For the definition of the assumed transverse extent of damage, reference is to be made to Pt B, Ch 3, Sec 3.

5.6 Provision for expansion

5.6.1 General

Piping systems are to be so designed and pipes so fixed as to allow for relative movement between pipes and the ship's structure, having due regard to:

- the temperature of the fluid conveyed
- the coefficient of thermal expansion of the pipes material
- the deformation of the ship's hull.

5.6.2 Fitting of expansion devices

All pipes subject to thermal expansion and those which, due to their length, may be affected by deformation of the hull, are to be fitted with expansion pieces or loops.

5.7 Supporting of the pipes

5.7.1 General

Unless otherwise specified, the fluid lines referred to in this Section are to consist of pipes connected to the ship's structure by means of collars or similar devices.

5.7.2 Arrangement of supports

Shipyards are to take care that:

a) The arrangement of supports and collars is to be such that pipes and flanges are not subjected to abnormal bending stresses, taking into account their own mass, the metal they are made of, and the nature and characteristics of the fluid they convey, as well as the contractions and expansions to which they are subjected.

b) Heavy components in the piping system, such as valves, are to be independently supported.

5.8 Protection of pipes

5.8.1 Protection of sea water pipes from mechanical damage

Seawater pipes in vehicle and ro-ro spaces are to be protected from impact of cargo where they are liable to be damaged.

For ships having a **SEA-KEEP** additional class notation, requirements of Pt E, Ch 9, Sec 3 also apply.

5.8.2 Protection against corrosion and erosion

a) Pipes are to be efficiently protected against corrosion, particularly in their most exposed parts, either by selection of their constituent materials, or by an appropriate coating or treatment.

b) The layout and arrangement of sea water pipes are to be such as to prevent sharp bends and abrupt changes in section as well as zones where water may stagnate. The inner surface of pipes is to be as smooth as possible, especially in way of joints. Where pipes are protected against corrosion by means of galvanizing or other inner coating, arrangements are to be made so that this coating is continuous, as far as possible, in particular in way of joints.

c) Provided that due consideration is given to water velocity with regards to maximum allowed noise levels, such velocity is not to exceed 3 m/s in continuously used sea water systems.

d) Arrangements are to be made to avoid galvanic corrosion.

5.8.3 Protection against frosting

Pipes are to be adequately insulated against cold wherever deemed necessary to prevent frost.

This applies specifically to pipes passing through refrigerated spaces and which are not intended to ensure the refrigeration of such spaces.

Were the pipes are normally kept empty and without risk of frost of condensate or were it is proven that the flow of internal fluid is sufficient to prevent frost the present requirement of insulation could be withdrawn.

5.8.4 Protection of high temperature pipes and components

a) All pipes and other components where the temperature may exceed 220°C are to be efficiently insulated. Where necessary, precautions are to be taken to protect the insulation from being impregnated with flammable oils.

b) Particular attention is to be paid to lagging in way of flanges.

5.9 Valves, accessories and fittings

5.9.1 General

Cocks, valves and other accessories are generally to be arranged so that they are easily visible and accessible for manoeuvring, control and maintenance. They are to be installed in such a way as to operate properly.

5.9.2 Valves and accessories

a) In machinery spaces and tunnels, the cocks, valves and other accessories of the fluid lines referred to in this Section are to be placed:
   - above the floor, or
   - when this is not possible, immediately under the floor, provided provision is made for their easy access and control in service.

b) Control-wheels of low inlet valves are to rise at least 0,45 m above the lowest floor.

5.9.3 Flexible hoses and expansion joints

a) Flexible hoses and expansion joints are to be so arranged as to be accessible at all times.

b) Flexible hoses and expansion joints are to be as short as possible.

c) The radius of curvature of flexible hoses is not to be less than the minimum recommended by the manufacturer.

d) The adjoining pipes are to be suitably aligned, supported, guided and anchored.

e) Isolating valves are to be provided permitting the isolation of flexible hoses intended to convey flammable oil or compressed air.

f) Expansion joints are to be protected against over extension or over compression.

g) Where they are likely to suffer external damage, flexible hoses and expansion joints are to be provided with adequate protection.

5.9.4 Thermometers

Thermometers and other temperature-detecting elements in fluid systems under pressure are to be provided with pockets built and secured so that the thermometers and detecting elements can be removed while keeping the piping under pressure.

5.9.5 Pressure gauges

Pressure gauges and other similar instruments are to be fitted with an isolating valve or cock at the connection with the main pipe.

5.9.6 Nameplates

a) Accessories such as cocks and valves on the fluid lines referred to in this Section are to be provided with nameplates indicating the apparatus and lines they serve except where, due to their location on board, there is no doubt as to their purpose.

b) Nameplates are to be fitted at the upper part of air and sounding pipes.

5.10 Additional arrangements for flammable fluids

5.10.1 General

The requirements in [5.10.3] and [5.10.4] apply to:

- fuel oil systems and JP5-NATO (F44), in all spaces
- lubricating oil systems, in machinery spaces
- other flammable oil systems, in locations where means of ignition are present.

5.10.2 Prohibition of carriage of flammable oils in forepeak tanks

In all ships fuel oil, JP5-NATO (F44) and lubricating oil and other flammable oils are not to be carried in forepeak tanks or tanks forward of the collision bulkhead.

5.10.3 Prevention of flammable oil leakage ignition

a) As far as practicable, parts of the fuel, JP5-NATO (F44) oil and lubricating oil systems containing heated oil under pressure exceeding 0,18 MPa are to be placed above the platform or in any other position where defects and leakage can readily be observed.

   The machinery spaces in way of such parts are to be adequately illuminated.

b) No flammable oil tanks are to be situated where spillage or leakage therefrom can constitute a hazard by falling on:
   - hot surfaces, including those of boilers, heaters, steam pipes, exhaust manifolds and silencers
   - electrical equipment
   - air intakes
   - other sources of ignition.

c) Parts of flammable oil systems under pressure exceeding 0,18 MPa such as pumps, filters and heaters are to comply with the provisions of item b) above.

d) Flammable oil lines are to be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakages onto hot surfaces, into machinery air intakes, or on other sources of ignition.

e) Any relief valve of fuel oil, JP5-NATO (F44) and lubricating oil systems is to discharge to a safe position, such as an appropriate tank.

5.10.4 Provisions for flammable oil leakage containment

a) Tanks used for the storage of flammable oils together with their fittings are to be so arranged as to prevent spillages due to leakage or overfilling.

b) Drip trays with adequate drainage to contain possible leakage from flammable fluid systems are to be fitted:
   - under independent tanks (refer to Ch 1, App 3, [2.3.2])
   - under burners
   - under purifiers and any other oil processing equipment
   - under pumps, heat exchangers and filters
   - under valves and all accessories subject to oil leakage
   - surrounding internal combustion engines.

c) The coaming height of drip trays is to suit the amount of potential oil spillage.

d) Where boilers are located in machinery spaces on decks and the boiler rooms are not separated from the machinery spaces by watertight bulkheads, the decks are to be provided with oil-tight coamings at least 200 mm in height.

e) Where drain pipes are provided for collecting leakages, they are to be led to an appropriate drain tank.

5.10.5 Drain tank

a) The drain tank is not to form part of an overflow system and is to be fitted with an overflow alarm device.

b) In ships provided with a double bottom, appropriate precautions are to be taken when the drain tank is constructed in the double bottom, in order to avoid flooding of the machinery space where drip trays are located, in the event of accidentally running aground.

5.10.6 Valves

All valves and cocks forming part of flammable oil systems are to be capable of being operated from readily accessible positions and, in machinery spaces, from above the working platform.

5.10.7 Level switches

Level switches fitted to flammable oil tanks are to be contained in a steel or other fire-resisting enclosure.

6 Bilge systems

6.1 Principle

6.1.1 General

An efficient bilge pumping system shall be provided, capable of pumping from and draining any watertight compartment other than spaces permanently dedicated to the carriage of fresh water, ballast water, fuel oil or JP5-NATO (F44) and for which other efficient means of pumping are provided, under all practical conditions.

To this purpose ships shall be provided with means to cope with drainage of great amount of water in every compartment. In addition propulsion machinery spaces and auxiliary machinery spaces, where substantial oil leakages may occur, shall be provided with bilge means which prevent sea pollution by avoiding overboard discharge of water and oil bilge (see requirements of Annex I of MARPOL 73/78).

6.2 Design of bilge systems

6.2.1 General

a) The bilge pumping installation is to include a bilge draining system serving all watertight spaces, designed to drain the effluents resulting from limited and occasional leakages, and consisting of:

- an oily bilge water draining and treatment system dedicated to machinery spaces, including auxiliary machinery spaces, tunnels and other spaces where oil leakage may occur
- a separate clean bilge water system dedicated to the other spaces. This system may be provided by a bilge main, by independent bilge main sections or by dedicated system.

  Power bilge pumps or ejectors are to serve the bilge main or each independent bilge main section. They may serve several compartments.

  Power bilge pumps or ejectors discharging locally overboard could be provided for dedicated systems.
- it is pointed out that where required the oily bilge water draining and treatment system is not in replacement of the clean bilge water system but in supplement.

b) If deemed acceptable by the Society, bilge pumping arrangements may be dispensed with in specific compartments provided the safety of the ship is not impaired.

6.2.2 Distribution of bilge suctions

a) Complete draining of watertight spaces is to be possible, when the ship is on an even keel and either is upright or has a list of up to 5°.

b) Clean bilge draining system

   At least one suction is to be fitted in all spaces served by the clean bilge draining system.

c) Oily bilge draining and treatment system

   At least two suctions are to be fitted in all spaces served by the oily bilge draining and treatment system.

d) In all cases, arrangements are to be made such as to allow a free and easy flow of water to bilge suctions.

6.2.3 Prevention of communication between spaces Independence of the lines

a) Provisions are to be made to avoid any risk of flooding of one compartment by another one through any bilge circuit.

b) Bilge lines are to be entirely independent and distinct from other lines.

6.3 Drainage arrangements of vehicle and ro-ro spaces and ammunition storages fitted with a fixed pressure water-spraying fire-extinguishing system

6.3.1 Vehicle and ro-ro spaces and ammunition spaces fitted with a fixed pressure water-spraying fire-extinguishing system shall be provided with draining arrangements such as to prevent the build-up of free surface.

Scuppers and discharge shall be provided as stated in [8], in particular in ammunition storages and shall discharge to ship bilge and thereafter drained by flooding power pumps or, if appropriate, equivalent (see [6.6.2]) ejectors.

6.4 Draining of machinery spaces

6.4.1 General

In propulsion machinery spaces and in auxiliary machinery spaces, where substantial oil leakages may occur, the bilge suctions are to be distributed and arranged in accordance with the provisions of [6.2.2].

6.4.2 Additional requirements for spaces containing electric motors

In electrically propelled ships, provision is to be made to prevent accumulation of water under electric generators and motors.

6.5 Draining of dry cofferdams, dry fore and after peaks and dry spaces above fore and after peaks, tunnels and refrigerated spaces

6.5.1 Draining of cofferdams

All cofferdams are to be provided with dedicated power bilge pumps or equivalent ejectors discharging locally overboard unless they are fitted with bilge suctions connected to the bilge main. Such pumps or ejectors may serve several compartments.

6.5.2 Draining of fore and after peaks

a) Where the peaks are not used as tanks the drainage of both peaks shall be realised by a dedicated power bilge pump or ejector discharging overboard locally.

b) Except where permitted in [5.3.2], the collision bulkhead is not to be pierced below the bulkhead deck.

6.5.3 Draining of spaces above fore and after peaks

a) Provision is to be made for the drainage of the chain lockers and watertight compartments above the fore peak tank by power pump suctions

b) In any case, steering gear compartments and other small enclosed spaces located above the peak tank are to be provided with bilge suctions of a dedicated power bilge pump, or an equivalent ejector, fitted above the bulkhead deck.

6.5.4 Draining of tunnels

For the purpose of the present Article [6] tunnels are to be considered as propulsion machinery spaces.

Tunnels are to be drained by means of suctions connected to the oily water bilge system. Such suctions are generally to be located in wells at the aft end of the tunnels.

6.5.5 Draining of refrigerated spaces

Provision is to be made for the continuous drainage of condensate in refrigerated and air cooler spaces. To this end, valves capable of blanking off the water draining lines of such spaces are not to be fitted.

6.6 Bilge pumps

6.6.1 Number and arrangement of pumps

a) The oily bilge pumping system is to be provided with two dedicated power pumps connected to the manifold of that system.

b) If a clean bilge main is fitted, at least two dedicated power pumps are to be connected to the bilge main.

c) If independent bilge main sections are fitted, at least two dedicated power pumps are to be connected to each section.

d) For dedicated bilge system as defined in [6.2.1] one dedicated power pump or ejector is to be connected.

6.6.2 Portable means of pumping

Each safety zone is to comprise at least one portable means of pumping (pump or ejector) allowing the draining of all spaces other than main and auxiliary machinery spaces.

6.6.3 Capacity of the pumps

a) The capacity of each pump serving the oily bilge water system shall be not less than 5 m^3/h.

b) The capacity of each pump, in m^3/h, of the clean water bilge system, where a bilge main is provided, is not to be less than:

$Q = 0,00565\ d^2$

where:

d : Internal diameter of the clean water bilge pipe as defined in [6.7.2], item a).

c) Where a bilge main is not provided, the capacity of each clean water dedicated power bilge pump, in m^3/h, is not to be less than:

$Q = 0,00565\ d_1^2$

where:

d_1 : Internal diameter of the clean water bilge pipe as defined in [6.7.2], item c).

d) The capacity of each dedicated pump of the clean water bilge system, in m^3/h, where several bilge main sections are provided, is not to be less than:

$Q = 0,00565\ d_2^2$

where:

d_2 : Internal diameter of each clean water bilge pipe as defined in [6.7.2], item b).

6.6.4 Choice of the pumps

a) All bilge pumps, including clean and oily water pumps, are to be of the self-priming type.

Centrifugal pumps are to be fitted with efficient priming means, unless an approved priming system is provided to ensure the priming of pumps under normal operating conditions.

6.7 Size of bilge pipes

6.7.1 Size of oily bilge water pipes

The actual internal diameter of the oily bilge water pipes is to be calculated assuming a water velocity less than 5 m/s. It is in any case not to be less than 40 mm.

6.7.2 Size of clean water bilge pipes

a) The internal diameter of the clean water bilge main, in mm, is to be calculated according to the following formula:

$$d = 25 + 1,68\sqrt{L(B + D)}$$

where:

L : Length between perpendiculars, in m

B : Breath of the ship at draught, in m

D : Moulded depth of the ship to the control deck, in m.

b) Were the bilge system consist of independent sections, the internal diameter of each section, in mm, is to be calculated according to the following formula:

$$d_2 = 25 + 1,68\sqrt{L_2(B + D)}$$

where:

L_2 : Total of length of the compartments served by the section, in m

B, D : As defined in item a).

c) The internal diameter of the clean water bilge pipe, in mm, between dedicated pumps or bilge main and suction in compartments, is to be calculated according to the following formula:

$$d_1 = 25 + 2,16\sqrt{L_1(B + D)}$$

where:

L_1 : Length of the compartment, in m

B, D : As defined in item a).

d_1 is not to be less than 50 mm and need not exceed 100 mm.

6.8 Bilge accessories

6.8.1 Drain valves on watertight bulkheads

a) Drain valves or similar devices shall not be fitted on the collision bulkhead.

b) On other watertight bulkheads, the fitting of drain valves or similar devices is allowed unless practical alternative draining means exist. Such valves are to be easily accessible at all times and are to be normally closed.

6.8.2 Screw-down non-return valves

a) Accessories are to be provided to prevent intercommunication of compartments or lines which are to remain segregated from one another. For this purpose, non-return devices are to be fitted:
   - on the pipe connections to bilge distribution boxes or to the alternative valves, if any
   - on flexible bilge hose connections
   - on the suctions of water bilge ejectors
   - in compliance with the provisions for prevention of progressive flooding.

b) Screw-down and other non-return valves are to be of a type recognized by the Society as not offering undue obstruction to the flow of water.

6.8.3 Strainers

The open ends of bilge lines are to be fitted with readily accessible strum boxes or strainers having an open area of not less than twice the area of the suction pipe.

Strum boxes are to be so designed that they can be cleaned without having to remove any joint on the suction pipe.

6.8.4 Bilge wells

a) The wells provided for draining the various compartments are to be made of steel plate and their capacity is to be not less than 0,15 m^3. In small compartments, smaller cylindrical wells may be fitted.

b) Bilge wells are to comply with the relevant provisions of Part B.

6.9 Bilge piping arrangement

6.9.1 Provision for expansion

Where necessary, bilge pipes inside tanks are to be fitted with expansion bends. Sliding joints are not permitted for this purpose.

6.9.2 Connections

Connections used for bilge pipes passing through tanks are to be welded joints or reinforced welded flange connections.

6.9.3 Access to valves and distribution boxes

All distribution boxes and manually operated valves in connection with the bilge pumping arrangement shall be in positions which are accessible under normal circumstances.

6.9.4 Location of bilge pumps and pipes

Bilge pumps and piping system are not to be situated at a distance less than B/5 from the ship side, where B is the ship’s width.

7 Ballast systems

7.1 Design of ballast systems

7.1.1 Ballast system and independence of ballast lines

The ship shall be provided with ballast systems if so requested by the Naval Authority.

Ballast lines are to be entirely independent and distinct from other lines except where allowed in [5.4] and in [7.2.1].

7.2 Ballast pumping arrangement

7.2.1 Filling and suction pipes

a) All tanks including aft and fore peak and double bottom tanks intended for ballast water are to be provided with suitable filling and suction pipes connected to power driven pumps of adequate capacity.

   Alternatively, ballast tanks can be filled by the fire main and drained by an ejector supplied by the fire main.

   Alternatively, ballast tanks can possibly be filled by gravity subject to additional valve on direct filling pipe.

b) Suctions are to be so positioned that the transfer of sea water can be suitably carried out in the normal operating conditions of the ship. In particular, two suctions may be required in long compartments.

7.2.2 Piping

In no case the internal diameter of ballast piping is to be less than 50 mm.

7.2.3 Passage of ballast pipes through tanks

If not contained in pipe tunnels, the parts of ballast pipes through tanks intended to contain fresh water or fuel oil shall have increased thickness, as per Tab 5 for steel pipes, and shall consist of either a single piece or several pieces assembled by welding or by devices deemed equivalent for the application considered. Parts of ballast pipes passing through JP5-NATO (F44) tanks, if not contained in pipe tunnel, shall be of jacketed type provided with means for ascertaining leakages.

8 Scuppers and sanitary discharges

8.1 Application

8.1.1

a) This Article applies to scuppers of any type of ships.

b) Discharges in connection with machinery operation are dealt with in [2.8].

8.1.2 Ships to be assigned the additional class notation **CBRN** or **CBRN-AIRBLAST RESISTANCE** are to comply with the requirements of Pt E, Ch 8, Sec 4 in addition to the requirements of the present Article.

8.2 Principle

8.2.1 Scuppers

a) The scupper installation is to be so designed as to allow overboard gravity draining of any water introduced in all spaces, compartments, open decks and areas located above the damage control deck.

b) The number of scuppers openings in the shell plating is to be reduced to a minimum by making each discharge, sufficient in number and suitable in size, are to be provided to permit the drainage of water likely to accumulate in the spaces which are not located in the ship's bottom.

c) The number of scuppers openings in the shell plating is to be reduced to a minimum by making each discharge serve as many pipes as possible. Alternative satisfactory solutions may be accepted.

d) The scupper piping system is to be designed and arranged so as to ensure quick draining of the concerned space considering a permanent list of 5° and in all normal trim conditions of the ship.

8.2.2 Sanitary discharges

The sewage piping system is to be designed taking into consideration the possible generation of toxic and flammable gases (such as hydrogen sulfide, methane, ammonia) during the sewage treatment.

Air pipes from the sewage and grey water systems are to be independent of all other air pipes and to be led to the outside of the ship, away from any air intake.

8.3 Drainage from spaces below the bulkhead deck or within enclosed superstructures and deckhouses on or above the bulkhead deck

8.3.1 Normal arrangement

Scuppers from spaces below the bulkhead deck or from within superstructures and deckhouses on or above the bulkhead deck the deck fitted with doors complying with the provisions of Pt B, Ch 8, Sec 6 are to be led to the bilge. As an alternative, [8.6] and [8.7] are to be complied with.

Scuppers of open deck shall be led overboard.

8.4 Drainage of enclosed vehicle and ro-ro spaces situated on the bulkhead deck

8.4.1 General

Means of drainage are to be provided for enclosed vehicle and ro-ro spaces situated on the bulkhead deck. The Society may allow the absence of means of drainage in any of the above spaces if it is satisfied that, due to the size or internal subdivision of such space, the safety of the ship is not impaired.

8.4.2 Cases where the bulkhead deck side line is not immersed when the ship heels more than 5°

Scuppers from vehicle and ro-ro spaces, led through the shell, are to comply with the requirements stated in [8.7]; alternatively drainage is to be led overboard in accordance to [8.4.3].

8.4.3 Cases where the bulkhead deck side line is immersed when the ship heels 5° or less

If scuppers from vehicle and ro-ro spaces are immersed when the ship heels 5° or less, the drainage of such spaces on the bulkhead deck is to be led to a suitable space, or spaces, of appropriate capacity, having a high water level alarm and provided with arrangements for discharge overboard. In addition, it is to be ensured that:

- the number, size and arrangement of the scuppers are such as to prevent unreasonable accumulation of free water
- the pumping arrangements take account of the requirements for any fixed pressure water-spraying fire-extinguishing system
- where the enclosed space is protected by a gas fire-extinguishing system, the deck scuppers are fitted with means to prevent the escape of the smothering gas.

8.5 Drainage arrangement of vehicle and ro-ro spaces or ammunition spaces fitted with a fixed pressure water-spraying fire-extinguishing system

8.5.1 Scupper draining

Scuppers from vehicle and ro-ro spaces are not to be led to machinery spaces or other places where sources of ignition may be present.

Scuppers from ammunition spaces are to discharge directly overboard. The discharge pipe is to be fitted with a valve whose opening is to be automatically controlled by the activation of the drenching system. Alternatively, the scupper pipe may be fitted with a spring loaded valve.

Each ammunition space is to have its own drainage system.

8.5.2 Prevention of build-up of free surfaces

In vehicle and ro-ro spaces fitted with a fixed pressure water-spraying fire-extinguishing system, the drainage arrangement is to be such as to prevent the build-up of free surfaces. If this is not possible, the adverse effect upon stability of the added weight and free surface of water are to be taken into account to the extent deemed necessary by the Society in its approval of the stability information. Refer to Pt B, Ch 3, Sec 3.

In ammunition spaces the adverse effect upon the stability of the added weight and free surface of water, as well as those of the spaces in which the water is collected, are to be accounted in Pt B, Ch 3, Sec 3.

8.6 Arrangement of discharges from spaces below the margin line

8.6.1 Normal arrangement

Each separate discharge led though the shell plating from spaces below the margin line is to be provided with one automatic non-return valve fitted with positive means of closing it from above the damage control deck.

8.6.2 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,01 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that the inboard valve:

- is above the deepest subdivision load line, and
- is always accessible for examination under service conditions.

8.7 Arrangement of discharges from spaces above the margin line

8.7.1 General

The provisions of this sub-article are applicable only to those discharges which remain open during the normal operation of a ship. For discharges which must necessarily be closed at sea, such as gravity drains from topside ballast tanks, a single screw-down valve operated from the deck may be accepted.

8.7.2 Normal arrangement

Normally, each separate discharge led though the shell plating from spaces above the margin line is to be provided with:

- one automatic non-return valve fitted with positive means of closing it from a position above the damage control deck, or
- one automatic non-return valve and one sluice valve controlled from above the damage control deck.

8.7.3 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,01 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,01 L, the discharge may have two automatic non-return valves without positive means of closing, provided that:

- the inboard valve is above the level of the deepest subdivision waterline so as to always be accessible for examination under service conditions, or
- where this is not practicable, a locally controlled sluice valve is interposed between the two automatic non-return valves.

8.7.4 Alternative arrangement when the inboard end of the discharge pipe is above the deepest subdivision waterline by more than 0,02 L

Where the vertical distance from the deepest subdivision waterline to the inboard end of the discharge pipe exceeds 0,02 L, a single automatic non-return valve without positive means of closing may be accepted subject to the approval of the Society.

8.7.5 Arrangement of discharges through manned machinery spaces

Where sanitary discharges and scuppers lead overboard through the shell in way of manned machinery spaces, the fitting at the shell of a locally operated positive closing valve together with a non-return valve inboard may be accepted. The operating position of the valve will be given special consideration by the Society.

8.7.6 Arrangement of discharges through the shell more than 450 mm below the watertight deck or less than 600 mm above the deepest subdivision waterline

Scupper and discharge pipes originating at any level and penetrating the shell either more than 450 mm below the watertight deck or less than 600 mm above the deepest subdivision waterline are to be provided with a non-return valve at the shell. Unless required by [8.7.2] to [8.7.4], this valve may be omitted if the piping is of substantial thickness, as per Tab 23.

8.7.7 Arrangement of discharges through the shell less than 450 mm below the watertight deck and more than 600 mm above the deepest subdivision waterline

Scupper and discharge pipes penetrating the shell less than 450 mm below the damage control deck and more than 600 mm above the deepest subdivision waterline are not required to be provided with a non-return valve at the shell.

8.8 Summary table of overboard discharge arrangements

8.8.1 The various arrangements acceptable for scuppers and sanitary overboard discharges are summarized in Fig 3.

8.9 Valves and pipes

8.9.1 Materials

a) All shell fittings and valves are to be of steel, bronze or other ductile material. Valves of ordinary cast iron or similar material are not acceptable. All scupper and discharge pipes are to be of steel or other ductile material. Refer to [2.1].

b) Plastic shall not be used for scuppers and discharge piping.

c) For the pipe likely to contain flammable oils, the provisions of Ch 4, Sec 10, [3.2.1] are also to be fulfilled.

8.9.2 Thickness of pipes

a) The thickness of scupper and discharge pipes led to the bilge or to draining tanks, or pipes other than in item b) is not to be less than that required in [2.2].

b) The thickness of scupper and discharge pipes led to the shell is not to be less than the minimum thickness given in Tab 22 and Tab 23.

8.9.3 Scupper size

Internal diameters of scupper pipes are not to be less than 40 mm.

8.9.4 Operation of the valves

Where valves are required to have positive means of closing, such means is to be readily accessible and provided with an indicator showing whether the valve is open or closed.

Figure 3 : Overboard discharge arrangement

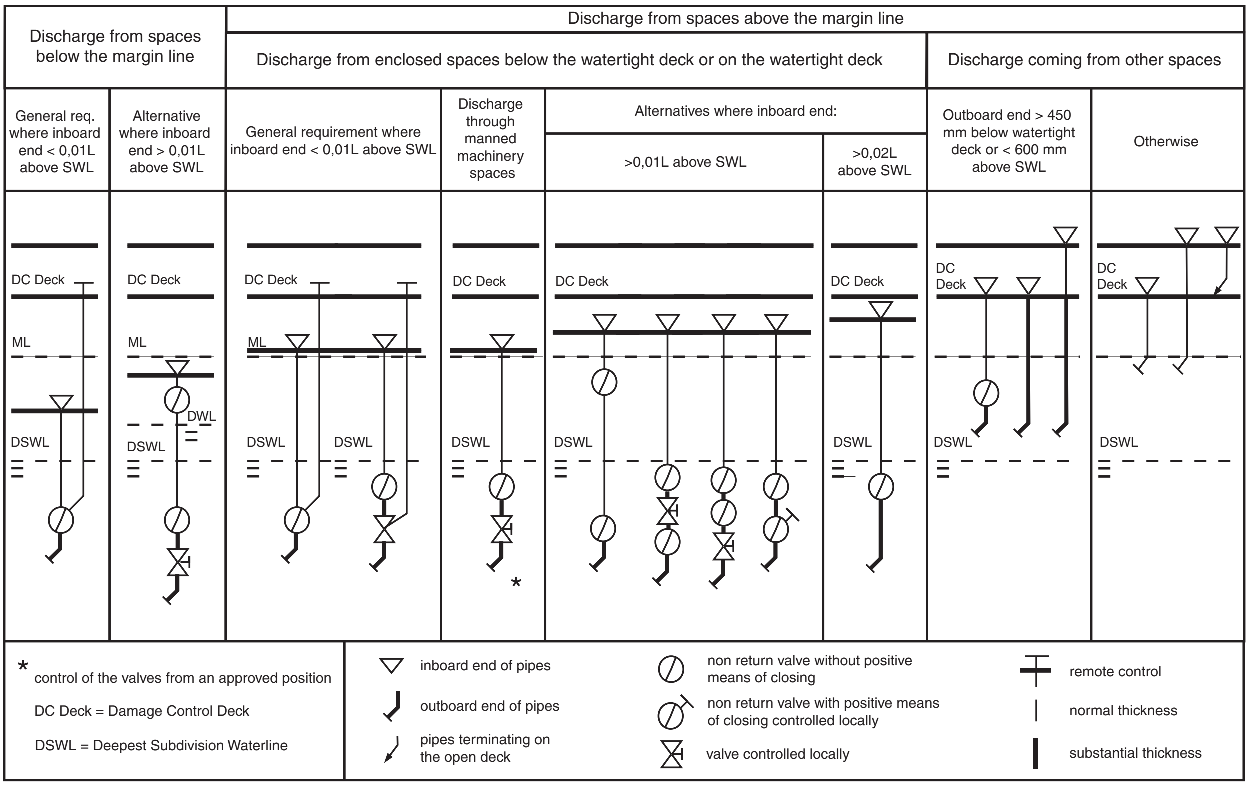


Table 22 : Thickness of scupper and discharge pipes led to the shell, according to their location

Applicable requirement -> / Pipe location	[8.6.1]	[8.7.1]	[8.7.2]	[8.7.3]	[8.7.4]	[8.7.5]	[8.7.6] with valve	[8.7.6] without valve	[8.7.7]
Between the shell and the first valve	Thickness according to Tab 23, column 1, or 0,7 times that of the shell side plating, whichever is the greater **(1)**							NA	NA
Beyond the first valve and the inboard end	Thickness according to [2.2]							NA	NA
Below the bulkhead deck	NA							Thickness according to Tab 23, column 1**(1)**	Thickness according t Tab 23, column 2**(1)**
Above the bulkhead deck	NA							Thickness according to [2.2]	Thickness according to [2.2]
(1) However, this thickness is not required to exceed that of the plating. **Note 1:** NA = Not Applicable.									

Table 23 : Minimum thickness of scupper and discharge pipes led to the shell

External diameter of the pipe d, in mm	Column 1 substantial thickness, in mm	Column 2 normal thickness, in mm
d ≤ 80,0	7,00	4,50
155	9,25	4,50
180	10,00	5,00
220	12,50	5,80
230 ≤ d	12,50	6,00
Note 1: Intermediate sizes may be determined by interpolation. **Note 2:** In any case it is not required a thickness greater than the shell plating		

8.10 Arrangement of scuppers

8.10.1 Overboard discharges and valve connections

a) Overboard discharges are to have pipe spigots extending through the shell plate and welded to it, and are to be provided at the internal end with a flange for connection to the valve or pipe flange.

b) Valves may also be connected to the hull plating in accordance with the provisions of [2.8.3], item c).

8.10.2 Passage through vehicle and ro-ro spaces

Where scupper and sanitary discharge pipes are led through vehicle and ro-ro spaces, the pipes and the valves with their controls are to be adequately protected by strong casings or guards.

8.10.3 Passage through tanks

a) As a rule, scupper and sanitary discharge pipes are not to pass through fuel oil tanks or JP5-NATO (F44) tanks.

b) Where scupper and discharge pipes pass unavoidably through fuel oil tanks and are led through the shell within the tanks, the thickness of the piping is not to be less than that given in Tab 23 column 1 (substantial thickness). It is not needed, however, to exceed the Rule thickness of the shell plating or the tank thickness in case of only passing through.

c) Scupper and sanitary discharge pipes shall not pass through fresh and drinking water tanks.

d) Scupper and sanitary discharge pipes shall not pass through JP5-NATO (F44) tanks unless of jacketed type provided with means for ascertain leakages.

8.10.4 Passage through ammunition spaces

Except where not practicable, scuppers pipes are not to pass through ammunition spaces

8.10.5 Discharge in refrigerated spaces

No scupper pipe from non-refrigerated spaces is to discharge in refrigerated spaces.

8.10.6 Discharge from galleys and their stores

Discharges from galleys and their stores are to be kept separate from other discharges and be drained overboard or in separate drainage tanks; alternatively, discharges are to be provided with adequate devices against odours and overflow.

8.10.7 Discharge from aircrafts-related areas

Scuppers of the spaces of the aircrafts-related areas likely to contain burning fuel are to be independent from the scupper network serving the spaces located outside the citadel. In addition, drainage facilities from aircraft-related areas are to comply with the following requirements, as applicable:

- drainage facilities from helidecks and flight decks: Ch 4, Sec 10, [3.2], Pt D, Ch 2, Sec 5, [8.1.1] and Pt D, Ch 5, Sec 6 [5.1.2]
- drainage facilities from aircraft hangars: Ch 4, Sec 10, [3.2.2], Pt D, Ch 2, Sec 5, [6.1.5] and Pt D, Ch 5, Sec 6, [8.1.5].

8.10.8 Discharge from aft spaces

Spaces located aft of the aft peak bulkhead not intended to be used as tanks are to be drained in compliance with [6].

8.10.9 Scupper tank

a) The scupper tank air pipe is to be led to above the bulkhead deck.

b) Provision is to be made to ascertain the level of water in the scupper tank.

9 Air, sounding and overflow pipes

9.1 Air pipes

9.1.1 Principle

Air pipes are to be fitted to all tanks, double bottoms, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements, in order to allow the passage of air or liquid so as to prevent excessive pressure or vacuum in the tanks or compartments, in particular in those which are fitted with piping installations. Their open ends are to be so arranged as to prevent the free entry of sea water in the compartments.

Note 1: Air pipes may be dispensed with in tunnels, cofferdams and other void spaces provided they do not contain any bilge suction.

Air pipes of JP5-NATO(F44) installations are to be independent of air pipes for spaces belonging to other types of system.

In addition, air pipes are to be fitted in ammunition spaces located below the waterline and fitted with fixed water spraying system in accordance with Ch 4, Sec 6, [6.1]. These air pipes are to be fitted with a flame arrester and with a pressure relief valve adjusted to 10mbar.

Note 2: Other means to avoid over pressurisation of the ammunition space may be accepted to the satisfaction of the Society.

9.1.2 Number and position of air pipes

a) Air pipes are to be so arranged and the upper part of compartments so designed that air or gas likely to accumulate at any point in the compartments can freely evacuate.

b) Air pipes are to be fitted opposite the filling pipes and/or at the highest parts of the compartments, the ship being assumed to be on an even keel.

c) Except for supply ship, in general only one air pipe may be fitted for each compartment. When the top of the compartment is of irregular form, the position of air pipes will be given special consideration by the Society.

d) Where only one air pipe is provided, it is not to be used as a filling pipe.

9.1.3 Location of open ends of air pipes

a) Air pipes of double bottom compartments, tunnels, deep tanks and other compartments which can come into contact with the sea or be flooded in the event of hull damage are to be led to above the bulkhead deck.

b) Air pipes of tanks intended to be pumped up are to be led to the open above the bulkhead deck.

c) Air pipes other than those of fuel oil tanks, JP5-NATO (F44) tanks and of any other oil tanks may be led to enclosed vehicle or ro-ro spaces, situated above the bulkhead deck, provided that such spaces are fitted with scuppers discharging overboard, which are capable of draining all the water which may enter through the air pipes without giving rise to any water accumulation.

d) Air pipes of tanks other than oil tanks, JP5-NATO (F44) tanks and of any other oil tank may discharge through the side of the superstructure.

e) The air pipe of the scupper tank is to be led to above bulkhead deck.

f) The location of air pipes for flammable oil tanks is also to comply with [9.1.7].

9.1.4 Height of air pipes

Air pipes are to extend above the V-line, as defined in Pt B, Ch 3, App 4.

9.1.5 Fitting of closing appliances

a) Permanently attached appliances are to be provided for closing the openings of air pipes in order to prevent the free entry of water into the spaces concerned, except for pipes of tanks fitted with cross-flooding connections.

b) Automatic closing appliances are to be fitted in the following cases:
   - in positions of [9.1.3] item c)
   - where air pipes have a height lower than that required in [9.1.4].

   See also Pt B, Ch 3, Sec 3, [2.2.2].

c) Automatic closing appliances are to be of a type approved by the Society. Requirements for type tests are given in [19.3.1].

9.1.6 Design of closing appliances

a) When closing appliances are requested to be of an automatic type, they are to comply with the following:
   - They are to be so designed that they withstand both ambient and working conditions up to an inclination of –40° to +40° without failure or damage.
   - They are to be so designed as to allow inspection of the closure and the inside of the casing as well as changing of the seals.
   - Where they are of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.
   - Efficient seating arrangements are to be provided for the closures.
   - They are to be self-draining.
   - The clear area through an air pipe closing appliance is to be at least equal to the area of the inlet.
   - The maximum allowable tolerances for wall thickness of floats is not to exceed ±10% of the nominal thickness.
   - Their casings are to be of approved metallic materials adequately protected against corrosion.
   - Closures and seats made of non-metallic materials are to be compatible with the media to be carried in the tank and with sea water at ambient temperatures between –25°C and +85°C.

b) Where closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out. For this purpose, a hole of approximately 10 mm in diameter may be provided in the bend of the air pipe or at any other suitable position in the closing appliance.

c) Wooden plugs and trailing canvas are not permitted.

9.1.7 Special arrangements for air pipes of flammable oil tanks

a) Air pipes from fuel oil, JP5-NATO (F44) and thermal oil tanks are to discharge to a safe position on the open deck where no danger will be incurred from issuing oil or gases.

   Air vents are to be fitted with wire gauze diaphragms made of corrosion resistant material and readily removable for cleaning and replacement. The clear area of such diaphragms is not to be less than the cross-sectional area of the pipe.

b) Air pipes of lubricating or hydraulic oil storage tanks not subject to flooding in the event of hull damage may be led to machinery spaces, provided that in the case of overflowing the oil cannot come into contact with electrical equipment, hot surfaces or other sources of ignition.

c) Air pipes of fuel oil, JP5-NATO (F44), service, settling and lubrication oil, tanks likely to be damaged by impact forces are to be adequately reinforced.

9.1.8 Construction of air pipes made of steel

a) Where air pipes to ballast and other tanks extend above the bulkhead deck or superstructure deck (see [9.1.4]), the exposed parts of the pipes are to be of substantial construction, with a minimum wall thickness of at least:
   - 6,0 mm for pipes of 80 mm or smaller external diameter
   - 8,5 mm for pipes of 165 mm or greater external diameter.

   Intermediate minimum thicknesses may be determined by linear interpolation.

   For stainless steel the above thickness may be respectively 3,0 mm and 4,0 mm.

Note 1: When the air pipes are protected against sea impacts, thicknesses in accordance with Tab 5 may be accepted.

b) Air pipes with height exceeding 900 mm are to be additionally supported.

c) In each compartment likely to be pumped up, and where no overflow pipe is provided, the total cross-sectional area of air pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

d) The internal diameter of air pipes is not to be less than 50 mm, except for tanks of less than 2 m^3.

9.2 Sounding pipes

9.2.1 Principle

a) Sounding devices are to be fitted to tanks intended to contain liquids as well as to other tanks, double bottoms, cofferdams, bilges and all compartments which are not readily accessible at all times.

b) For service tanks, the following systems may be accepted in lieu of sounding pipes:
   - a level gauge of an approved type efficiently protected against shocks, or
   - a remote level gauging system of an approved type, provided an emergency means of sounding is available in the event of failure affecting such system.

9.2.2 Position of sounding pipes

Sounding pipes are to be located as close as possible to suction pipes.

9.2.3 Termination of sounding pipes

a) As a general rule, sounding pipes are to end above the bulkhead deck in easily accessible places and are to be fitted with efficient, permanently attached, metallic closing appliances.

b) In machinery spaces where the provisions of a) cannot be satisfied, short sounding pipes led to readily accessible positions above the floor and fitted with efficient closing appliances may be accepted.

   In ships required to be fitted with a double bottom, such closing appliances are to be of the self-closing type.

9.2.4 Special arrangements for sounding pipes of flammable oil tanks

a) Where sounding pipes are used in flammable (except lubricating, sludge, dirty bilge, oil leakage and similar) oil systems, they may terminate below the open deck where no risk of ignition of spillage from the sounding pipe might arise. In particular, they are not to terminate in crew spaces dedicated to off-duty activities. As a general rule, they are not to terminate in machinery spaces.

b) The Society may permit termination in machinery spaces of sounding pipes for lubricating oil, fuel oil leakage, sludge and dirty bilge tanks, provided that the terminations of sounding pipes are fitted with appropriate means of closure.

9.2.5 Closing appliances

a) Self-closing appliances are to be fitted with cylindrical plugs having counterweights such as to ensure automatic closing.

b) Closing appliances not required to be of the self-closing type may consist of a metallic screw cap secured to the pipe by means of a chain or a shut-off valve.

9.2.6 Construction of sounding pipes

a) Sounding pipes are normally to be straight. If it is necessary to provide bends in such pipes, the curvature is to be as small as possible to permit the ready passage of the sounding apparatus.

b) The sounding arrangement of compartments by means of bent pipes passing through other compartments will be given special consideration by the Society. Such an arrangement is normally accepted only if the compartments passed through are cofferdams or are intended to contain the same liquid as the compartments served by the sounding pipes.

c) Bent portions of sounding pipes are to have reinforced thickness and be suitably supported.

d) The internal diameter of sounding pipes is not to be less than 32 mm. Where sounding pipes pass through refrigerated spaces, or through the insulation of refrigerated spaces in which the temperature may be below 0°C, their internal diameter is to be at least 60 mm.

e) Doubling plates are to be placed under the lower ends of sounding pipes in order to prevent damage to the hull. When sounding pipes with closed lower ends are used, the closing plate is to have reinforced scantlings.

9.3 Overflow pipes

9.3.1 Principle

Overflow pipes of JP5-NATO(F44) installations are to be independent of overflow pipes for tanks belonging to other types of system.

Overflow pipes are to be fitted to tanks:

- which can be filled by pumping and are designed for a hydrostatic pressure lower than that corresponding to the height of the air pipe, or
- where the cross-sectional area of air pipes is less than that prescribed in [9.1.8], item d).

9.3.2 Design of overflow systems

a) Overflow pipes are to be led:
   - either outside, or
   - in the case of fuel oil or JP5-NATO (F44) or lubricating oil, to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. For JP5-NATO(F44) a dedicated tank is to be provided.

Note 1: As an alternative to the overflow tank, for JP5-NATO (F44), an isolating valve on the tank filling line arranged for automatic closing in case of high level can be accepted. The filling line is to fitted with a protection device against overpressure, which may be located outside the ship (on the refuelling installation).

b) Where tanks containing the same liquid are connected to a common overflow system, the arrangement is to be such as to prevent any risk of:

- intercommunication between the various tanks due to movements of liquid when emptying or filling, or due to the inclination of the ship
- overfilling of any tank from another assumed flooded due to hull damage.

For this purpose, overflow pipes are to be led to a high enough point above the bulkhead deck. Safety devices protecting from a risk of hydrostatic overpressure in overflow pipes could be accepted subject to an alarm of discharging in the dripping pan.

c) Arrangements are to be made so that a compartment cannot be flooded from the sea through the overflow in the event of another compartment connected to the same overflow main being bilged. To this end, the openings of overflow pipes discharging overboard are as a rule to be placed above the maximum draft of the ship and are to be fitted where necessary with non-return valves on the plating, or, alternatively, overflow pipes from tanks are to be led to a point above the maximum draft of the ship.

d) Where tanks alternately containing fuel oil and ballast water are connected to a common overflow system, arrangements are to be made to prevent the ballast water overflowing into the tanks containing fuel oil and vice-versa.

9.3.3 Overflow tanks

a) Overflow tanks are to be fitted with an air pipe complying with [9.1] which may serve as an overflow pipe for the same tank. When the vent pipe reaches a height exceeding the design head of the overflow tank, suitable means are to be provided to limit the actual hydrostatic head on the tank.

Such means are to discharge to a position which is safe in the opinion of the Society.

b) An alarm device is to be provided to give warning when the oil reaches a predetermined level in the tank, or alternatively, a sight-flow glass is to be provided in the overflow pipe to indicate when any tank is overflowing. Such sight-flow glasses are only to be placed on vertical pipes and in readily visible positions.

9.3.4 Specific requirements for construction of overflow pipes

a) The internal diameter of overflow pipes is not to be less than 50 mm.

b) In each compartment which can be pumped up, the total cross-sectional area of overflow pipes is not to be less than 1,25 times the cross-sectional area of the corresponding filling pipes.

c) The cross-sectional area of the overflow main is not to be less than the aggregate cross-sectional area of the two largest pipes discharging into the main.

9.4 Constructional requirements applying to sounding, air and overflow pipes

9.4.1 Materials

a) Sounding, air and overflow pipes are to be made of steel or any other material approved for the application considered.

b) Exposed parts of sounding, air and overflow pipes are to be made of approved metallic materials.

9.4.2 Minimum thickness of steel pipes

The minimum thickness of sounding, air and overflow steel pipes is given in Tab 24.

Table 24 : Minimum wall thickness of sounding, air and overflow pipes

External diameter, in mm	Minimum wall thickness, in mm **(1)(2)**
up to 168,3	4,5
177,8	5,0
193,7	5,4
219,1	5,9
above 244,5	6,3

(1) Applies only to structural tanks.
(2) However the wall thickness may not be greater than that it would be required for the tank filling pipes.
For independent tanks, refer to Tab 5.

9.4.3 Passage of pipes through certain spaces

a) Air pipes and sounding pipes led through refrigerated spaces are to be suitably insulated.

b) When sounding, air and overflow pipes made of steel are permitted to pass through ballast tanks or fuel oil tanks, they are to be of reinforced thickness, in accordance with Tab 5. However pipes passing through JP5-NATO(F44) tanks are only permitted if they are of jacketed type with means for ascertain leakages.

c) Sounding, air and overflow pipes are to be adequately protected against impact of product handling.

9.4.4 Self-draining of pipes

Air pipes and overflow pipes are to be so arranged as to be self-draining when the ship is on an even keel.

9.4.5 Name plates

Nameplates are to be fixed at the upper part of air pipes and sounding pipes.

10 Cooling systems

10.1 Application

10.1.1 This article applies to all cooling systems using the following cooling media:

- sea water
- fresh water
- lubricating oil.

Air cooling systems will be given special consideration.

10.2 Principle

10.2.1 General

Sea water and fresh water cooling systems are to be so arranged as to maintain the temperature of the cooled media (lubricating oil, hydraulic oil, charge air, etc.) for propulsion machinery and essential equipment within the manufacturers' recommended limits during all operations, including starting and manoeuvring, under the inclination angles and the ambient conditions specified in Ch 1, Sec 1.

10.2.2 Availability of the cooling system

The cooling system is to be so designed that, in the event of one essential component being inoperative, the cooling of propulsion machinery is maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

10.3 Design of sea water cooling systems

10.3.1 General

a) Sea water cooling of the propulsion engines, auxiliary engines and other essential equipment is to be capable of being supplied by two different means.

b) Where required, standby pumps are not to be connected to the sea inlet serving the other sea water pumps, unless permitted under [10.7.1], item b).

10.3.2 Centralised cooling systems

a) In the case of centralized cooling systems, i.e. systems serving a group of propulsion engines and/or auxiliary engines, reduction gears, compressors and other essential equipment, the following sea water pumps and heat exchangers are to be arranged:
    - one main cooling water pump, which may be driven by the engines, of a capacity sufficient to provide cooling water to all the equipment served
    - one independently driven standby pump of at least the same capacity
    - two heat exchangers, each having at least 50% of the total capacity necessary to provide cooling water to all the equipment served.

b) Where the cooling system is served by a group of identical pumps, the capacity of the standby pump needs only to be equivalent to that of each of these pumps.

c) Ballast pumps or other suitable sea water pumps of appropriate capacity may be used as standby pumps, provided arrangements are made against overpressure in the cooling system.

d) In ships having one or more propulsion engines, each with an output not exceeding 375 kW, the independent standby pump may be replaced by a complete spare pump of appropriate capacity ready to be connected to the cooling circuit.

e) In cases of centralized cooling systems serving only a group of auxiliary engines, the second means of cooling may consist of a connection to a cooling water pump serving the propulsion plant, provided such pump is of sufficient capacity to provide cooling water to both propulsion plant and auxiliary engines.

10.3.3 Individual cooling of propulsion engines

a) Individual cooling systems of propulsion engines are to include at least:
   - one main cooling water pump, which can be driven by the engine
   - one independently driven standby pump
   - two heat exchangers having an aggregate capacity of at least 100% of that required by the engine.

   Where the output of the engine does not exceed 375 kW, the following arrangements may be accepted:
   - one main cooling water pump, which can be driven by the engine
   - one spare pump of appropriate capacity ready to be connected to the cooling circuit
   - one heat exchanger of appropriate capacity.

b) Where, in ships having more than one engine per propeller or having several propellers, each engine is served by its own cooling circuit, the second means requested in [10.3.1] is to be provided, consisting of:
   - a connection to an independently driven pump, such as a ballast pump or any other suitable sea water pump of sufficient capacity provided arrangements against overpressure in the cooling system are made. (see [10.7.4], item b)), or
   - a complete spare pump identical to those serving the engines and ready to be connected to the cooling circuit.

   This second means may be omitted, however, when safety justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with one cooling circuit disabled.

10.3.4 Individual cooling of auxiliary engines

Where each auxiliary engine is served by its own cooling circuit, no second means of cooling is required.

10.3.5 Cooling of steam plants

a) Steam plants are to be fitted with:
   - a main circulating pump
   - a standby pump capable of ensuring the circulation in the main condenser in the event of failure of the main circulating pump.

b) Where the installation includes more than one propulsive unit, the standby pump is not required, provided a branch pipe is fitted between the discharges of the circulating pumps of each unit.

c) In lieu of the main circulating pump, a sea inlet scoop system may be accepted, provided that an additional means is fitted to ensure the circulation of sea water to the condenser when the ship is manoeuvring. Such means may be:
   - an additional independent pump, or
   - a connection to an available pump of sufficient capacity.

10.3.6 Cooling of other essential equipment

a) The second means of cooling required in [10.3.1] for essential equipment may consist of a connection to a ballast pump or other suitable sea water pump of sufficient capacity, provided arrangements are made against overpressure in the cooling system (see [10.7.4], item b)).

b) However, where such essential equipment is duplicate, this second means may be omitted when justifications are provided as regards the propulsion and manoeuvring capabilities of the ship with the cooling circuit of one set of equipment disabled.

10.4 Design of fresh water cooling systems

10.4.1 General

Fresh water cooling systems are to be designed according to the applicable requirements of [10.3].

10.4.2 Cooling systems

a) Fresh water cooling systems of essential equipment are to include at least:
   - one main cooling water pump, which can be driven by the equipment
   - one independently driven standby pump.

b) The standby pump may be omitted provided an emergency connection to a suitable sea water system is fitted and arranged with a suitable change-over device. Provisions against overpressure in the cooling system are to be made in accordance with [10.7.4], item b).

c) The standby pump may also be omitted in the case of redundancy of the cooled equipment.

10.4.3 Expansion tanks

Fresh water expansion tanks are to be provided with at least:

- a de-aerating device
- a water level indicator
- a filling connection
- a drain.

10.4.4 Protection of contamination by oil

Suitable means are to be provided in fresh water cooling systems comprising fuel oil or lubricating oil heat exchangers in order to detect any contamination of the water by fuel oil or lubricating oil.

If cooling water is used for heating of oil, the heating coils are to be located on the pressure side of the cooling pumps and connected by welding, with no detachable connections where mixing of oil and water may occur. Alternatively a primary and secondary system arrangement may be used.

10.5 Design of oil cooling systems

10.5.1 General

Oil cooling systems are to be designed according to the applicable requirements of [10.3].

10.5.2 Second means of cooling

The second means of cooling requested in [10.3.1] may consist of a satisfactory connection to a lubricating oil pump of sufficient capacity. Arrangements are to be made against overpressure in the cooling system.

10.6 Control and monitoring

10.6.1 Alarms are to be provided for water cooling systems in accordance with Tab 25, in addition to the requirements stated for diesel engines in Ch 1, Sec 2.

10.7 Arrangement of cooling systems

10.7.1 Sea inlets

a) Cooling systems serving propulsion machinery and essential equipment are to be supplied by at least two sea inlets complying with [2.8].

b) The two sea inlets may be connected by a cross-over.

c) The sea inlets are to be so designed as to remain submerged under all normal navigating conditions.

In general, one low sea inlet and one high sea inlet are to be arranged.

d) One of the sea inlets may be that of the fire pump.

10.7.2 Coolers

a) Coolers are to be fitted with isolating valves at the inlets and outlets.

b) Coolers external to the hull (chest coolers and keel coolers) are to be fitted with isolating valves at the shell.

10.7.3 Filters

a) Where propulsion engines and auxiliary engines for essential services are directly cooled by sea water, both in normal service and in emergency operating conditions, filters are to be fitted on the suction of cooling pumps.

b) These filters are to be so arranged that they can be cleaned without interrupting the cooling water supply.

Table 25 : Cooling systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water pump pressure or flow	L	local					
Fresh water pump pressure or flow	L	local					
Level in cooling water expansion tank	L	local					

10.7.4 Pumps

a) Cooling pumps for which the discharge pressure may exceed the design pressure of the piping system are to be fitted with relief valves in accordance with [2.5].

b) Where general service pumps, ballast pumps or other pumps may be connected to a cooling system, arrangements are to be made, in accordance with [2.5], to avoid overpressure in any part of the cooling system.

10.7.5 Air venting

Cocks are to be installed at the highest points of the pipes conveying cooling water to the water jackets for venting air or gases likely to accumulate therein. In the case of closed fresh water cooling systems, the cock is to be connected to the expansion tank.

11 Fuel oil and JP5-NATO (F44) systems

11.1 Application

11.1.1 Scope

This Article applies to all fuel oil systems supplying any kind of installation and all JP5-NATO (F44) systems.

Dedicated systems and arrangements shall be provided for each JP5-NATO (F44) fuel system (e.g. one dedicated system for refuelling and one dedicated system for carrying).

11.1.2 Additional requirements applying to fuel oil and JP5-NATO (F44) systems

Additional requirements are given:

- for independent fuel oil tanks: in Ch 1, App 3
- for fuel oil supply equipment forming part of engines, gas turbines, boilers and incinerators: in the corresponding sections of Part C, Chapter 1
- for the installation of purifiers: in Part C, Chapter 4
- for the location and scantling of tanks forming part of the ship's structure: in Part B, Chapter 2 and Part B, Chapter 7
- for helicopter refuelling facilities: in Ch 4, Sec 10, [4]
- for **aircraft carriers**: in Part D, Chapter 2
- for **amphibious vessels**: in Part D, Chapter 5.

11.2 Principle

11.2.1 General

a) Fuel oil and JP5-NATO (F44) systems are to be so designed as to ensure the proper characteristics (purity, viscosity, pressure) of the fuel oil supply to ship's engines or of aircrafts or helicopters and boilers.

b) Fuel oil and JP5-NATO (F44) systems are to be so designed as to prevent:
   - overflow or spillage of fuel oil and JP5-NATO (F44) from tanks, pipes, fittings, etc.
   - fuel oil from coming into contact with sources of ignition
   - overheating and seizure of fuel oil and JP5-NATO (F44).

c) Fuel oils used for engines and boilers are to have a flashpoint complying with the provisions of Ch 1, Sec 1, [2.9].

11.2.2 Availability of fuel systems

a) Fuel oil systems are to be so designed that, in the event that any one essential auxiliary of such systems becomes inoperative, the fuel oil supply to boilers and engines can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) Fuel oil tanks are to be so arranged that, in the event of damage to any one tank, complete loss of the fuel supply to essential services does not occur.

11.3 General

11.3.1 Arrangement of fuel oil systems

a) In a ship in which fuel oil is used, or JP5-NATO (F44) is carried or used for refuelling, the arrangements for the storage, distribution and utilization of the fuel oil or JP5-NATO (F44) are to be such as to ensure the safety of the ship and persons on board.

b) The provisions of [5.10] are to be complied with.

11.3.2 Provision to prevent overpressure

Provisions are to be made to prevent overpressure in any oil or JP5-NATO (F44) tank or in any part of the fuel oil and JP5-NATO (F44) systems. Any relief valve is to discharge to a safe position.

11.3.3 Ventilation

The ventilation of machinery spaces is to be sufficient under all normal conditions to prevent accumulation of oil vapour.

11.3.4 Access

Spaces where fuel oil or JP5-NATO (F44) are handled are to be readily accessible.

11.4 Design of fuel oil and JP5-NATO (F44) filling and transfer systems

11.4.1 General

A system of pumps and piping for filling and transferring fuel oil or JP5-NATO (F44) is to be provided. Provisions are to be made to allow the transfer of fuel oil or JP5-NATO (F44) from any storage tank to another tank.

11.4.2 Filling systems

a) Filling pipes of fuel oil or JP5-NATO (F44) tanks are to terminate on open deck or in filling stations isolated from other spaces and efficiently ventilated. Suitable coamings and drains are to be provided to collect any leakage resulting from filling operations.

b) Arrangements are to be made to avoid overpressure in the filling lines which are served by pumps on board. Where safety valves are provided for this purpose, they are to discharge to the overflow tank referred to in [9.3.3] or to other safe positions deemed satisfactory.

11.4.3 Independence of fuel oil and JP5-NATO (F44) transfer lines

The fuel oil transfer piping system is to be completely separate from the other piping systems of the ship. This requirement is also to be complied with by JP5-NATO (F44) transfer piping system.

Note 1: A fuel oil tank may be used to carry JP5/NATO (F44) provided arrangements are made to avoid any inadvertent filling of other fuel oil tanks, and with particular care for quality control (filtration, fuel oil and water content) before refuelling of aircrafts.

11.4.4 Transfer pumps

a) Fuel oil system is to include at least two means of transfer. One of these means is to be a power pump. The other may consist of a standby pump.

b) Where necessary, transfer pumps are to be fitted on their discharge side with a relief valve leading back to the suction of the pump or to any other place deemed satisfactory.

c) No stand-by pump is required for JP5-NATO (F44).

11.5 Arrangement of fuel oil, bunkers and JP5-NATO (F44) tanks

11.5.1 Location of fuel oil and JP5-NATO (F44) tanks

a) No fuel oil tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

b) Fuel oil tanks and bunkers are not to be situated immediately above boilers or in locations where they could be subjected to high temperatures, unless specially agreed by the Society. In general, the distance between fuel oil tanks and boilers is not to be less than 450 mm. Where boilers are situated above double bottom fuel oil tanks, the distance between the double bottom tank top and the lower metallic part of the boilers is not to be less than:

- 750 mm for water tube boilers
- 600 mm for cylindrical boilers.

c) As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of category A, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum.

Note 1: Machinery spaces of category A are defined in Ch 4, Sec 1.

Note 2: Service tanks may be located within machinery spaces provided the following conditions are met:

- the tank is fitted with a quick draining system connected to a suitable tank and operable from an accessible position outside the concerned space.
- a water extinguishing system is provided in case of fire in way of the tank as mentioned in Ch 4, Sec 6, [4.1.1]. See also Ch 4, Sec 13, [7.1.1].

d) The location of fuel oil tanks is to be in compliance with the requirements of Part B, Chapter 2, particularly as regards the installation of cofferdams, the separation between fuel oil tanks or bunkers and the other spaces of the ship, and the protection of these tanks and bunkers against any abnormal rise in temperature.

11.5.2 Use of free-standing fuel oil tanks

a) In general the use of free-standing fuel oil tanks is to be avoided except on supply ships, where their use is permitted in category A machinery spaces.

b) For the design and the installation of independent tanks, refer to Ch 1, App 3.

11.6 Design of fuel oil tanks and bunkers and JP5-NATO (F44) tanks

11.6.1 General

Tanks such as collector tanks, de-aerator tanks etc. are to be considered as fuel oil tanks for the purpose of application of this sub-article, and in particular regarding the valve requirements.

Tanks with a volume lower than 500 l will be given special consideration by the Society.

11.6.2 Scantlings

a) The scantlings of fuel oil tanks and bunkers and JP5-NATO (F44) tanks forming part of the ship's structure are to comply with the requirements stated in Part B, Chapter 7.

b) Scantlings of fuel oil tanks and bunkers which are not part of the ship's structure are to comply with Ch 1, App 3. For cases which are not contained in the Tables of that appendix, scantlings will be given special consideration by the Society.

11.6.3 Filling and suction pipes

a) All suction pipes from JP5-NATO (F44) tanks, fuel oil tanks and bunkers, including those in the double bottom, are to be provided with valves.

b) For storage tanks, filling pipes may also be used for suction purposes.

c) Where the filling pipes to JP5-NATO (F44) tanks, fuel oil bunkers and tanks are not led to the upper part of the such bunkers and tanks, they are to be provided with non-return valves at their ends, unless they are fitted with valves arranged in accordance with the requirements stated in [11.6.4].

11.6.4 Remote control of valves

a) Every fuel oil and JP5-NATO (F44) pipe which, if damaged, would allow oil to escape from a storage, settling or daily service tank situated above the double bottom, is to be fitted with a cock or valve directly on the tank or directly on plating of last tank, capable of being closed from a safe position outside the space in which such tanks are situated in the event of a fire occurring in such space.

Note 1: For the location of the remote controls, refer to [11.10.3], item c).

b) Such valves and cocks are also to include local control and indicators are to be provided on the remote and local controls to show whether they are open or shut (see [2.7.3]).

c) Where fuel oil tanks are situated outside boiler and machinery spaces, the remote control required in a) may be transferred to a valve located inside the boiler or machinery spaces on the suction pipes from these tanks.

d) In the special case of storage tanks situated in any shaft or pipe tunnel or similar space, valves are to be fitted on the tank but control in the event of fire may be effected by means of an additional valve on the pipe or pipes outside the tunnel or similar space. If such additional valve is fitted in the machinery space it is to be operated from a position outside this space.

11.6.5 Drain pipes

Where fitted, drain pipes are to be provided with self-closing valves or cocks. See also [11.5.1], item c), Note 2.

11.6.6 Air and overflow pipes

Air and overflow pipes are to comply with [9.1] and [9.3].

11.6.7 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of fuel oil and JP5-NATO (F44) contained in any fuel oil tank and JP5-NATO (F44) tank are to be provided.

b) Sounding pipes of fuel oil and JP5-NATO (F44) tanks are to comply with the provisions of [9.2].

c) Gauge cocks for ascertaining the level in the tanks are not to be used.

11.7 Design of fuel oil heating systems

11.7.1 Fuel oil heaters

a) Where steam heaters or heaters using other heating media are provided in fuel oil system, they are to be fitted with at least a high temperature alarm or a low flow alarm in addition to a temperature control, except where temperatures dangerous for the ignition of the fuel oil cannot be reached.

b) When electric heaters are fitted, means are to be provided to ensure that heating elements are permanently submerged during operation. In all cases a safety temperature switch is to be fitted in order to avoid a surface temperature of 220°C and above. It is to be:

- independent from the automatic control sensor
- designed to cut off the electrical power supply in the event of excessive temperature
- provided with manual reset.

c) Fuel oil heaters are to be fitted with relief valves leading back to the pump suction concerned or to any other place deemed satisfactory.

11.8 Design of fuel oil and JP5-NATO (F44) treatment systems

11.8.1 General

Fuel oils and JP5-NATO (F44) used for the engines of the ship, of the aircrafts or of the helicopters are to be purified and filtered according to the relevant manufacturer’s requirements.

11.8.2 Drains

a) Storage tanks and, where provided, settling tanks, are to be provided with drains permitting the evacuation of water and impurities likely to accumulate in the lower part of such tanks.

b) Efficient means are to be provided for draining oily water escaping from the drains.

11.8.3 Treatment installation

a) Where fuel oil needs to be treated, at least two means of treatment are to be installed on board, each means is to be capable of efficiently purifying the amount of fuel oil necessary for the normal operation of the ship's engines.

b) For JP5 NATO (F44), one means of treatment may be accepted.

c) Subject to special consideration by the Society, the capacity of the standby purifier fuel oil may be less than that required in item a), depending on the arrangements made for the fuel oil service tanks to satisfy the requirement in [11.9.2].

d) The standby purifier may also be used for other ship's services.

e) Each purifier is to be provided with an alarm in case of failures likely to affect the quality of the purified fuel oil or JP5-NATO (F44).

f) Fuel oil purifiers and JP5-NATO (F44) purifiers are to be installed as required in Part C, Chapter 4.

11.9 Design of fuel supply systems

11.9.1 General

When necessary, arrangements are to be made for cooling the marine diesel oil from engine return lines.

11.9.2 Fuel oil service tanks

a) The propulsion plant and the generator plant are to be supplied by at least two service tanks, which may be common to both plants.

b) The aggregate capacity of the service tanks is to allow at least 3 hours operation at maximum continuous rating of the propulsion plant and normal operating load at sea of the generator plant.

11.9.3 Fuel oil supply to internal combustion engines

a) The suctions of engine fuel pumps are to be so arranged as to prevent the pumping of water and sludge likely to accumulate after decanting at the lower part of service tanks.

b) Internal combustion engines intended for main propulsion are to be fitted with at least two filters, or similar devices, so arranged that one of the filters can be overhauled while the other is in use.

Note 1: Where the propulsion plant consists of:

- two or more engines, each one with its own filter, or
- one engine with an output not exceeding 375 kW,

the second filter may be replaced by a readily accessible and easily replaceable spare filter.

c) Oil filters fitted in parallel are to be so arranged as to minimize the possibility of a filter under pressure being opened by mistake.

Filter chambers are to be provided with suitable means for:

- ventilating when put into operation
- de-pressurizing before being opened.

Valves or cocks used for this purpose are to be fitted with drain pipes led to a safe location.

d) Excess fuel oil from pumps or injectors is to be led back to the service or settling tanks, or to other tanks intended for this purpose.

e) For high pressure fuel oil pipes, refer to Ch 1, Sec 2.

11.10 Control and monitoring

11.10.1 Monitoring

Alarms and safeguards are to be provided for fuel oil and for JP5-NATO (F44) systems in accordance with Tab 26.

11.10.2 Automatic controls

Automatic temperature control is to be provided for all heaters.

11.10.3 Remote controls

a) The remote control arrangement of valves fitted on fuel oil and on JP5-NATO (F44) tanks is to comply with [11.6.4].

b) The power supply to:

- transfer pumps and other pumps of the fuel oil and JP5-NATO (F44) system
- fuel oil and JP5-NATO (F44) purifiers, and other treatment equipment,

is to be capable of being stopped from a position within the space containing the pumps and from another position located outside such space and always accessible in the event of fire within the space.

Note 1: Locally controlled pneumatic pumps are not required to be provided with a remote control system.

c) Remote control of the valve fitted to the emergency generator fuel tank is to be in a separate location from that of other valves fitted to tanks in the engine room.

d) The positions of the remote controls are also to comply with Part C, Chapter 3.

Table 26 : Fuel oil and JP5-NATO (F44) systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Fuel oil and JP5-NATO (F44) overflow tank level	H **(1)** HH			X **(2)** X**(2)**			
Sludge tank level		local					
Fuel oil level in daily service tank and JP5-NATO (F44) service tank	L+H **(1)**	local					
(1) Or sightglasses on the overflow pipe **(2)** Filling valve shut down **Note 1:** Blank box means no provision.							

11.11 Construction of fuel oil and JP5-NATO (F44) piping systems

11.11.1 Materials

a) Fuel oil pipes and their valves are to be of steel or other approved material, except that the use of flexible pipes may be accepted provided they comply with [2.6.3].

For JP5-NATO (F44), such pipes and valves located on the refuelling line (i.e. downstream the treatment equipment) are to be of stainless steel.

b) For valves fitted to fuel oil tanks and which are under a static pressure head, steel or nodular cast iron may be accepted.

c) Internal galvanisation of fuel oil pipes and tank or bunker walls are not allowed.

11.12 Arrangement of fuel oil and JP5-NATO (F44) piping systems

11.12.1 Passage of fuel oil or JP5-NATO (F44) pipes through tanks

a) Fuel oil pipes are not to pass through tanks containing fresh water or other flammable oil, unless they are contained within tunnels.

JP5-NATO (F44) pipes are not allowed to pass through tanks containing other fluids.

b) Transfer pipes of fuel oil passing through ballast tanks are to have a reinforced thickness complying with Tab 5, however the thickness of the pipe need not to exceed the Rule thickness of tank plate.

11.12.2 Passage of pipes through fuel oil or JP5-NATO (F44) tanks

Fresh water pipes are not to pass through fuel oil tanks, unless such pipes are contained within tunnels.

JP5-NATO (F44) tanks are not to be passed through by any other piping system.

11.12.3 Segregation of fuel oil purifiers

Purifiers fuel oil or JP5-NATO (F44) are to be in accordance with Ch 4, Sec 6, [4.1.2].

12 Lubricating oil systems

12.1 Application

12.1.1 This Article applies to lubricating oil systems serving diesel engines, steam and gas turbines, reverse and reduction gears, clutches and controllable pitch propellers, for lubrication or control purposes.

This Article also applies to separate oil systems intended for the cooling of engine pistons

12.2 Principle

12.2.1 General

a) Lubricating oil systems are to be so designed as to ensure reliable lubrication of the engines, turbines and other equipment, including electric motors, intended for propulsion:
   - over the whole speed range, including starting, stopping and, where applicable, manoeuvring
   - for all the inclinations angles stated in Ch 1, Sec 1

b) Lubricating oil systems are to be so designed as to ensure sufficient heat transfer and appropriate filtration of the oil.

c) Lubricating oil systems are to be so designed as to prevent oil from entering into contact with sources of ignition.

12.2.2 Availability

a) Lubricating oil systems serving propulsion plants are to be so designed that, in the event that any one pump is inoperative, the lubrication of the engines and other equipment is maintained. Reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired.

b) For auxiliary engines fitted with their own lubrication system, no additional pump is required.

c) Main engines are to be provided with at least two power lubricating pumps, of such a capacity as to maintain normal lubrication with any one pump out of action.

d) In the case of propulsion plants comprising more than one engine, each with its own lubricating pump, one of the pumps mentioned in item a) may be a spare pump.

12.3 General

12.3.1 Arrangement of lubricating oil systems

The provisions of [5.10] are to be complied with, where applicable.

12.3.2 Filtration

a) In forced lubrication systems, a device is to be fitted which efficiently filters the lubricating oil in the circuit.

b) The filters provided for this purpose for main machinery and machinery driving electric propulsion generators are to be so arranged that they can be easily cleaned without stopping the supply of filtered lubricating oil to the machines.

c) The fineness of the filter mesh is to comply with the requirements of the engine or turbine manufacturers.

d) Where filters are fitted on the discharge side of lubricating oil pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

12.3.3 Purification

Where provided, lubricating oil purifiers are to comply with [11.8.3] item d) and item e).

12.3.4 Heaters

Lubricating oil heaters are to comply with [11.7.1].

12.4 Design of lubricating oil tanks

12.4.1 Remote control of valves

Lubricating oil tanks with a capacity of 500 litres and above are to be fitted with remote controlled valves in accordance with the provisions of [11.6.4].

Suction valves and draining valves from storage tanks need not be arranged with remote controls provided they are kept closed except during transfer operations.

12.4.2 Filling and suction pipes

Filling and suction pipes are to comply with the provisions of [11.6.3].

12.4.3 Air and overflow pipes

Air and overflow pipes are to comply with the provisions of [9.1] and [9.3].

12.4.4 Sounding pipes and level gauges

a) Safe and efficient means of ascertaining the amount of lubricating oil contained in the tanks are to be provided.

b) Sounding pipes are to comply with the provisions of [9.2].

c) Oil-level gauges complying with [2.9.2] may be used in place of sounding pipes.

d) Gauge cocks for ascertaining the level in the tanks are not to be used.

12.4.5 Oil collecting tanks for engines

a) In ships required to be fitted with a double bottom, wells for lubricating oil under main engines may be permitted by the Society provided it is satisfied that the arrangements give protection equivalent to that afforded by a double bottom complying with Pt B, Ch 4, Sec 4.

b) Where, in ships required to be fitted with a double bottom, oil collecting tanks extend to the outer bottom, a valve is to be fitted on the oil drain pipe, located between the engine sump and the oil drain tank. This valve is to be capable of being closed from a readily accessible position located above the working platform.

Alternative arrangements will be given special consideration.

c) Oil collecting pipes from the engine sump to the oil collecting tank are to be submerged at their outlet ends.

12.5 Control and monitoring

12.5.1 In addition to the requirements in Ch 1, Sec 2 for diesel engines, in Ch 1, Sec 4 for steam turbines, in Ch 1, Sec 5 for gas turbines and in Ch 1, Sec 6 for gears, alarms are to be provided for lubricating oil systems in accordance with Tab 27.

Table 27 : Lubricating oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sludge tank level		local					
Note 1: Blank box means no provision.							

12.6 Construction of lubricating oil piping systems

12.6.1 Materials

Materials used for oil piping system in machinery spaces are to comply with the provisions of [11.11.1].

12.6.2 Sight-flow glasses

The use of sight-flow glasses in lubricating systems is permitted, provided that they are shown by testing to have a suitable degree of fire resistance.

13 Hydraulic systems

13.1 Application

13.1.1 Hydraulic installations intended for essential services

Unless otherwise specified, this Article applies to all hydraulic power installations intended for essential services, including:

- actuating systems of controllable pitch propellers. Additional requirements are also given in Ch 1, Sec 8, [2.6.2]
- actuating systems of clutches
- actuating systems of thrusters
- actuating systems of steering gear. Additional requirements are also given in Ch 1, Sec 12, [2.6]
- actuating systems of lifting appliances
- manoeuvring systems of hatch covers
- manoeuvring systems of stern, bow and side doors and bow visors
- manoeuvring systems of mobile ramps, movable platforms, elevators and telescopic wheelhouses
- starting systems of diesel engines and gas turbines
- remote control of valves
- stabilizing installations.

The provisions of [5.10] are to be complied with.

13.1.2 Hydraulic installations located in spaces containing sources of ignition

Hydraulic power installations not serving essential services but located in spaces where sources of ignition are present are to comply with the provisions of [5.10], [13.3.2], [13.3.3], [13.4.4] [13.4.5].

13.1.3 Low pressure or low power hydraulic installations

Hydraulic power installations with a design pressure of less than 2,5 MPa and hydraulic power packs of less than 5 kW will be given special consideration by the Society.

13.1.4 Very high pressure hydraulic installations

Hydraulic power installations with a design pressure exceeding 35 MPa will be given special consideration by the Society.

13.2 Principle

13.2.1 General

Hydraulic systems are to be so designed as to:

- avoid any overload of the system
- maintain the actuated equipment in the requested position (or the driven equipment at the requested speed)
- avoid overheating of the hydraulic oil
- prevent hydraulic oil from coming into contact with sources of ignition.

13.2.2 Availability

a) Hydraulic systems are to be so designed that, in the event that any one essential component becomes inoperative, the hydraulic power supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted, however, when it is demonstrated that the safe operation of the ship is not impaired. Such reduction of capability is not acceptable for steering gear.

b) When a hydraulic power system is simultaneously serving one essential system and other systems, it is to be ensured that:
   - any operation of such other systems, or
   - any failure in the whole installation external to the essential system,

   does not affect the operation of the essential system.

c) Provision of item b) applies in particular to steering gear.

d) Hydraulic systems serving lifting or hoisting appliances, including platforms, ramps, hatch covers, lifts, etc., are to be so designed that a single failure of any component of the system may not result in a sudden undue displacement of the load or in any other situation detrimental to the safety of the ship and persons on board.

13.3 General

13.3.1 Definitions

a) A power unit is the assembly formed by the hydraulic pump and its driving motor.

b) An actuator is a component which directly converts hydraulic pressure into mechanical action.

13.3.2 Limitations of use of hydraulic oils

a) Oils used for hydraulic power installations are to have a flashpoint not lower than 150°C and be suitable for the entire service temperature range.

b) The hydraulic oil is to be replaced in accordance with the specification of the installation manufacturer.

13.3.3 Location of hydraulic power units

a) Whenever practicable, hydraulic power units are to be located outside main engine room.

b) Where this requirement is not complied with, shields or similar devices are to be provided around the units in order to avoid an accidental oil spray or mist on heated surfaces which may ignite oil.

13.4 Design of hydraulic systems

13.4.1 Power units

Low power hydraulic installations not supplying essential services may be fitted with a single power unit, provided that alternative means, such as a hand pump, are available on board.

13.4.2 Pressure reduction units

Pressure reduction units used in hydraulic power installations are to be duplicated.

13.4.3 Filtering equipment

a) A device is to be fitted which efficiently filters the hydraulic oil in the circuit.

b) Where filters are fitted on the discharge side of hydraulic pumps, a relief valve leading back to the suction or to any other convenient place is to be provided on the discharge of the pumps.

13.4.4 Provision for cooling

Where necessary, appropriate cooling devices are to be provided.

13.4.5 Provision against overpressure

a) Safety valves of sufficient capacity are to be provided at the high pressure side of the installation.

b) Safety valves are to discharge to the low pressure side of the installation or to the service tank.

13.4.6 Provision for venting

Cocks are to be provided in suitable positions to vent the air from the circuit.

13.4.7 Provision for drainage

Provisions are to be made to allow the drainage of the hydraulic oil contained in the installation to a suitable collecting tank.

13.5 Design of hydraulic tanks and other components

13.5.1 Hydraulic oil service tanks

a) Service tanks intended for hydraulic power installations supplying essential services are to be provided with at least:
   - a level gauge complying with [2.9.2]
   - a temperature indicator
   - a level switch complying with [13.6.2].

b) The free volume in the service tank is to be at least 10% of the tank capacity.

13.5.2 Hydraulic oil storage tanks

Hydraulic power installations supplying essential services are to include a storage means of sufficient capacity to refill the whole installation should the need arise in case of necessity.

13.5.3 Hydraulic accumulators

The hydraulic side of the accumulators which can be isolated is to be provided with a relief valve.

13.6 Control and monitoring

13.6.1 Indicators

Arrangements are to be made for connecting a pressure gauge where necessary in the piping system.

13.6.2 Monitoring

Alarms and safeguards for hydraulic power installations intended for essential services, except steering gear, for which the provisions of Ch 1, Sec 12 apply, are to be provided in accordance with Tab 28.

Note 1: Tab 28 does not apply to steering gear.

Table 28 : Hydraulic oil systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Pump pressure	L						
Service tank level	L(**1**)						

(1) The low level alarm is to be activated before the quantity of lost oil reaches 100 liters or 50% of the circuit volume, whichever is the less.

Note 1: Blank box means no provision.

13.7 Construction of hydraulic oil piping systems

13.7.1 Materials

a) Pipes are to be made of seamless steel or seamless stainless steel. The use of welded steel pipes will be given special consideration by the Society.

b) Casings of pumps, valves and fittings are to be made of steel or other ductile material.

13.7.2 Pipe connections

Where flanged connections are used they are to be of the recess type or of another approved type offering suitable protection against projections.

14 Steam systems

14.1 Application

14.1.1 Scope

This Article applies to all steam systems intended for essential and non-essential services.

Steam systems with a design pressure of 10 MPa or more will be given special consideration.

14.2 Principle

14.2.1 Availability

a) Where a single boiler is installed, the steam system may supply only non-essential services.

b) Where more than one boiler is installed, the steam piping system is to be so designed that, in the event that any one boiler is out of action, the steam supply to essential services can be maintained.

14.3 Design of steam lines

14.3.1 General

a) Every steam pipe and every connected fitting through which steam may pass is to be designed, constructed and installed such as to withstand the maximum working stresses to which it may be subjected.

b) When the design temperature of the steam piping system exceeds 400°C, calculations of thermal stresses are to be submitted to the Society as specified in [2.3].

c) Steam connections on boilers and safety valves are to comply with the applicable requirements of Ch 1, Sec 3.

14.3.2 Provision against overpressure

a) If a steam pipe or fitting may receive steam from any source at a higher pressure than that for which it is designed, a suitable reducing valve, relief valve and pressure gauge are to be fitted.

b) When, for auxiliary turbines, the inlet steam pressure exceeds the pressure for which the exhaust casing and associated piping up to the exhaust valves are designed, means to relieve the excess pressure are to be provided.

14.3.3 Provision for dumping

In order to avoid overpressure in steam lines due to excessive steam production, in particular in systems where the steam production cannot be adjusted, provisions are to be made to allow the excess steam to be discharged to the condenser by means of an appropriate dump valve.

14.3.4 Provision for draining

Means are to be provided for draining every steam pipe in which dangerous water hammer action might otherwise occur.

14.3.5 Steam heating pipes

a) When heating coils are fitted in compartments likely to contain either fuel oil or liquid or dry cargoes, arrangements such as blind flanges are to be provided in order to disconnect such coils in the event of carriage of dry or liquid cargoes which are not to be heated.

b) The number of joints on heating coils is to be reduced to the minimum consistent with dismantling requirements.

14.3.6 Steam lines in cargo holds

a) Live and exhaust steam pipes are generally not to pass through cargo holds, unless special provisions are made with the Society's agreement.

b) Where steam pipes pass through cargo holds in pipe tunnels, provision is to be made to ensure the suitable thermal insulation of such tunnels.

c) When a steam smothering system is provided for cargo holds, provision is to be made to prevent spurious damage of the cargo by steam or condensate leakage.

14.3.7 Steam lines in accommodation spaces

Steam lines are not to pass through accommodation spaces, unless they are intended for heating purposes.

14.3.8 Turbine connections

a) A sentinel valve or equivalent is to be provided at the exhaust end of all turbines. The valve discharge outlets are to be visible and suitably guarded if necessary.

b) Bled steam connections are to be fitted with non-return valves or other approved means to prevent steam and water returning to the turbines.

14.3.9 Strainers

a) Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines or, alternatively, at the inlets to manoeuvring valves.

b) Where required by the manufacturer of the auxiliaries, steam strainers are also to be fitted in the steam lines supplying these auxiliaries.

15 Boiler feed water and condensate systems

15.1 Application

15.1.1 This Article applies to:

- feed water systems of oil fired and exhaust gas boilers
- steam drain and condensate systems.

15.2 Principle

15.2.1 General

Boiler feed water and condensate systems are to be so designed that:

- reserve feed water is available in sufficient quantity to compensate for losses
- feed water is free from contamination by oils or chlorides
- feed water for propulsion systems is suitably de-aerated.

15.2.2 Availability

a) Feed water systems are to be so designed that, in the event of failure of any one component, the steam supply to essential services can be maintained or restored.

b) Condensate systems are to be so designed that, in the event of failure of:
   - one condensate pump, or
   - the arrangements to maintain vacuum in the condenser,

   the steam supply to essential services can be maintained. Partial reduction of the propulsion capability may be accepted.

15.3 Design of boiler feed water systems

15.3.1 Number of feed water systems

a) Every steam generating system which supplies essential services is to be provided with not less than two separate feed water systems from and including the feed pumps, noting that a single penetration of the steam drum is acceptable.

b) The requirement stated in a) may be dispensed with for boilers heated exclusively by engine exhaust gases or by steam for which one feed system is considered as sufficient, provided an alternative supply of steam is available on board.

c) Each boiler is to be provided with feed regulators as specified in Ch 1, Sec 3, [5].

15.3.2 Feed pumps

a) The following pumps are to be provided:
   - at least one main feed pump of sufficient capacity to supply the boilers under nominal conditions, and
   - one standby feed pump.

b) The capacity of the standby pump may be less than that of the main feed pumps provided it is demonstrated that, taking into account the reduction of the propulsion capability, the ship remains safely operable.

c) Main feed pumps may be either independent or driven by the main turbines. The standby feed pump is to be independent.

d) In twin-screw ships in which there is only one independent feed pump, each main turbine is to be fitted with a driven pump. Where all feed pumps are independent, they are to be so arranged as to be capable of dealing with the feed water necessary to supply steam either to both turbines or to one turbine only.

e) Independent feed pumps for main boilers are to be fitted with a delivery control and regulating system.

f) Unless overpressure is prevented by the feed pump characteristics, means are to be provided which will prevent overpressure in the feed water system.

g) The pressure head of feed pumps is to take into account the maximum service pressure in the boiler as well as the pressure losses in the discharge piping. The suction head of feed pumps is to be such as to prevent cavitation as far as possible.

h) Feed pumps and pipes are to be provided with valves so arranged that any one pump can be overhauled while the boilers are operating at full load.

15.3.3 Harbour feed pumps

a) Where main turbine driven pumps are provided and there is only one independent pump, a harbour feed pump or an ejector is to be fitted in addition to provide the second means for feeding the boilers which are in use when the main turbine is not working.

b) The harbour feed pump may be used for the general service of the ship, but in no case is this pump to be used to convey liquid fuel, lubricating oil or oily water.

c) The suction pipes of the harbour feed pump from the hotwell, from reserve feed water tanks and from filters are to be fitted with non-return valves.

15.3.4 Feed water tanks

a) All ships fitted with main boilers or auxiliary boilers for essential services are to be provided with reserve feed water tanks.

b) Boilers are to be provided with means to supervise and control the quality of the feed water. Suitable arrangements are to be provided to preclude, as far as practicable, the entry of oil or other contaminants which may adversely affect the boiler.

c) Feed water tanks are not to be located adjacent to fuel oil tanks. Fuel oil pipes are not to pass through feed water tanks.

d) For main boilers, one or more evaporators are to be provided, the capacity of which is to compensate for the losses of feed water due to the operation of the machines, in particular where the fuel supplied to the boilers is atomized by means of steam.

15.3.5 Provision for de-aerating feed water

A de-aerator is to be provided to ensure the de-aeration of the feed water intended for main boilers before it enters such boilers.

15.4 Design of condensate systems

15.4.1 Condensers

a) Appropriate arrangements, such as air ejectors, are to be provided to maintain vacuum in the main condenser or restore it to the required value.

b) Cooling of the main condenser is to comply with the provisions of [10.3.5].

15.4.2 Condensate pumps

a) Condensate pumps are to include at least:
   - one main condensate pump of sufficient capacity to transfer the maximum amount of condensate produced under nominal conditions, and
   - one independently driven standby condensate pump.

b) The standby condensate pump may be used for other purposes.

15.4.3 Condensate observation tanks

Any condensate from the steam heating pipes provided for fuel oil tanks and bunkers, cargo tanks and fuel oil or lubricating oil heaters is to be led to an observation tank or some other device of similar efficiency located in a well-lighted and readily accessible position.

15.5 Control and monitoring

15.5.1 General

The provisions of this sub-article apply only to feed water and condensate systems intended for propulsion.

15.5.2 Monitoring

Alarms and safeguards are to be provided for feed water and condensate systems in accordance with Tab 29.

15.5.3 Automatic controls

Automatic level control is to be provided for:
- de-aerators
- condensers.

Table 29 : Boiler feed and condensate system

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Sea water flow or equivalent	L						
Condenser pressure	H	local					
	HH			X			
Water level in main condenser (unless justified)	H	local					
Feed water salinity	H	local					
Feed water pump delivery pressure	L	local					
						X	
Feed water tank level	L						

15.6 Arrangement of feed water and condensate piping

15.6.1

a) Feed water pipes are not to pass through fuel oil or lubricating oil tanks.

b) Pipes connected to feed water tanks are to be so arranged as to prevent the contamination of feed water by fuel oil, lubricating oil or chlorides.

16 Compressed air systems

16.1 Application

16.1.1 This Article applies to compressed air systems intended for essential services, and in particular to:

- starting of engines
- control and monitoring
- breathable air systems.

16.2 Principle

16.2.1 General

a) Compressed air systems are to be so designed that the compressed air delivered to the consumers:
   - is free from oil and water
   - does not have an excessive temperature.

b) Compressed air systems are to be so designed as to prevent overpressure in any part of the systems.

16.2.2 Availability

a) Compressed air systems are to be so designed that, in the event of failure of one air compressor or one air receiver intended for starting, control purposes or other essential services, the air supply to such services can be maintained.

b) At the specific request of the Naval Authority, it may be required that the compressed air system for starting main engines and auxiliary engines for essential services is to be so arranged that it is possible to ensure the initial charge of air receiver(s) without the aid of a power source outside the ship. Equivalent solutions allowing the starting of the engines may be accepted by the Society on a case by case basis.

c) If the air receivers are used for engine starting as in [16.3] the total capacity of air receivers hall take into account the air to be delivered to other consumers such as control systems, ship systems, etc., which are connected to the air receivers.

16.3 Design of starting air systems

16.3.1 Number and capacity of air compressors

a) Where main and auxiliary engines are arranged for starting by compressed air, two or more air compressors are to be fitted with a total capacity sufficient to supply within one hour the quantity of air needed to satisfy the provisions of Ch 1, Sec 2, [3.1.1]. This capacity is to be approximately equally divided between the number of compressors fitted, excluding the emergency compressor fitted in pursuance of [16.3.2].

b) At least one of the compressors is to be independent of the engines for which starting air is supplied and is to have a capacity of not less than 50% of the total required in item a).

16.3.2 Initial charge of starting air receivers

a) Where, for the purpose of [16.2.2], an emergency air compressor is fitted, its driving engine is to be capable of being started by hand-operated devices. Independent electrical starting batteries may also be accepted.

b) A hand compressor may be used for the purpose of [16.2.2] only if it is capable of charging within one hour an air receiver of sufficient capacity to provide 3 consecutive starts of a propulsion engine or of an engine capable of supplying the energy required for operating one of the main compressors.

16.3.3 Number and capacity of air receivers

a) Where main engines are arranged for starting by compressed air, at least two air receivers are to be fitted of approximately equal capacity and capable of being used independently.

b) The total capacity of air receivers is to be sufficient to provide without replenishment the number of starts required in Ch 1, Sec 2, [3.1.1].

16.3.4 Air supply for starting the emergency generating set

Starting air systems serving main or auxiliary engines may be used for starting the emergency generator under the conditions specified in Ch 1, Sec 2, [3.1.3].

16.4 Design of control and monitoring air systems

16.4.1 Air supply

a) The control and monitoring air supply to essential services is to be available from two sources of a sufficient capacity to allow normal operation with one source out of service.

b) At least one air vessel fitted with a non-return valve is to be provided for control and monitoring purposes.

Note 1: The Society may accept, as an alternative to the above clause, provisions allowing the configuration of the compressed air installation in such a way as that the control and monitoring air circuit can be isolated from the rest of the installation.

c) Pressure reduction units used in control and monitoring air systems intended for essential services are to be duplicated, unless an alternative air supply is provided.

d) Failure of the control air supply is not to cause any sudden change of the controlled equipment which may be detrimental to the safety of the ship.

16.4.2 Pressure control

Arrangements are to be made to maintain the air pressure at a suitable value in order to ensure satisfactory operation of the installation.

16.4.3 Air treatment

In addition to the provisions of [16.8.3], arrangements are to be made to ensure cooling, filtering and drying of the air prior to its introduction in the monitoring and control circuits.

16.5 Design of air compressors

16.5.1 Prevention of excessive temperature of discharged air

Air compressors are to be so designed that the temperature of discharged air cannot exceed 95°C. For this purpose, the air compressors are to provided where necessary with:

- suitable cooling means
- fusible plugs or alarm devices set at a temperature not exceeding 120°.

16.5.2 Prevention of overpressure

a) Air compressors are to be fitted with a relief valve complying with [2.5.3].

b) Means are to be provided to prevent overpressure wherever water jackets or casings of air compressors may be subjected to dangerous overpressure due to leakage from air pressure parts.

c) Water space casings of intermediate coolers of air compressors are to be protected against any overpressure which might occur in the event of rupture of air cooler tubes.

16.5.3 Crankcase relief valves

Air compressors having a crankcase volume of at least 0,6 m^3 are to be fitted with crankcases explosion relief valves satisfying the provisions of Ch 1, Sec 2, [2.4.4].

16.5.4 Provision for draining

Air compressors are to be fitted with a drain valve.

16.6 Control and monitoring of compressed air systems

16.6.1 Monitoring

Alarms and safeguards are to be provided for compressed air systems in accordance with Tab 30.

16.6.2 Automatic controls

Automatic pressure control is to be provided for maintaining the air pressure in the air receivers within the required limits.

16.7 Materials

16.7.1 Pipes and valves bodies in control and monitoring air systems and other air systems intended for non-essential services may be made of plastic in accordance with the provisions of Ch 1, App 2.

16.8 Arrangement of compressed air piping systems

16.8.1 Prevention of overpressure

Means are to be provided to prevent overpressure in any part of compressed air systems. Suitable pressure relief arrangements are to be provided for all systems discharging in a safe position.

16.8.2 Air supply to compressors

a) Provisions are to be made to reduce to a minimum the entry of oil into air pressure systems.

b) Air compressors are to be located in spaces provided with sufficient ventilation.

Table 30 : Compressed air systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Compressor lubricating oil pressure (except where splash lubrication)	L						
Air pressure after reducing valves **(1)**	L+H	local					
Starting air pressure before main shut-off valve	L	local + R					
Air vessel pressure **(2)**	L+H	local					

Note 1: Blank box means no provisions.
(1) Applicable to the pressure reducing valves referred to in [15.4.1] c).
(2) Applicable to air vessel group where the air vessels are normally in communication.

16.8.3 Air treatment and draining

a) Provisions are be made to drain air pressure systems.

b) Efficient oil and water separators, or filters, are to be provided on the discharge of compressors, and drains are to be installed on compressed air pipes wherever deemed necessary.

16.8.4 Lines between compressors, receivers and engines

All discharge pipes from starting air compressors are to be lead directly to the starting air receivers, and all starting air pipes from the air receivers to main or auxiliary engines are to be entirely separate from the compressor discharge pipe system.

Note 1: Air vessels may be arranged as buffer vessels (common filling and discharge line) provided that a non return valve is fitted between the engine and the compressor, in addition to that required in Ch 1, Sec 2, [3.1.1], item c).

16.8.5 Protective devices for starting air mains

Non-return valves and other safety devices are to be provided on the starting air mains of each engine in accordance with the provisions of Ch 1, Sec 2, [3.1.1].

16.9 Compressed breathable air systems

16.9.1 Number of refilling air breathable stations and station arrangement

A refilling station for breathing apparatus of fire-fighter's outfits is to be provided in each safety zone. The station is to be provided with an electric driven compressor capable of refilling the number of bottles mentioned in the ship specification at 30 MPa in less than one hour. Arrangements are to be made for refilling other equipment such as breathing apparatuses for CBRN protection purposes or divers apparatus.

Where necessary, pressure reducing devices are to be provided.

Ships to be assigned the additional class notation **CBRN** or **CRBN-AIRBLAST RESISTANCE** are to comply with the provisions of Pt E, Ch 8, Sec 3, [5] in addition to those of the present requirement.

16.9.2 Breathable air properties

The breathable air properties shall comply with standards to be stated by the Naval Authority.

16.9.3 Air compressors

a) The air inlet of the compressors is to be positioned so that particulate matters are minimized and the content of water and oil in the suctioned air remains below 50 mg/Nm^3. For ships to be assigned the **CBRN** or **CBRN-AIRBLAST RESISTANCE** additional class notation, these criteria are to be fulfilled in CBRN mode as well.

b) All compressors shall be so designed and constructed that prevention of overpressure and excessive temperature and shall comply with the requirements of [16.5.1] and [16.5.2].

c) The compressors shall also be provided with filter and valves at the air inlet, valve at air outlet, automatic drain valve and safety valve at stages as well as automatic condensate baffle separators after stages.

d) Furthermore, for the electric compressor, at least the followings operations are to be provided from the control panel required in [16.9.5]:

- emergency shut down
- automatic stop at a delivered preset pressure
- emergency stop in case of compressed air high temperature

and the following monitors:
- lubricating oil level
- delivered air pressure.

16.9.4 Air filtering systems
The air filtering systems shall be consistent with the air breathable properties stated by the Naval Authority.

16.9.5 Air breathable monitor and control panels
Air process, air properties as well as filling/refilling process shall be controlled and monitored.

16.9.6 Prevention of over pressure
The requirements in [16.8.1] shall be complied with.

16.9.7 Metallic materials
All metallic materials which are used in the construction of pipes for breathable systems shall be AISI 316, or other stainless steel with a nickel content not less than 10% and a yielding strength R_S not less than 250 Mpa, or Monel 400.

16.9.8 Class of components of breathable air systems and tests
For pipes, fittings, containers, filter and absorption devices containers and compressors, class shall be in accordance with the present Ch 1, Sec 10 and, where appropriate, with Ch 1, Sec 3.

The tests of such components shall be in accordance with [19].

17 Combustion air and exhaust gas systems

17.1 General

17.1.1 Application
This Article applies to:
- combustion air intake systems that may be provided for machinery required to run in CBRN condition
- exhaust gas pipes from engines and gas turbines, and
- smoke ducts from boilers and incinerators.

17.1.2 Principle
Combustion air systems are to be designed so as to:
- prevent CBRN contamination in manned spaces
- prevent water from entering engines.

Exhaust gas systems are to be designed so as to:
- limit the risk of fire
- prevent gases from entering manned spaces
- prevent water from entering engines.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 2, [6] for ships to be assigned the **CBRN** additional class notation.

17.1.3 Exhaust gas pollution prevention systems
Additional requirements for the installation of exhaust gas pollution prevention systems and storage and use of chemical treatment fluids consumed in the associated process are given in Ch 1, Sec 11.

17.2 Design of combustion air and exhaust systems

17.2.1 General
Combustion air and exhaust systems are to be so arranged as to minimise the intake of exhaust gases into manned spaces, air conditioning systems and engine intakes.

17.2.2 Limitation of exhaust line surface temperature
a) Exhaust gas pipes and silencers are to be either water cooled or efficiently insulated where:
   - their surface temperature may exceed 220°C, or
   - they pass through spaces of the ship where a temperature rise may be dangerous.

b) The insulation of exhaust systems is to comply with the provisions of Ch 1, Sec 1, [3.7.1].

17.2.3 Limitation of pressure losses
Combustion air and exhaust gas systems are to be so designed that pressure losses in the intake and exhaust lines do not exceed the maximum values permitted by the engine or boiler manufacturers.

17.2.4 Intercommunication of engine exhaust gas lines or boiler smoke ducts

Exhaust gas from different engines is not to be led to a common exhaust main, exhaust gas boiler or economizer, unless each exhaust pipe is provided with a suitable isolating device.

17.2.5 Air intake and exhaust gas pipe terminations

a) Where exhaust pipes are led overboard close to the load waterline, means are to be provided to prevent water from entering the engine or the ship.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

c) Air intake systems are to be so arranged to prevent water and waterspray from entering the air duct.

d) Air intake systems are to be protected against entering of dust as per requirement of engine manufacturer.

17.3 Materials

17.3.1 General

Materials of exhaust gas pipes and fittings are to be resistant to exhaust gases and suitable for the maximum temperature expected.

17.4 Arrangement of combustion air and exhaust piping systems

17.4.1 Provision for thermal expansion

a) Exhaust pipes and smoke ducts are to be so designed that any expansion or contraction does not cause abnormal stresses in the piping system, and in particular in the connection with engine turbochargers.

b) The devices used for supporting the pipes are to allow their expansion or contraction.

17.4.2 Provision for displacement

Where engine are elastic mounted, the devices used for supporting the combustion air, if any, and exhaust pipes or ducts are to be so designed that any displacement does not cause abnormal stresses in the piping system and in particular in the connection with engine turbochargers.

17.4.3 Provision for draining

a) Drains are to be provided where necessary in combustion air and exhaust systems in order to prevent water flowing into the engine.

b) Where exhaust pipes are water cooled, they are to be so arranged as to be self-draining overboard.

18 Oxyacetylene welding systems

18.1 Application

18.1.1 This Article applies to centralized fixed plants for oxyacetylene welding installed on ships. It may also be applied, at the discretion of the Society, to other plants using liquefied gas, such as propane.

While it is to be noted that oxyacetylene welding systems are generally not in use in naval ships the following provisions apply if this system are present.

18.2 Definitions

18.2.1 Centralised plants for oxyacetylene welding

A centralized plant for oxyacetylene welding is a fixed plant consisting of a gas bottle room, distribution stations and distribution piping, where the total number of acetylene and oxygen bottles exceeds 4.

18.2.2 Acetylene

Acetylene (C_2H_2) is assumed to be contained in pressurized gas bottles with pressure equal to 1,5-1,8 MPa at 15°C.

18.2.3 Oxygen

Oxygen (O_2) is assumed to be contained in pressurized gas bottles, with pressure equal to 15-20 MPa at 15°C.

18.2.4 Gas bottle rooms

A gas bottle room is a room containing acetylene and oxygen bottles, where distribution headers, non-return and stop valves, pressure reducing devices and outlets of supply lines to distribution stations are also installed.

Note 1: Gas bottle rooms may also contain non dangerous equipment.

18.2.5 Distribution stations

Distribution stations are adequately protected areas or cabinets equipped with stop valves, pressure regulating devices, pressure gauges, non-return valves and oxygen as well as acetylene hose connections for the welding torch.

18.3 Design of oxyacetylene welding systems

18.3.1 General

Except on pontoons and service working ships, no more than two distribution stations are normally permitted.

18.3.2 Acetylene and oxygen bottles

a) The bottles are to be tested by the Society or by a body recognized by the Society.

b) Bottles with a capacity exceeding 50 liters are not permitted.

c) Bottles supplying the plant and spare bottles are to be installed in the gas bottle room. Installation within accommodation spaces, service spaces, control stations and machinery spaces is not permitted.

d) Bottles are to be installed in a vertical position and are to be safely secured. The securing system is to be such as to allow the ready and easy removal of the bottles.

18.3.3 Piping systems

a) Acetylene and oxygen piping systems are to comply with the following provisions:
- all valves and fittings as well as welding torches and associated supply hoses are to be adapted to this specific service and suitable for the conditions expected in the different parts of the system
- acetylene piping is to be of stainless steel and seamless drawn
- oxygen piping is to be of copper or stainless steel and seamless drawn
- the connections between the various pipe sections are to be carried out by means of butt welding. Other types of connections including threaded connections and flange connections are not permitted
- only a minimum number of unavoidable connections are permitted provided they are located in a clearly visible position.

b) High pressure lines (i.e. lines between bottles and pressure reducing devices) are to be installed inside the gas bottle room and are to comply with the following provisions:
- acetylene and oxygen piping and associated fittings are to be suitable for a design pressure of 29,5 MPa
- a non-return valve is to be installed on the connection of each acetylene and oxygen bottle to the header
- stop valves are to be provided on the bottles and kept shut when distribution stations are not working.

c) Low pressure lines (i.e. lines between pressure reducing devices and distribution stations) are to comply with the following provisions:
- steel piping is to have a thickness of not less than:
  - 2,5 mm when installed in the open air
  - 2 mm otherwise.
- stainless steel piping is to have a thickness of not less than 1,7 mm.
- supply lines to each distribution station are to include, at the station inlet:
  - a stop valve to be kept shut when the station is not working
  - devices to protect the supply lines from back flow of gas or flame passage.

d) Safety valves are to be provided on the low pressure side of the pressure reducing devices and led to the open air above the deck in a safe location where the gas can easily be spread and where no source of ignition is present.

18.4 Arrangement of oxyacetylene welding systems

18.4.1 Gas bottle rooms

a) The gas bottle room is to be located in an independent space over the highest continuous deck and provided with direct access from outside. The limiting bulkheads and decks are to be gas-tight and made of steel.

Note 1: Alternatively, the bottles may be stored in an open area.

b) When the total number of gas bottles, including possible spare bottles which are not connected to the plant, does not exceed 8, acetylene and oxygen bottles may be installed in the same room. Otherwise, acetylene and oxygen bottles are to be separated by a gas-tight bulkhead.

c) The bottle room is to be adequately ventilated. See also Ch 4, Sec 5, [6.8.6].

d) Flammable oil or gas piping, except that related to the oxyacetylene welding plant, is not to be led through this room.

18.4.2 Distribution stations

Distribution stations are to be located in the engine room or in the workshop, in a well-ventilated position and protected against possible mechanical damage.

18.4.3 Piping

a) Piping is not to be led through accommodation or service spaces.

b) Piping is to be protected against any possible mechanical damage.

c) In way of deck or bulkhead penetrations, piping is to be suitably enclosed in sleeves so arranged as to prevent any fretting of the pipe with the sleeve.

18.4.4 Signboards

Signboards are to be posted on board the ship in accordance with Tab 31.

Table 31 : Signboards

Location of the signboard	Signboard to be posted
In the gas bottle room	Diagram of the oxyacetylene plant
	"No smoking"
In way of: • bottle stop valves • distribution station stop valves	"To be kept shut when distribution stations are not working"
In way of the pressure reducing devices	Indication of the maximum allowable pressure at the pressure reducing device outlet
In way of the safety valve discharge outlet	"No smoking"

19 Certification, inspection and testing of piping systems

19.1 Application

19.1.1 This Article defines the certification and workshop inspection and testing programme to be performed on:

- the various components of piping systems
- the materials used for their manufacture.

On board testing is dealt with in Ch 1, Sec 16.

19.2 Type tests of flexible hoses and expansion joints

19.2.1 General

a) Prototype test programmes are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

b) Prototype test programmes are to be made in accordance with recognised standards which are suitable for the intended service of the flexible hose or of an expansion joint.

c) Tests are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to the installation.

d) All flexible hose assemblies or expansion joints are to be satisfactorily prototype burst tested to an international standard (see Note 1) to demonstrate that they are able to withstand a pressure not less than 4 times their design pressure without indication of failure or leakage.

Note 1: The international standards (e.g. EN or SAE standards) for burst testing of non-metallic hoses require the pressure to be increased until burst without any holding period. Burst is to occur at a pressure greater than 4 times the maximum working pressure.

19.2.2 Flexible hoses

a) For flexible hoses which are to comply with [2.6], prototype tests are to be carried out for each size of hose assembly. However, for ranges with more than 3 different diameters, the prototype tests are to be carried out for at least:

   - the smallest diameter
   - the largest diameter
   - intermediate diameters selected based on the principle that prototype tests carried out for a hose assembly with a diameter D are considered valid only for the diameters ranging between 0,5 D and 2 D.

   For fire resistance tests the specimens are to be selected in accordance with ISO 15540:2016.

b) The flexible hoses subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [19.2.1], including, but not limited to, the scope of testing specified in Tab 32 for metallic flexible hoses and in Tab 33 for non-metallic flexible hoses.

Table 32 : Type tests and procedures for metallic flexible hoses depending on the application

	Burst	Pliability (bending)	Cycle test: U bend (Hoses up to 100 DN)	Cycle test: Cantilever bend (Hoses above DN 100)	Pressure and elongation	Impulse	Vibration
	ISO 10380:2012**(1)**					**(2)**	Ch 3, Sec 6, Tab 1 **(1)**
Fuel Oil	X	X	X	X	X	**(3)**	**(4)**
Lubricating Oil	X	X	X	X	X	**(3)**	**(4)**
Hydraulic Oil	X	X	X	X	X	**(3)**	**(4)**
Thermal Oil	X	X	X	X	X	**(3)**	**(4)**
Fresh water	X	X	X	X	X	**(3)**	**(4)**
Sea water	X	X	X	X	X	**(3)**	**(4)**
Compressed air	X	X	X	X	X	**(3)**	**(4)**
Bilge	X	X	X	X	X	**(3)**	**(4)**
Exhaust Gas	X	X	X	X	X	**(3)**	**(4)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) Impulse pressure is to be raised from 0 to 1,5 times the design pressure with a frequency equal to 30-100 cycles per minute for at least 150 000 cycles.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 33 : Type tests and procedures for non-metallic flexible hoses depending on the application

	Burst	Fire resistance	Visual inspection and dimensional check	Change in length	Resistance against liquid	Cover adhesion	Ozone resistance **(2)**	Impulse	Vibration	Vacuum	Cold flexibility
	EN ISO 1402:2021 **(1)**	EN ISO 15540:2016 / EN ISO 15541:2016 **(1)**	EN ISO 4671:2022 **(1)**	EN ISO 1402:2021 **(1)**	ISO 1817:2022 **(1)**	EN ISO 8033:2016 **(1)**	ISO 7326:2016 **(1)**	EN ISO 6802:2018 / EN ISO 6803:2017 **(1)**	Ch 3, Sec 6, Tab 1 **(1)**	EN ISO 7233:2016 **(1)**	EN ISO 10619-2:2021 **(1)**
Fuel Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	X	X	X	**(3)**	**(4)**	**(5)**	**(6)**
Fresh water	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Sea water	X	X	X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Compressed air	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Bilge	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**
Exhaust Gas	X		X	X		X	X	**(3)**	**(4)**	**(5)**	**(6)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For rubber hoses only.
(3) For piping systems subject to pressure pulsation.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.
(5) For suction hoses only.
(6) For piping systems subject to low temperature (< 0°C).

19.2.3 Expansion Joints

a) For the expansion joints which are to comply with [2.6], relevant type approval tests are to be carried out on a representative sampling on each type and for each pressure range.

b) The expansion joints subjected to the tests are to be fitted with their connections.

c) Type approval tests are to be carried out in accordance with the prototype test programmes required in [19.2.1], including, but not limited to, the scope of testing specified in Tab 34 for metallic expansion joints and in Tab 35 for non-metallic expansion joints.

d) Exemptions from prototype burst test may be granted for expansion joints of large diameter used on sea water lines and to large diameter expansion joints used on exhaust gas lines, except for those which are fitted directly on engines. Testing may be limited to pressure test.

Table 34 : Type tests and procedures to be performed for metallic expansion joints

	Burst	Hydrostatic	Cyclic expansion **(2)**	Vibration
	see [19.2.1] d)**(1)**	see [19.6.6]**(1)**	EJMA Code **(3)(1)**	Ch 3, Sec 6, Tab 1**(1)**
Fuel Oil	X		X	**(4)**
Lubricating Oil	X		X	**(4)**
Hydraulic Oil	X		X	**(4)**
Thermal Oil	X		X	**(4)**
Fresh water	X		X	**(4)**
Sea water	X		X	**(4)**
Compressed air	X		X	**(4)**
Bilge	X		X	**(4)**
Exhaust Gas		X	X	**(4)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For piping systems subject to expansion cycles.
(3) Type test is an alternative. A test procedure is to be submitted to the Society for approval.
(4) Where fitted to engines, pumps, compressors or other sources of high vibrations.

Table 35 : Type tests and procedures for non-metallic expansion joints

	Burst	Fire resistance	Resistance against liquid	Cyclic expansion**(2)**	Ozone resistance	Impulse	Vibration
	[19.2.1] d)**(1)**	EN ISO 15540:2016 / EN ISO 15541:2016**(1)**	ISO 1817:2022**(1)**	**(3)(1)**	ISO 7326:2016**(1)**	EN ISO 6802:2018 / EN ISO 6803:2017**(1)**	Ch 3, Sec 6, Tab 1**(1)**
Fuel Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Lubricating Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Hydraulic Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Thermal Oil	X	X	X	X	**(4)**	**(5)**	**(6)**
Fresh water	X			X	**(4)**	**(5)**	**(6)**
Sea water	X	X		X	**(4)**	**(5)**	**(6)**
Compressed air	X			X	**(4)**	**(5)**	**(6)**
Bilge	X			X	**(4)**	**(5)**	**(6)**

(1) Other recognized standards may be accepted where agreed by the Society.
(2) For piping systems subject to expansion cycles.
(3) Test procedure is to be submitted to the Society for approval
(4) For rubber expansion joints only.
(5) For piping systems subject to pressure pulsation.
(6) Where fitted to engines, pumps, compressors or other sources of high vibrations

19.3 Type tests of air pipe closing devices

19.3.1 Type approval tests are to be carried out on each type and size of air pipe closing device, in accordance with Tab 36 and the “Rules for type approval and testing of air pipe closing devices”.

19.4 Type tests of mechanical pipe joints

19.4.1 Type approval tests of mechanical pipe joints are to be carried out in accordance with the provisions of Tab 37.

Table 36 : Type tests to be performed for air pipe closing appliances

Test to be performed	Type of air closing appliance	
	Float type	Other types
Tightness test **(1)**	X	X
Flow characteristic determination **(2)**	X	X
Impact test of floats	X	
Pressure loading test of floats	X **(3)**	

(1) The tightness test is to be carried out during immerging/ emerging in water, in the normal position and at an inclination of 40 degrees.
(2) Pressure drop is to be measured versus flow rate using water.
(3) only for non-metallic floats.
Note 1: X = required.

Table 37 : Type tests to be performed for mechanical joints

Tests		Types of mechanical joints		
		Compression couplings and pipes unions	Slip-on joints	
			Grip type & machine grooved type	Slip type
1	Tightness test	+	+	+
2	Vibration (fatigue) test	+	+	–
3	Pressure pulsation test **(1)**	+	+	–
4	Burst pressure test	+	+	+
5	Pull-out test	+	+	–
6	Fire endurance test	+	+	+
7	Vacuum test	+ **(3)**	+	+
8	Repeated assembly test	+ **(2)**	+	–

Abbreviations:
+ : test is required
– : test is not required.
(1) For use in those systems where pressure pulsation other than water hammer is expected
(2) Except press type
(3) Except joints with metal-to-metal tightening surfaces.

19.5 Testing of materials

19.5.1 General

a) Detailed specifications for material tests are given in NR216 Materials and Welding.

b) Requirements for the inspection of welded joints are given in NR216 Materials and Welding.

19.5.2 Tests for materials

a) Where required in Tab 38, materials used for pipes, valves and other accessories are to be subjected to the following tests:

- tensile test at ambient temperature
- flattening test or bend test, as applicable

- tensile test at the design temperature, except if one of the following conditions is met:
  - the design temperature is below 200°C
  - the mechanical properties of the material at high temperature have been approved
  - the scantling of the pipes is based on reduced values of the permissible stress.

b) Plastic materials are to be subjected to the tests specified in Ch 1, App 2, however installation shall be avoided if not agreed by the Society and the Naval Authority.

19.6 Hydrostatic testing of piping systems and their components

19.6.1 General

Pneumatic tests are to be avoided wherever possible. Where such testing is absolutely necessary in lieu of the hydraulic pressure test, the relevant procedure is to be submitted to the Society for acceptance prior to testing.

19.6.2 Hydrostatic pressure tests of piping

a) Hydrostatic pressure tests are to be carried out to the Surveyor’s satisfaction for:
- all class I and II pipes and their integral fittings
- all steam pipes, feed water pipes, compressed air pipes, and fuel oil and other flammable oil pipes with a design pressure greater than 0,35 MPa and their associated integral fittings.

b) These tests are to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

Note 1: Classes of pipes are defined in [1.5.2].

c) Pressure testing of small bore pipes (less than 15 mm) may be waived except for fuel oil system, JP5-NATO (F44) system, aircraft/helicopter refuelling system and compressed air system at the discretion of the Surveyor, depending on the application.

d) Where the design temperature does not exceed 300°C, the test pressure is to be equal to 1,5 p.

e) Where the design temperature exceeds 300°C, the test pressure is to be as follows:
- for carbon and carbon-manganese steel pipes, the test pressure is to be equal to 2 p
- for alloy steel pipes, the test pressure P_H is to be determined by the following formula, but need not exceed 2 p:

$$p_H = 1{,}5\frac{K_{100}}{K_T}p$$

where:

K_{100} : Permissible stress for 100°C, as stated in Tab 10

K_T : Permissible stress for the design temperature, as stated in Tab 10.

Note 2: Where alloy steels not included in Tab 10 are used, the permissible stresses will be given special consideration.

f) Where it is necessary to avoid excessive stress in way of bends, branches, etc., the Society may give special consideration to the reduction of the test pressure to a value not less than p_H equal to1,5 p. The membrane stress is in no case to exceed 90% of the yield stress at the testing temperature.

g) While satisfying the condition stated in b), the test pressure of pipes located on the discharge side of centrifugal pumps driven by steam turbines is not to be less than the maximum pressure liable to be developed by such pumps with closed discharge at the operating speed of their overspeed device.

h) When the hydrostatic test of piping is carried out on board, these tests, except for class I, may be carried out in conjunction with the tests required in [19.6.7].

19.6.3 Hydrostatic tests of valves, fittings and heat exchangers

a) Valves and fittings non-integral with the piping system and intended for class I and II pipes are to be subjected to hydrostatic tests in accordance with standards recognized by the Society, at a pressure not less than 1,5 times the design pressure p defined in [1.3.2].

b) Valves and distance pieces intended to be fitted on the ship side below the maximum ship draft are to be subjected to hydrostatic tests under a pressure not less than 0,5 MPa.

c) The shells of appliances such as heaters, coolers and heat exchangers which may be considered as pressure vessels are to be tested under the conditions specified in Ch 1, Sec 3.

d) The nests of tubes or coils of heaters, coolers and heat exchangers are to be submitted to a hydraulic test under the same pressure as the fluid lines they serve.

e) For coolers of internal combustion engines, see Ch 1, Sec 2.

19.6.4 Hydrostatic tests of fuel oil and JP5-NATO (F44) bunkers and tanks not forming part of the ship’s structure

Fuel oil, JP5-NATO (F44) and bunkers tanks not forming part of the ship’s structure are to be subjected to a hydrostatic test under a pressure corresponding to the maximum liquid level in such spaces or in the air or overflow pipes, with a minimum of 2,40 m above the top.

19.6.5 Hydrostatic tests of pumps and compressors

a) Cylinders, covers and casings of pumps and compressors are to be subjected to a hydrostatic test under a pressure at least equal to the test pressure p_H , in MPa, determined by the following formulae:

- $p_H = 1,5\ p$ where $p \leq 4$
- $p_H = 1,4\ p + 0,4$ where $4 < p \leq 25$
- $p_H = p + 10,4$ where $p > 25$

where:

p : Design pressure, in MPa, as defined in [1.3.2].

p_H is not to be less than 0,4 MPa.

b) While satisfying the condition stated in a), the test pressure for centrifugal pumps driven by steam turbines is not to be less than 1,05 times the maximum pressure likely to be recorded with closed discharge at the operating speed of the overspeed device.

c) Intermediate coolers of compressors are to undergo a hydrostatic test under a pressure at least equal to the pressure p_H defined in a). When determining p_H, the pressure p to be considered is that which may result from accidental communication between the cooler and the adjoining stage of higher pressure, allowance being made for any safety device fitted on the cooler.

d) The test pressure for water spaces of compressors and their intermediate coolers is not to be less than 1,5 times the design pressure in the space concerned, subject to a minimum of 0,2 MPa.

e) For air compressors and pumps driven by diesel engines, see Ch 1, Sec 2.

19.6.6 Hydrostatic test of flexible hoses and expansion joints

a) Each flexible hose or expansion joint, together with its connections, is to undergo a hydrostatic test under a pressure at least equal to 1,5 times the maximum service pressure.

b) During the test, the flexible hose or expansion joint is to be repeatedly deformed from its geometrical axis.

19.6.7 Pressure tests of piping after assembly on board

After assembly on board, the following tightness tests are to be carried out in the presence of the Surveyor.

In general, all the piping systems covered by these requirements are to be checked for leakage under operational conditions and, if necessary, using special techniques other than hydrostatic testing. In particular, heating coils in tanks and liquid lines are to be tested to not less than 1,5 times the design pressure but in no case less than 0,4 MPa.

Bilge and drainage systems are to be tested against air suction along the relevant lines which are to be provided with the necessary fittings for such purpose.

19.7 Testing of piping system components during manufacturing

19.7.1 Pumps

a) Bilge and fire pumps are to undergo a performance test.

b) Rotors of centrifugal feed pumps for main boilers are to undergo a balancing test.

c) All pumps are to undergo to vibration according to a recognized standard.

19.7.2 Centrifugal separators

Centrifugal separators used for fuel oil, JP5-NATO (F44) and lubricating oil are to undergo a running test, normally with a fuel water mixture.

19.8 Inspection and testing of piping systems

19.8.1 The inspections and tests required for piping systems and their components are summarised in Tab 38.

Table 38 : Inspection and testing at works for piping systems and their components

Item **(6)**		Tests for the materials **(1)**		Inspections and tests for the product **(1)**		
		Tests required**(8)**	Type of material certificate **(2)**	During manufacturing (NDT)	After completion	Type of product certificate **(2)**
Valves, pipes and fittings **(9)**	a) class I, ND ≥ 50 mm or class II, ND ≥ 100 mm	[19.5.2]	C	[3.6.2] **(5)** [3.6.3]	[19.6.3]	C **(3)**
	b) class I, ND < 50 mm or class II, ND < 100 mm	[19.5.2]	W	[3.6.2] **(5)** [3.6.3]	[19.6.3]	C **(3)**
Flexible hoses and expansion joints		[19.5.2]	W		[19.6.6]	C **(3)**
Pumps and air compressors within piping systems covered by Sections of this Chapter **(7)**	a) all	NR216 Materials and Welding			[19.6.5]	C **(3)**
	b) bilge and fire pumps	NR216 Materials and Welding			[19.6.5] [19.7.1] a)	C **(3)**
	c) feed pumps for main boilers: - casing and bolts - main parts - rotor	NR216 Materials and Welding **(10)**	C **(10)**	[3.6.2] **(5)** [3.6.3]	[19.6.5] [19.7.1] b)	C **(3)**
	d) forced circulation pumps for main boiler: - casing and bolts	NR216 Materials and Welding	C	[3.6.2] **(5)** [3.6.3]	[19.6.5]	C **(3)**
Centrifugal separators					[19.7.2]	C **(3)**
Prefabricated pipe lines	a) class I and II with: - ND ≥ 65 mm, or - t ≥ 10 mm			[3.6.2] **(5)** [3.6.3]	[19.6.2]	C **(3)**
	b) class I and II with: - ND < 65 mm, or - t < 10 mm			[3.6.2] **(5)** [3.6.3]	[19.6.2]	W
	c) class III **(4)**				[19.6.2]	W

(1) [x.y.z] = test required, as per referent regulation.
(2) C = class certificate ; W = works' certificate.
(3) or alternative type of certificate, depending on the Survey Scheme. See Part A.
(4) where required by [19.6.2].
(5) if of welded construction, for welded connections.
(6) ND = nominal diameter of the corresponding pipe.
(7) for other pumps and compressors, see also additional Rules relevant for related systems.
(8) The material generally shall comply with [2.1.2] and Tab 5. Detail requirements where specified, are given by NR216 Materials and Welding.
(9) Attention is to be drawn to Tab 3 (valves and fittings fitted to the ship side are considered class II, as well as valves on the collision bulkheads, on fuel oil tanks or on lubricating oil tanks under static pressure).
(10) Applies only for casing and bolts.

Section 11 Exhaust Gas Pollution Prevention System

1 General

1.1 Application

1.1.1 This Section applies to installation, storage of chemical treatment fluids, piping system and equipment dedicated to NOx reducing system.

1.1.2 The requirements of this Section are additional to those of Ch 1, Sec 10, [17].

1.1.3

a) Requirements for exhaust gas pipes from engines, gas turbines, boilers and incinerators are given in Ch 1, Sec 10, [17].

b) General requirements applying to the installation of NOx reducing equipment and systems are contained in Article [2] for their installation.

c) Requirements for the storage and use of Urea as reductant in SCR are given in Article [3].

1.2 Definitions

1.2.1 Chemical treatment fluid

Unless otherwise specified, chemical treatment fluid means any chemical consumed in a process for the treatment of exhaust gas.

1.2.2 SCR

Equipment used to reduce NOx emission from the exhaust of marine engines using Selective Catalytic Reduction process.

1.3 Documents to be submitted

1.3.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	General arrangement of the exhaust gas pollution prevention system
2	A	Diagrams of sea water and / or fresh water piping systems **(3)**
3	A	Diagram of chemical piping system, including filling, storage and dosing **(3)**
4	I	Risk analysis report covering a failure of the exhaust gas pollution prevention system, a leakage of washwater, sludge or chemical, or a fire, as applicable following [3.1]
(1) A = to be submitted for approval ; I = to be submitted for information		
(2) Diagrams are also to include, where applicable, the (local and remote) control and monitoring systems and automation systems		
(3) Where applicable, depending on the design of the exhaust gas pollution prevention system		

2 Installation requirements

2.1 General

2.1.1 Exhaust gas pollution prevention systems are to be designed, arranged and installed in accordance with the following requirements.

2.2 Design

2.2.1 Attention is drawn on IMO Guidelines regarding the environmental performance of selective catalytic reduction (SCR) systems.

2.2.2 Tank design and construction requirements are given in Pt B, Ch 2, Sec 2, [11].

2.2.3 The chemical treatment fluids tanks are to be included in the ship's stability calculation.

2.3 Availability

2.3.1 The availability of the machinery served by the exhaust gas pollution prevention system is to be substantiated by a risk analysis.

The exhaust gas pollution prevention equipment is to be so arranged that, in the case of failure of such equipment, propulsion power and auxiliary power supplying essential functions are not affected. Where necessary, a bypass is to be installed.

In case of blackout, automatic starting of engines, if provided, is to remain effective as if no exhaust gas pollution prevention system were installed and not detrimental to the exhaust gas pollution prevention installation.

2.4 Arrangement

2.4.1 Exhaust systems connections

As mentioned in Ch 1, Sec 10, [17.2.4], no interconnection is permitted between different exhaust piping systems for engines. In case of one exhaust gas pollution prevention system used for several installations, interconnections may be acceptable with additional devices installed as follows:

- Individual isolating devices for exhaust pipes are to be provided on each individual exhaust pipe; and
- Forced ventilation is to be installed at the outlet of the common exhaust pipe, preventing any backflow of exhaust gases in individual exhaust ducts in any possible working conditions.

  As an alternative to forced ventilation, exhaust systems interconnections might be accepted on a case-by-case basis and considering an exhaust gas back pressure analysis to the satisfaction of the Society.

2.4.2 Bypass

When the exhaust gas pollution prevention system may be by-passed, proper means are to be installed providing double barrier upstream from the exhaust gas pollution prevention system, in order to enable safe inspection in exhaust gas pollution prevention equipment in any working configuration of combustion units.

2.4.3 Filling systems for chemical treatment fluids

Filling systems for chemical treatment fluids are to be located in places where no interference with other ship activities would happen. In case interference is unavoidable, a risk analysis is to be provided in order to evaluate occurrence and level of danger for the crew.

Filling systems are to fulfil the requirements of Ch 1, Sec 10, [11.4.2]. Drainage of drip trays if any and outlet of safety valves are to be led to a tank designed for that purpose.

2.4.4 Materials

Materials used for equipment and piping systems are to be suitable with fluids conveyed, not leading to early corrosion or creating hazardous gases, when in contact with treatment liquid or vapours. This requirement is also valid for drip-trays, fans and ducts being part of exhaust gas pollution prevention system.

2.4.5 Control and monitoring

Alarms and indications are to be provided in accordance with Tab 2.

Information related to exhaust gas pollution prevention device and washwater, discharge measurements is to be made available in a control station.

Table 2 : Control and monitoring for exhaust gas pollution prevention systems

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			System			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Failure of exhaust fans (each fan)	X						
Exhaust temperature before entering in plastic parts or Cooling medium flow	H L	local local					
Chemical treatment fluids storage tank level **(1)**	H **(2)**	local **(2)**					

(1) Not applicable to process tanks
(2) High level alarm is to be independent from the tank level indicator.

3 Storage and use of SCR reductant

3.1 Application

3.1.1 The following requirements apply to urea/water solutions used in SCR which are typically carried on board in bulk.

For other reductants falling in the scope of IMDG Code like aqueous ammonia or anhydrous ammonia, the following conditions are to be fulfilled:

- It is to be demonstrated that the use of urea based reductant is not practicable and, in case of use of anhydrous ammonia, that the use of aqueous ammonia is not practicable either

Note 1: It is reminded that use of anhydrous ammonia need the agreement of the Naval Authority

- A risk analysis is to be provided regarding the loading, carriage and use of the product
- Requirements mentioned in [4] are to be fulfilled.

3.2 Storage tank

3.2.1 The storage tank is to be arranged so that any leakage will be contained and prevented from making contact with heated surfaces. All pipes or other tank penetrations are to be provided with manual closing valves attached to the tank.

3.2.2 The storage tank may be located in the engine room.

3.2.3 Each urea storage tank is to be provided with temperature and level monitoring arrangements. High and low level alarms together with high and low temperature alarms are also to be provided.

3.2.4 Where urea based ammonia solution is stored in integral tanks, these tanks are to be coated with appropriate anti-corrosion coating and are not to be located adjacent to any fuel oil or fresh water tank.

3.2.5 Urea storage tanks are to be arranged so that they can be emptied of urea and ventilated by means of portable or permanent systems.

3.3 Ventilation

3.3.1 If a urea storage tank is installed in a closed compartment, the area is to be served by an effective mechanical ventilation system of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be independent from the ventilation systems of accommodation, service spaces, or control stations. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

Alternatively, where a urea storage tank is located within an engine room, a separate ventilation system is not required when the general ventilation system for the space is arranged so as to provide an effective movement of air in the vicinity of the storage tank and is maintained in operation continuously except when the storage tank is empty and has been thoroughly ventilated.

3.3.2 The requirements specified in [3.3.1] also apply to closed compartments normally entered:

- when they are adjacent to the urea integral tanks and there are possible leak points (e.g. manhole, fittings) from these tanks; or
- when the urea piping systems pass through these compartments, unless the piping system is made of steel or other equivalent material with melting point above 925°C and with fully welded joints.

3.4 Piping

3.4.1 The reductant piping and venting systems are to be independent of other ship service piping and/or systems. Reductant piping systems are not to be located in accommodation, service spaces, or control stations. The vent pipes of the storage tank are to terminate in a safe location on the weather deck and the tank venting system is to be arranged to prevent entrance of water into the urea tank.

3.5 Materials

3.5.1 Reductant tanks are to be of steel or other equivalent material with a melting point above 925°C. Pipes/piping systems are to be of steel or other equivalent material with melting point above 925°C, except downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire. In such case, type approved plastic piping may be accepted even if it has not passed a fire endurance test.

Reductant tanks and pipes/piping systems are to be made with a material compatible with the reductant or coated with appropriate anti-corrosion coating.

Copper is to be avoided for equipment and piping systems in contact with fluids containing ammonia.

3.6 Protection of crew members

3.6.1 For the protection of crew members, the ship is to have on board suitable personnel protective equipment. Eyewash are to be provided, the location and number of these eyewash stations are to be derived from the detailed installation arrangements.

4 Storage and use of other substances mentioned in IMDG Code

4.1 Application

4.1.1 For exhaust gas pollution prevention systems using chemical treatment fluids other than those mentioned in [3], the following requirements are to be followed. Additionally a risk analysis is to be conducted, in order to eliminate or mitigate the hazards to personnel brought by the use of such exhaust gas pollution prevention systems, to an extent equivalent to systems complying with Article [3].

4.2 Risk analysis

4.2.1 For compartment containing chemical treatment fluid tanks a risk analysis is to be provided, taking into account normal or abnormal operating conditions (failure, fluid leakage, fire) regarding human health and damage to essential equipment contained in compartment.

4.2.2 In case of use of substances classed in IMO IMDG Code in categories 1, 2.1, 3, 4.1, 4.2, 4.3, 5.1, 6.1, 8 or 9, application of IEC standard 60079-10-1 is required regarding electric installations, hazardous areas definition and ventilation, and a specific risk analysis is to submitted.

4.3 Containment of leakage

4.3.1 In case substances mentioned in IMO IMDG Code are used in exhaust gas pollution prevention systems, drainage and/or bilge pumping of compartments where such systems are located is to be separated from ship bilge system. Retention of potential leakages using drip trays associated to spill kits is to be implemented. Draining pipes from drip trays are to be led to a tank designed for that purpose.

4.4 Storage tank

4.4.1 Chemical treatment fluids tanks are not to be contiguous with tanks containing sea water, fresh water, fuel, lubricating tanks. A ventilated cofferdam between treatment chemical tanks and above mentioned tanks is an acceptable solution. Arrangement of the ventilation system is to be in accordance with [4.5].

Chemical treatment fluids tanks are not to be located in category A machinery spaces unless a specific risk analysis, as required in [4.2], is submitted to the Society for approval.

Chemical treatment fluids tanks when located adjacent to or within a compartment used for other purposes are to be surrounded by coamings delimitating space fitted with a high level alarm.

Bilge system of this compartment may be connected to ship bilge system provided arrangements are made to isolate this bilge suction. An additional fixed pumping system is to be installed in order to pump liquid with chemical substance from bilge and inside drip trays to draining tank. Isolation means and additional pumping system are to be remotely controlled.

4.4.2 Toxic or flammable product pipes, which, if damaged, would allow the product to escape from a tank, are to be fitted with a quick closing valve directly on the tank, capable of being closed from a safe position outside the compartment involved.

4.4.3 Overflow

Overflow pipes of chemical treatment fluids tanks are to be led to a specific tank dedicated for one kind of product. If several chemical treatment fluids tanks exist for a same product, overflow tank may be common.

4.4.4 Sounding and air pipes

Sounding pipes and air pipes are to end in an open space above freeboard deck. Means in order to prevent water entry through these pipe ends in any circumstances are to be provided.

4.5 Ventilation

4.5.1 Ventilation of compartments where chemical treatment fluids are stored or used is to be of the extraction type providing not less than 6 air changes per hour. This ventilation system is to be separated from any other ventilation system. The ventilation system is to be capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment is to be provided outside the compartment adjacent to each point of entry.

The ventilation system is to be included in the risk analysis requested in [4.2].

4.6 Piping

4.6.1 Piping systems involved in process are not to pass through accommodations, control stations or service spaces.

Section 12 Steering Gear

1 General

1.1 Application

1.1.1 Scope

Unless otherwise specified, the requirements of this Section apply to the steering gear systems of all mechanically propelled ships, and to the steering mechanism of thrusters used as means of propulsion.

1.1.2 Cross references

In addition to those provided in this Section, steering gear systems are also to comply with the requirements of:

- Ch 1, Sec 16, as regards sea trials
- Pt B, Ch 9, Sec 1, as regards the rudder and the rudder stock

1.2 Documentation to be submitted

1.2.1 Documents to be submitted for all steering gear

Before starting construction, all plans and specifications listed in Tab 1 are to be submitted to the Society for approval.

Table 1 : Documents to be submitted for steering gear

No.	I/A **(2)**	Description of the document **(1)**
1	I	Assembly drawing of the steering gear including sliding blocks, guides, stops and other similar components
2	I	General description of the installation and of its functioning principle
3	I	Operating manuals of the steering gear and of its main components
4	I	Description of the operational modes intended for steering in normal and emergency conditions
5	A	For hydraulic steering gear, the schematic layout of the hydraulic piping of power actuating systems, including the hydraulic fluid refilling system, with indication of: • the design pressure • the maximum working pressure expected in service • the diameter, thickness, material specification and connection details of the pipes • the hydraulic fluid tank capacity • the flashpoint of the hydraulic fluid
6	I	For hydraulic pumps of power units, the assembly longitudinal and transverse sectional drawings and the characteristic curves
7	A	Assembly drawings of the rudder actuators and constructional drawings of their components, with, for hydraulic actuators, indication of: • the design torque • the maximum working pressure • the relief valve setting pressure
8	I	Constructional drawings of the relief valves for protection of the hydraulic actuators, with indication of: • the setting pressure • the relieving capacity
9	A	Diagrams of the electric power circuits
10	A	Functional diagram of control, monitoring and safety systems including the remote control from the navigating bridge, with indication of the location of control, monitoring and safety devices
11	A	Constructional drawings of the strength parts providing a mechanical transmission of forces to the rudder stock (tiller, quadrant, connecting rods and other similar items), with the calculation notes of the shrink-fit connections
12	I/A	For azimuth thrusters used as steering means, the specification and drawings of the steering mechanism and, where applicable, documents 2 to 6 and 8 to 11 above

(1) Constructional drawings are to be accompanied by the specification of the materials employed and, where applicable, by the welding details and welding procedures.
(2) A = to be submitted for approval ; I = to be submitted for information.

1.2.2 Additional documents

The following additional documents are to be submitted:

- analysis in relation to the risk of single failure, where required by [2.4.2]
- analysis in relation to the risk of hydraulic locking, where required by [2.4.5]
- fatigue analysis and/or fracture mechanics analysis, where required.

1.3 Definitions

1.3.1 Steering system

Steering system means ship's directional control system, including main steering gear, auxiliary steering gear, steering gear control system and rudder if any.

1.3.2 Steering gear control system

Steering gear control system is the equipment by which orders are transmitted from the navigation bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

Steering gear control system is also understood to cover the equipment required to control the steering gear power actuating system.

1.3.3 Main steering gear

Main steering gear is the machinery, rudder actuators, steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudder stock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.3.4 Steering gear power unit

Steering gear power unit is:

- in the case of electric steering gear, an electric motor and its associated electrical equipment
- in the case of electrohydraulic steering gear, an electric motor and its associated electrical equipment and connected pump
- in the case of other hydraulic steering gear, a driving engine and connected pump.

1.3.5 Auxiliary steering gear

Auxiliary steering gear is the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.3.6 Power actuating system

Power actuating system is the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller, quadrant and rudder stock, or components serving the same purpose.

1.3.7 Rudder actuator

Rudder actuator is the component which directly converts hydraulic pressure into mechanical action to move the rudder.

1.3.8 Maximum ahead service speed

Maximum ahead service speed is the greatest speed which the ship is designed to maintain in service at sea at the deepest seagoing draught.

1.3.9 Maximum astern speed

Maximum astern speed is the speed which it is estimated the ship can attain at the designed maximum astern power at the deepest seagoing draught.

1.3.10 Maximum working pressure

Maximum working pressure is the maximum expected pressure in the system when the steering gear is operated to comply with the provisions of [2.2.1] item b).

1.3.11 Hydraulic locking

Hydraulic locking means all situations where two hydraulic systems (usually identical) oppose each other in such a way that it may lead to loss of steering. It can either be caused by pressure in the two hydraulic systems working against each other or by hydraulic "bypass" meaning that the systems puncture each other and cause pressure drop on both sides or make it impossible to build up pressure.

1.4 Symbols

1.4.1 The following symbols are used for strength criteria of steering gear components:

V : Maximum service speed, in knots, with the ship on summer load waterline. When the speed is less than 10 knots, V is to be replaced by the value $(V+20)/3$

d_s : Rule diameter of the rudder stock in way of the tiller, in mm, defined in Pt B, Ch 9, Sec 1, [4] and calculated with a material factor $k_1 = 1$

d_{se} : Actual diameter of the upper part of the rudder stock in way of the tiller, in mm
(in the case of a tapered coupling, this diameter is measured at the base of the assembly)

T_R : Rule design torque of the rudder stock given, in kN.m, by the following formula:

$$T_R = 13{,}5 \cdot d_s^3 \cdot 10^{-6}$$

T_E : For hand emergency operation, design torque due to forces induced by the rudder, in kN.m, given by the following formulae:

$$T_E = 0{,}62 \cdot \left(\frac{V_E + 2}{V + 2}\right)^2 \cdot T_R$$

where:

- $V_E = 7$ where $V \le 14$
- $V_E = 0{,}5\ V$ where $V > 14$

T_G : For main hydraulic or electrohydraulic steering gear, torque induced by the main steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 1: for hand-operated main steering gear, the following value is to be used:
$T_G = 1{,}25.T_R$

T_A : For auxiliary hydraulic or electrohydraulic steering gears, torque induced by the auxiliary steering gear on the rudder stock when the pressure is equal to the setting pressure of the relief valves protecting the rudder actuators

Note 2: for hand-operated auxiliary steering gear, the following value is to be used:
$T_A = 1{,}25.T_E$

T'_G : For steering gear which can activate the rudder with a reduced number of actuators, the value of T_G in such conditions

σ : Normal stress due to the bending moments and the tensile and compressive forces, in N/mm²

τ : Tangential stress due to the torsional moment and the shear forces, in N/mm²

σ_a : Permissible stress, in N/mm²

σ_c : Combined stress, determined by the following formula:

$$\sigma_c = \sqrt{\sigma^2 + 3\tau^2}$$

R : Value of the minimum specified tensile strength of the material at ambient temperature, in N/mm²

R_e : Value of the minimum specified yield strength of the material at ambient temperature, in N/mm²

R'_e : Design yield strength, in N/mm², determined by the following formulae:

- $R'_e = R_e$, where $R \ge 1{,}4\ R_e$
- $R'_e = 0{,}417\ (R_e + R)$ where $R < 1{,}4\ R_e$

2 Design and construction

2.1 General

2.1.1 Unless expressly provided otherwise, every ship shall be provided with main steering gear and auxiliary steering gear to the satisfaction of the Society.

2.2 Strength, performance and power operation of the steering gear

2.2.1 Main steering gear

The main steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated

b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and, under the same conditions, from 35° on either side to 30° on the other side in not more than 28 s

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

Note 1: “even keel” means that the vessel is an acceptable trim condition

Note 2: “fully submerged” means A_T is greater than $0.95 \cdot A_F$, where A_T and A_F are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the main steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition. The speed of the ship shall correspond to the number of maximum continuous revolutions of the main engine and maximum design pitch of the propeller;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition;

c) operated by power where necessary to meet the requirements of b) and in any case when the Society requires a rudder stock of over 120 mm diameter in way of the tiller, excluding strengthening for navigation in ice, and

d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm^2, i.e. with a material factor $k_1 = 1$.

2.2.2 Auxiliary steering gear

The auxiliary steering gear and rudder stock shall be:

a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency

b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60s with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

Where it is impractical to demonstrate compliance with this requirement during sea trials with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater, ships may demonstrate compliance with this requirement by one of the following methods:

1) during sea trials the ship is at even keel and the rudder fully submerged whilst running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

Note 1: “even keel” means that the vessel is an acceptable trim condition.

Note 2: “fully submerged” means A_T is greater than $0.95 \cdot A_F$, where AT and AF are defined in [2.2.3].

2) where full rudder immersion during sea trials cannot be achieved, an appropriate ahead speed shall be calculated using the submerged rudder blade area in the proposed sea trial loading condition. The calculated ahead speed shall result in a force and torque applied to the auxiliary steering gear which is at least as great as if it was being tested with the ship at its deepest seagoing draught and running ahead at one half of the speed corresponding to the number of maximum continuous revolutions of the main engine and maximum design pitch or 7 knots, whichever is greater; or

3) the rudder force and torque at the sea trial loading condition have been reliably predicted and extrapolated to the full load condition;

Specific requirements of [2.2.3] are to be applied for trials not performed at full load condition;

and

c) operated by power where necessary to meet the requirements of b) and in any case when the Society requires a rudder stock of over 230 mm diameter in way of the tiller, excluding strengthening for navigation in ice.

Note 3: The mentioned diameter is to be taken as having been calculated for rudder stock of mild steel with a yield stress of 235 N/mm^2, i.e. with a material factor $k_1 = 1$.

2.2.3 Steering gear test with the vessel not at the deepest seagoing draught

In order to meet the performance stated in item b) of [2.2.1] and item b) of [2.2.2] the following requirements are applicable.

When it is justified that the trials cannot practically be performed with the vessel at the deepest seagoing draught, the loading condition can be accepted on the conditions that:

a) The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition P_F has been extrapolated from the maximum measured actuator hydraulic pressure in the trial condition P_T using one of the following methods:

1) P_F is obtained according to the following formula:

$$P_F = P_T \cdot \alpha$$

$$\alpha = 1{,}25\left(\frac{A_F}{A_T}\right)\left(\frac{V_F}{V_T}\right)^2$$

where:

P_F : estimated steering actuator hydraulic pressure in the deepest seagoing draught condition

P_T : maximum measured actuator hydraulic pressure in the trial condition.

α : extrapolation factor

A_F : total immersed projected area of the movable part of the rudder in the deepest seagoing condition

A_T : total immersed projected area of the movable part of the rudder in the trial condition

V_F : contractual design speed of the vessel corresponding to the maximum continuous revolutions of the main engine at the deepest seagoing draught

V_T : measured speed of the vessel (considering current) in the trial condition.

Note 1: Above formulae assumes that the rudder actuator system pressure is shown to have a linear relationship to the rudder stock torque.

2) The following methodology is applied for determination of P_F:

- The designer or builder uses computational fluid dynamic (CFD) studies or experimental investigations to predict the estimated rudder stock moment at the full sea going draught condition and service speed Q_F

  These calculations or experimental investigations are to be to the satisfaction of the Society.

- the rudder torque at the trial loading condition Q_T have been reliably predicted based on the maximum measured actuator hydraulic pressure in the trial condition P_T
- The estimated steering actuator hydraulic pressure in the deepest seagoing draught condition is obtained according to the following formula:

$$P_F = P_T \frac{Q_F}{Q_T}$$

b) Where constant volume fixed displacement pumps are utilised, the estimated steering actuator hydraulic pressure at the deepest draught P_F is to be less than the specified maximum working pressure of the rudder actuator.

Where a variable delivery pump is utilised, the pump data is to be supplied and interpreted to estimate the delivered flow rate corresponding to the deepest seagoing draught in order to calculate the estimated steering time, not to be greater than to the required time specified in [2.2.1] or [2.2.2], as applicable.

c) In any case for the main steering gear trial, the speed of the ship corresponding to the number of maximum continuous revolution of main engine and maximum design pitch applies.

2.3 Control of the steering gear

2.3.1 Main and auxiliary steering gear control

Steering gear control shall be provided:

a) for the main steering gear, both on the navigation bridge and in the steering gear compartment

b) where the main steering gear is arranged in accordance with [2.4.2], by two independent control systems, both operable from the navigation bridge and the steering gear compartment. This does not require duplication of the steering wheel or steering lever. Where the control system consists in a hydraulic telemotor, a second independent system need not be fitted, except in auxiliary naval vessel of 10 000 gross tonnage and upwards

The two independent steering gear control systems are to be:

- so arranged that a mechanical or electrical failure in one of them will not render the other one inoperative, and
- in accordance with [2.3.3]

c) for the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigation bridge and to be independent of the control system for the main steering gear.

Note 1: The term "steering gear control system" is to be understood to cover "the equipment required to control the steering gear power actuating system".

2.3.2 Control systems operable from the navigating bridge

Any main and auxiliary steering gear control system operable from the navigating bridge shall comply with the following:

- if electrical, it shall be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit
- means shall be provided in the steering gear compartment for disconnecting any control system operable from the navigation bridge from the steering gear it serves
- the system shall be capable of being brought into operation from a position on the navigating bridge
- in the event of failure of electrical power supply to the control system, an audible and visual alarm shall be given on the navigation bridge, and
- short-circuit protection only shall be provided for steering gear control supply circuits.

2.3.3 Installation

a) Duplicated steering gear control systems with their associated components are to be separated as far as practicable.

b) Wires, terminals and the components for duplicated steering gear control systems installed in units, control boxes, switchboards or bridge consoles are to be separated as far as practicable.

   Where physical separation is not practicable, separation may be achieved by means of a fire-retardant plate.

c) All electrical components of the steering gear control systems are to be duplicated. This does not require duplication of the steering wheel or steering lever.

d) If a joint steering mode selector switch (uniaxial switch) is employed for both steering gear control systems, the connections for the control systems are to be divided accordingly and separated from each other by an isolating plate or air gap.

e) In the case of double follow-up control, the amplifier is to be designed and fed so as to be electrically and mechanically separated. In the case of non-follow-up control and follow-up control, it is to be ensured that the follow-up amplifier is protected selectively.

f) Control circuits for additional control systems, e.g. steering lever or autopilot, are to be designed for all-pole disconnection.

g) The feedback units and limit switches, if any, for the steering gear control systems are to be separated electrically and mechanically connected to the rudder stock or actuator separately.

2.4 Availability

2.4.1 Arrangement of main and auxiliary steering gear

The main steering gear and the auxiliary steering gear shall be so arranged that the failure of one will not render the other inoperative.

2.4.2 Omission of the auxiliary steering gear

Where the main steering gear comprises two or more identical power units, auxiliary steering gear need not be fitted, provided that:

a) the main steering gear is capable of operating the rudder as required in [2.2.1] while any one of the power units is out of operation

b) the main steering gear is so arranged that after a single failure in its piping system or in one of the power units, the defect can be isolated so that steering capability can be maintained or speedily regained.

Steering gear other than of the hydraulic type is to achieve standards equivalent to the requirements of this paragraph to the satisfaction of the Society.

2.4.3 Hydraulic power supply

The hydraulic system intended for main and auxiliary steering gear is to be independent of all other hydraulic systems of the ship.

2.4.4 Non-duplicated components

Special consideration is to be given to the suitability of any essential component which is not duplicated.

2.4.5 Hydraulic locking

Where the steering gear is so arranged that more than one system (either power or control) can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

2.4.6 Additional requirements for ships of 70 000 gross tonnage and above

In ships of 70,000 gross tonnage and upwards, the main steering gear shall comprise two or more identical power units complying with the provisions of [2.4.2].

2.5 Mechanical components

2.5.1 General

a) All steering gear components and the rudder stock are to be of sound and reliable construction to the satisfaction of the Society.

b) Any non-duplicated essential component is, where appropriate, to utilise anti-friction bearings, such as ball bearings, roller bearings or sleeve bearings, which are to be permanently lubricated or provided with lubrication fittings

c) The construction is to be such as to minimise local concentration of stress.

d) All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

Table 2 : Scantling of components protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_G	• if $T_G \leq 1{,}25\ T_R$: $\sigma_a = 1{,}25\ \sigma_0$ • if $1{,}25\ T_R < T_G < 1{,}50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T_G \geq 1{,}50\ T_R$: $\sigma_a = 1{,}50\ \sigma_0$ where $\sigma_0 = 0{,}55\ R'_e$
Normal operation, with a reduced number of actuators	T'_G	• if $T'_G \leq 1{,}25\ T_R$: $\sigma_a = 1{,}25\ \sigma_0$ • if $1{,}25\ T_R < T'_G < 1{,}50\ T_R$: $\sigma_a = \sigma_0\ T_G/T_R$ • if $T'_G \geq 1{,}50\ T_R$: $\sigma_a = 1{,}50\ \sigma_0$ where $\sigma_0 = 0{,}55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0{,}8\ T_A$	$0{,}69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0{,}8\ T'_G$	$0{,}69\ R'_e$
Emergency operation achieved by hand	T_E	$0{,}69\ R'_e$

Table 3 : Scantling of components not protected against overloads induced by the rudder

Conditions of use of the components	M_T	σ_a
Normal operation	T_R	$0{,}55\ R'_e$
Normal operation, with a reduced number of actuators	lower of T_R and $0{,}8\ T'_G$	$0{,}55\ R'_e$
Emergency operation achieved by hydraulic or electrohydraulic steering gear	lower of T_R and $0{,}8\ T_A$	$0{,}69\ R'_e$
Emergency operation, with a reduced number of actuators	lower of T_R and $0{,}8\ T'_G$	$0{,}69\ R'_e$
Emergency operation achieved by hand	T_E	$0{,}69\ R'_e$

2.5.2 Materials and welds

a) All steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material complying with the requirements of NR216 Materials and Welding. In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

b) The use of grey cast iron is not permitted, except for redundant parts with low stress level, subject to special consideration by the Society. It is not permitted for cylinders.

c) The welding details and welding procedures are to be submitted for approval.

d) All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

2.5.3 Scantling of components

The scantling of steering gear components is to be determined considering the design torque M_T and the permissible value σ_a of the combined stress, as given in:

- Tab 2 for components which are protected against overloads induced by the rudder
- Tab 3 for components which are not protected against overloads induced by the rudder.

2.5.4 Tillers, quadrants and rotors

a) The scantling of the tiller is to be determined as follows:
   - the depth H_0 of the boss is not to be less than $0{,}75.d_s$
   - the radial thickness of the boss in way of the tiller is not to be less than the greater of:
     - $0,3 \cdot d_s \cdot \sqrt{\dfrac{235}{R'_e}}$
     - $0,25 \cdot d_s$
   - the section modulus of the tiller arm in way of the end fixed to the boss is not to be less than the value Z_b, in cm^3, calculated from the following formula:

$$Z_b = \frac{0{,}147 \cdot d_s^3}{1000} \cdot \frac{L'}{L} \cdot \frac{R_e}{R'_e}$$

   where:

   L : Distance from the centreline of the rudder stock to the point of application of the load on the tiller (see Fig 1)

L' : Distance between the point of application of the above load and the root section of the tiller arm under consideration (see Fig 1)

- the width and thickness of the tiller arm in way of the point of application of the load are not to be less than one half of those required by the above formula
- in the case of double arm tillers, the section modulus of each arm is not to be less than one half of the section modulus required by the above formula.

b) The scantling of the quadrants is to be determined as specified in a) for the tillers. When quadrants having two or three arms are provided, the section modulus of each arm is not to be less than one half or one third, respectively, of the section modulus required for the tiller.

Arms of loose quadrants not keyed to the rudder stock may be of reduced dimensions to the satisfaction of the Society, and the depth of the boss may be reduced by 10 per cent.

c) Keys are to satisfy the following provisions:

- the key is to be made of steel with a yield stress not less than that of the rudder stock and that of the tiller boss or rotor without being less than 235 N/mm^2
- the width of the key is not to be less than $0,25.d_s$
- the thickness of the key is not to be less than $0,10.d_s$
- the ends of the keyways in the rudder stock and in the tiller (or rotor) are to be rounded and the keyway root fillets are to be provided with small radii of not less than 5 per cent of the key thickness.

d) Bolted tillers and quadrants are to satisfy the following provisions:

- the diameter of the bolts is not to be less than the value d_b, in mm, calculated from the following formula:

$$d_b = 153\sqrt{\frac{T_R}{n(b + 0{,}5d_{se})} \cdot \frac{235}{R_{eb}}}$$

where:

n : Number of bolts located on the same side in respect of the stock axis (n is not to be less than 2)

b : Distance between bolts and stock axis, in mm (see Fig 2)

R_{eb} : Yield stress, in N/mm^2, of the bolt material

Figure 1 : Tiller arm

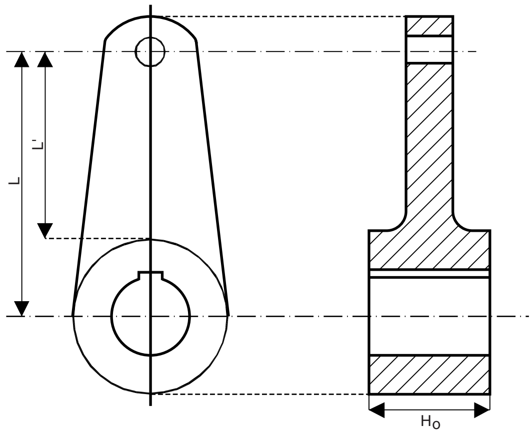
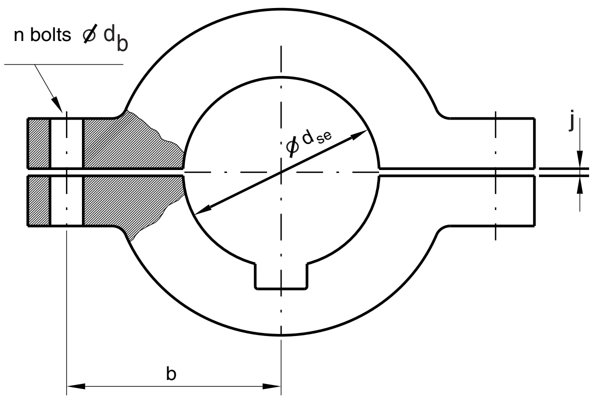


Figure 2 : Bolted tillers



- the thickness of each of the tightening flanges of the two parts of the tiller is not to be less than the following value:

  $$1,85 \cdot d_b \cdot \sqrt{\frac{n \cdot (b - 0,5 \cdot D_e)}{H_0} \cdot \frac{R_{eb}}{R'_e}}$$

  Where:

  D_e : External boss diameter, in mm (average value)

- in order to ensure the efficient tightening of the coupling around the stock, the two parts of the tiller are to bored together with a shim having a thickness not less than the value j, in mm, calculated from the following formula:

  $j = 0,0015 \cdot d_s$

e) Shrink-fit connections of tiller (or rotor) to stock are to satisfy the following provisions:

- the safety factor against slippage is not to be less than:
  - 1 for keyed connections
  - 2 for keyless connections
- the friction coefficient is to be taken equal to:
  - 0,15 for steel and 0,13 for spheroidal graphite cast iron, in the case of hydraulic fit
  - 0,17 in the case of dry shrink fitting
- the combined stress according to the von Mises criterion, due to the maximum pressure induced by the shrink fitting and calculated in way of the most stressed points of the shrunk parts, is not to exceed 80 per cent of the yield stress of the material considered

Note 1: Alternative stress values based on FEM calculations may also be considered by the Society.

- the entrance edge of the tiller bore and that of the rudder stock cone are to be rounded or bevelled.

2.5.5 Piston rods

The scantling of the piston rod is to be determined taking into account the bending moments, if any, in addition to compressive or traction forces and is to satisfy the following provisions:

a) $\sigma_c \leq \sigma_a$

where:

σ_c : Combined stress as per [1.4.1]

σ_a : Permissible stress as per [2.5.3]

b) in respect of the buckling strength:

$$\frac{4}{\pi D_2^{\,2}} \cdot \left(\omega F_c + \frac{8M}{D_2}\right) \leq 0,9\sigma_a$$

with:

D_2 : Piston rod diameter, in mm

F_c : Compression force in the rod, in N, when it extends to its maximum stroke

M : Possible bending moment in the piston rod, in N.mm, in way of the fore end of the cylinder rod bearing

$$\omega = \beta + \sqrt{\beta^2 - \alpha}$$

$$\alpha = 0,0072\left(\frac{\ell_s}{D_2}\right)^2 \frac{R'_e}{235}$$

$$\beta = 0,48 + 0,5\alpha + 0,1\sqrt{\alpha}$$

ℓ_s : Length, in mm, of the maximum unsupported reach of the cylinder rod.

2.6 Hydraulic system

2.6.1 General

a) The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in [3], taking into account any pressure which may exist in the low pressure side of the system.

   At the discretion of the Society, high cycle and cumulative fatigue analysis may be required for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

b) The power piping for hydraulic steering gear is to be arranged so that transfer between units can be readily effected.

c) Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

d) The hydraulic piping system, including joints, valves, flanges and other fittings, is to comply with the requirements of Ch 1, Sec 10 for class I piping systems, and in particular with the requirements of Ch 1, Sec 10, [13], unless otherwise stated.

2.6.2 Materials

a) Ram cylinders, pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings are to be of steel or other approved ductile material.

b) In general, such material is to have an elongation of not less than 12% and a tensile strength not greater than 650 N/mm^2.

Grey cast iron may be accepted for valve bodies and redundant parts with low stress level, excluding cylinders, subject to special consideration.

2.6.3 Isolating valves

Shut-off valves, non-return valves or other appropriate devices are to be provided:

- to comply with the availability requirements of [2.4]
- to keep the rudder steady in position in case of emergency.

In particular, for all ships with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

2.6.4 Flexible hoses

a) Flexible hoses may be installed between two points where flexibility is required but are not to be subjected to torsional deflexion (twisting) under normal operation. In general, the hose is to be limited to the length necessary to provide for flexibility and for proper operation of machinery.

b) Hoses are to be high pressure hydraulic hoses according to recognised standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

c) They are to be of a type approved by the Society.

d) The burst pressure of hoses is to be not less than four times the design pressure.

2.6.5 Relief valves

a) Relief valves shall be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The setting of the relief valves shall not exceed the design pressure. The valves shall be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

b) The setting pressure of the relief valves is not to be less than 1,25 times the maximum working pressure.

c) The minimum discharge capacity of the relief valve(s) is not to be less than the total capacity of the pumps which can deliver through it (them), increased by 10%. Under such conditions, the rise in pressure is not to exceed 10% of the setting pressure. In this respect, due consideration is to be given to the foreseen extreme ambient conditions in relation to oil viscosity.

2.6.6 Hydraulic oil reservoirs

Hydraulic power-operated steering gear shall be provided with the following:

- a low level alarm for each hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Audible and visual alarms shall be given on the navigation bridge and in the machinery space where they can be readily observed.
- a fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank shall be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and shall be provided with a contents gauge.

Note 1: For cargo ships of less than 500 tons displacement, the storage means may consist of a readily accessible drum, of sufficient capacity to refill one power actuating system if necessary.

2.6.7 Hydraulic pumps

a) Hydraulic pumps are to be type tested in accordance with the provisions of [6.1.1].

b) Special care is to be given to the alignment of the pump and the driving motor.

2.6.8 Filters

a) Hydraulic power-operated steering gear shall be provided with arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

b) Filters of appropriate mesh fineness are to be provided in the piping system, in particular to ensure the protection of the pumps.

2.6.9 Accumulators

Accumulators, if fitted, are to be designed in accordance with Ch 1, Sec 10, [13.5.3].

2.6.10 Rudder actuators

a) Rudder actuators, other than non-duplicated rudder actuators fitted to tankers, chemical carriers and gas carriers of 10000 gross tonnage and above, are to be designed in accordance with the relevant requirements of Ch 1, Sec 3 for class 1 pressure vessels also considering the following provisions.

b) The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{R}{A} \quad \text{or} \quad \frac{R_e}{B}$$

where A and B are given in Tab 4.

c) Oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal or equivalent type.

d) Oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

e) The strength and connection of the cylinder heads (or, in the case of actuators of the rotary type, the fixed vanes) acting as rudder stops are to comply with the provisions of [5.3.1].

Table 4 : Value of coefficients A and B

Coefficient	Steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

2.7 Electrical systems

2.7.1 General design

The electrical systems of the main steering gear and the auxiliary steering gear are to be so arranged that the failure of one will not render the other inoperative.

2.7.2 Power circuit supply

a) Electric or electrohydraulic steering gear comprising one or more power units is to be served by at least two exclusive circuits fed directly from the main switchboard; however, one of the circuits may be supplied through the emergency switchboard.

b) Auxiliary electric or electrohydraulic steering gear, associated with main electric or electrohydraulic steering gear, may be connected to one of the circuits supplying the main steering gear.

c) The circuits supplying electric or electrohydraulic steering gear are to have adequate rating for supplying all motors which can be simultaneously connected to them and may be required to operate simultaneously.

d) When, in a ship of less than 1600 gross tonnage, auxiliary steering gear which is required by [2.2.2], item c) to be operated by power is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard.

e) Where the rudder stock is required to be over 230 millimetres in diameter in way of the tiller, excluding strengthening for navigation in ice, an alternative power supply either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment is to be provided, sufficient at least to supply the steering gear power unit such that the latter is able to perform the duties of auxiliary steering gear.

   This power source is to be activated automatically, within 45 seconds, in the event of failure of the main source(s) of electrical power.

   The independent source is to be used only for this purpose.

   The alternative power source is also to supply the steering gear control system, the remote control of the power unit and the rudder angle indicator.

f) In every ship of 10 000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 minutes of continuous operation and in any other ship for at least 10 minutes.

2.7.3 Motors and associated control gear

a) To determine the required characteristics of the electric motors for power units, the breakaway torque and maximum working torque of the steering gear under all operating conditions are to be considered. The ratio of pull-out torque to rated torque is to be at least 1,6.

b) Motors for steering gear power units may be rated for intermittent power demand.

   The rating is to be determined on the basis of the steering gear characteristics of the ship in question; the rating is always to be at least:

   - S3 - 40% for motors of electric steering gear power units
   - S6 - 25% for motors of electrohydraulic steering gear power units and for convertors.

c) Each electric motor of a main or auxiliary steering gear power unit is to be provided with its own separate motor starter gear, located within the steering gear compartment.

2.7.4 Supply of motor control circuits and steering gear control systems

a) Each control for starting and stopping of motors for power units is to be served by its own control circuits supplied from its respective power circuits.

b) Any electrical main and auxiliary steering gear control system operable from the navigating bridge is to be served by its own separate circuit supplied from a steering gear power circuit from a point within the steering gear compartment, or directly from switchboard busbars supplying that steering gear power circuit at a point on the switchboard adjacent to the supply to the steering gear power circuit. The power supply systems are to be protected selectively.

c) The remote control of the power unit and the steering gear control systems is to be supplied also by the alternative power source when required by [2.7.2], item e).

2.7.5 Circuit protection

a) Short-circuit protection is to be provided for each control circuit and each power circuit of electric or electrohydraulic main and auxiliary steering gear.

b) No protection other than short-circuit protection is to be provided for steering gear control system supply circuits.

c) Protection against excess current (e.g. by thermal relays), including starting current, if provided for power circuits, is to be for not less than twice the full load current of the motor or circuit so protected, and is to be arranged to permit the passage of the appropriate starting currents.

d) Steering gear motor circuits obtaining their power supply via an electronic converter, e.g. for speed control, and which are limited to full load current are exempt from the requirement to provide protection against excess current, including starting current, of not less than twice the full load current of the motor. The required overload alarm is to be set to a value not greater than the normal load of the electronic converter.

Note 1: "Normal load" is the load in normal mode of operation that approximates as close as possible to the most severe conditions of normal use in accordance with the manufacturer's operating instructions.

e) Where fuses are fitted, their current ratings are to be two step higher than the rated current of the motors. However, in the case of intermittent service motors, the fuse rating is not to exceed 160% of the rated motor current.

f) The instantaneous short-circuit trip of circuit breakers is to be set to a value not greater than 15 times the rated current of the drive motor.

g) The protection of control circuits is to correspond to at least twice the maximum rated current of the circuit, though not, if possible, below 6 A.

2.7.6 Starting and stopping of motors for steering gear power units

a) Motors for power units are to be capable of being started and stopped from a position on the navigation bridge and from a point within the steering gear compartment.

b) Means are to be provided at the position of motor starters for isolating any remote control starting and stopping devices (e.g. by removal of the fuse-links or switching off the automatic circuit breakers).

c) Main and auxiliary steering gear power units are to be arranged to restart automatically when power is restored after a power failure.

2.7.7 Installation

a) Duplicated electric power circuits are to be separated as far as practicable.

b) Cables for duplicated electric power circuits with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

c) Actuators controlling the power systems of the steering gear, e.g. magnetic valves, are to be duplicated and separated.

d) Cables for duplicated steering gear control systems with their associated components are to be separated as far as practicable. They are to follow different routes separated both vertically and horizontally, as far as practicable, throughout their entire length.

2.8 Alarms and indications

2.8.1 Power units

a) In the event of a power failure to any one of the steering gear power units, an audible and visual alarm shall be given on the navigating bridge.

b) Means for indicating that the motors of electric and electrohydraulic steering gear are running shall be installed on the navigating bridge and at a suitable main machinery control position.

c) Where a three-phase supply is used, an alarm shall be provided that will indicate failure of any one of the supply phases.

d) An overload alarm shall be provided for each motor of electric or electrohydraulic steering gear power units.

e) The alarms required in c) and d) shall be both audible and visual and situated in a conspicuous position in the main machinery space or control room from which the main machinery is normally controlled.

2.8.2 Hydraulic system

a) Hydraulic oil reservoirs are to be provided with the alarms required in [2.6.6].

b) Where hydraulic locking, caused by a single failure, may lead to loss of steering, an audible and visual alarm, which identifies the failed system, is to be provided on the navigating bridge.

Note 1: This alarm is to be activated when, for example:

- the position of the variable displacement pump control system does not correspond with the given order, or
- an incorrect position in the 3-way valve, or similar, in the constant delivery pump system is detected.

2.8.3 Control system

In the event of a failure of electrical power supply to the steering gear control systems, an audible an visual alarm shall be given on the navigating bridge.

2.8.4 Rudder angle indication

The angular position of the rudder is to be:

a) indicated on the navigating bridge, if the main steering gear is power operated. The rudder angle indication is to be independent of the steering gear control system and be supplied through the emergency switchboard, or by an alternative and independent source of electrical power such as that referred to in [2.7.2], item e);

b) recognisable in the steering gear compartment.

2.8.5 Steering gear failure

The steering gear failures likely to cause uncontrolled movements of rudder are to be clearly identified. In the event of detection of such failure, the rudder is to stop in the current position without manual intervention or, subject to the discretion of the Society, is to return to the midship/neutral position.

For mechanical failures such as sticking valves and failure of static components (pipes, cylinders), the system response without manual intervention is not mandatory, and the operator can follow instructions on the signboard in case of such failures, in accordance with [5.5.1].

Additionally, for hydraulic locking failure, refer to [2.8.2] item b).

2.8.6 Summary table

Displays and alarms are to be provided in the locations indicated in Tab 5.

Table 5 : Location of displays and alarms

<table>
<tr><th colspan="2" rowspan="2">Item</th><th rowspan="2">Display</th><th rowspan="2">Alarms (audible and visible)</th><th colspan="3">Location</th></tr>
<tr><th>Navigation Bridge</th><th>Engine Control Room (3)</th><th>Steering gear compartment</th></tr>
<tr><td colspan="2">Indication that electric motor of each power unit is running</td><td>X</td><td></td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Rudder angle indicator</td><td>X</td><td></td><td>X</td><td></td><td>X</td></tr>
<tr><td colspan="2">Power failure of each power unit</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Power failure of each control system</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Overload of electric motor of each power unit</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Phase failure of electric motor of each power unit</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Earth fault on AC and DC circuits</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="4">Control system failures</td><td>Loop failures in closed loop systems, coth command and feed back loops (1)</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Data communication errors</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Programmable system failures (Hardware and software failures)</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Deviation between rudder order and feedback (2)</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Low level of each hydraulic fluid reservoir</td><td></td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td colspan="2">Hydraulic lock</td><td></td><td>X</td><td>X</td><td></td><td></td></tr>
<tr><td colspan="7">(1) Normally short circuit, broken connections and earth faults
(2) Deviation alarm is to be initiated if the rudder’s actual position does not reach the set point within acceptable time limits for the closed loop control systems (e.g. follow-up control and autopilot). Deviation alarm may be caused by mechanical, hydraulic or electrical failures.
(3) Common alarm may be accepted if individual alarms are available locally.</td></tr>
</table>

3 Design and construction - Requirements for ships equipped with several rudders

3.1 Principle

3.1.1 General

In addition to the provisions of Article [2], ships equipped with two or more aft rudders are to comply with the provisions of the present Article.

3.1.2 Availability

Where the ship is fitted with two or more rudders, each having its own actuation system, the latter need not be duplicated.

3.1.3 Equivalent rudder stock diameter

Where the rudders are served by a common actuating system, the diameter of the rudder stock referred to in [2.2.1], item c), is to be replaced by the equivalent diameter d obtained from the following formula:

$$d = \sqrt[3]{\sum_j d_j^3}$$

with:

d_j : Rule diameter of the upper part of the rudder stock of each rudder in way of the tiller, excluding strengthening for navigation in ice.

3.2 Synchronisation

3.2.1 General

A system for synchronising the movement of the rudders is to be fitted, either:

- by a mechanical coupling, or
- by other systems giving automatic synchronising adjustment.

3.2.2 Non-mechanical synchronisation

Where the synchronisation of the rudder motion is not achieved by a mechanical coupling, the following provisions are to be met:

a) the angular position of each rudder is to be indicated on the navigation bridge

b) the rudder angle indicators are to be independent from each other and, in particular, from the synchronising system

c) in case of failure of the synchronising system, means are to be provided for disconnecting this system so that steering capability can be maintained or rapidly regained.

4 Design and construction - Requirements for ships equipped with thrusters as steering means

4.1 Principle

4.1.1 General

The main and auxiliary steering gear referred to in Article [3] may consist of thrusters of the following types:

- azimuth thrusters
- water-jets
- cycloidal propellers

complying with the provisions of Ch 1, Sec 13, as far as applicable.

4.1.2 Control system

Where the steering means of the ship consists of two or more thrusters, their control system is to include a device ensuring an automatic synchronisation of the thruster rotation, unless each thruster is so designed as to withstand any additional forces resulting from the thrust exerted by the other thrusters.

4.2 Steering arrangements

4.2.1 General

The requirements in this sub-article apply to ships fitted with alternative propulsion and steering arrangements, such as but not limited to, azimuthing propulsors or water jet propulsion systems.

4.2.2 Steering arrangements for ships fitted with multiple steering-propulsion units

For a ship fitted with multiple steering-propulsion units, such as, but not limited to, azimuthing propulsors or water jet propulsion systems, each of the steering-propulsion units is to be provided with a main steering gear and an auxiliary steering gear or with two or more identical steering actuating systems in compliance with [4.2.7]. The main steering gear and the auxiliary steering gear are to be so arranged that the failure of one of them will not render the other one inoperative.

4.2.3 Steering arrangements for ships fitted with single steering-propulsion unit

For a ship fitted with a single steering-propulsion unit, the steering gear is to be provided with two or more steering actuating systems complying with [4.2.7]. A detailed risk assessment is to be submitted in order to demonstrate that in the case of any single failure in the steering gear, control system and power supply, the ship steering is maintained.

4.2.4 Design of components used in steering arrangements

All components used in steering arrangements for ship directional control are to be of sound reliable construction to the satisfaction of the Administration or recognized organizations acting on its behalf. Special consideration should be given to the suitability of any essential component which is not duplicated. Any such essential component is, where appropriate, to utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which should be permanently lubricated or provided with lubrication fittings.

4.2.5 Main steering arrangements

The main steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at maximum ahead service speed which should be demonstrated
- capable of changing direction of the steering-propulsion unit from one side to the other at declared steering angle limits at an average turning speed of not less than 2,3°/s with the ship running ahead at maximum ahead service speed
- for all ships, operated by power; and
- so designed that they will not be damaged at maximum astern speed; this design requirement need not be proved by trials at maximum astern speed and declared steering angle limits.

Note 1: Declared steering angle limits are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturers' guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation; the “declared steering angle limits” are to be declared by the directional control system manufacturer for each ship specific non-traditional steering mean.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.6 Auxiliary steering arrangements

The auxiliary steering arrangements for ship directional control are to be:

- of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency
- capable of changing direction of the ship's directional control system from one side to the other at declared steering angle limits at an average turning speed, of not less than 0.5°/s; with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
- for all ships, operated by power where necessary to meet the requirements of SOLAS regulation II-1/29.4.2 and in any ship having power of more than 2,500 kW propulsion power per steering-propulsion unit.

Note 1: The definition of “declared steering angle limits”, set out in [4.2.5], applies.

Note 2: Ship manoeuvrability tests, such as those in the Standards for ship manoeuvrability (IMO Resolution MSC.137(76)) should be carried out with steering angles not exceeding the declared steering angle limits.

4.2.7 Omission of the auxiliary steering gear

a) For a ship fitted with a single steering-propulsion unit where the main steering gear comprises two or more identical power units and two or more identical steering actuators, an auxiliary steering gear need not be fitted provided that the steering gear:
   - is capable of satisfying the requirements in [4.2.5] while any one of the power units is out of operation
   - is arranged so that after a single failure in its piping system or in one of the power units, steering capability can be maintained or speedily regained.

b) For a ship fitted with multiple steering-propulsion units, where each main steering system comprises two or more identical steering actuating systems, an auxiliary steering gear need not be fitted provided that each steering gear:
   - is capable of satisfying the requirements in [4.2.5] while any one of the steering gear steering actuating systems is out of operation
   - is arranged so that after a single failure in its piping or in one of the steering actuating systems, steering capability can be maintained or speedily regained; and
   - the above capacity requirements apply regardless whether the steering systems are arranged with common or dedicated power units.

Note 1: For the purposes of alternative steering arrangements, the steering gear power unit should be considered as defined in [1.3.4]. For electric steering gears, refer to [1.3.4]; electric steering motors should be considered as part of the power unit and actuator.

4.2.8 Case of the steering-propulsion units having a residual steering capability when propulsion power is lost

This requirement applies to steering-propulsion units having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power exceeds 2,500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of [2.2.2], item b), and also its associated control system and the steering gear response indicator, is to be provided automatically, within 45 s, either from the emergency source of electrical power or from an independent source of power located in the steering gear compartment. This independent source of power is to be used only for this purpose. In every ship of 10,000 gross tonnage and upwards, the alternative power supply is to have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

4.2.9 Additional requirement for ships fitted with multiple electric or electrohydraulic steering systems

For a ship fitted with multiple electric or electrohydraulic steering systems, the requirements of [2.7.2], items a), b) and c), are to be applied to each of the steering systems.

4.3 Use of water-jets

4.3.1 The use of water-jets as steering means will be given special consideration by the Society.

5 Arrangement and installation

5.1 Steering gear room arrangement

5.1.1 The steering gear compartment shall be:

a) readily accessible and, as far as practicable, separated from machinery spaces, and

b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements shall include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

5.2 Rudder actuator installation

5.2.1

a) Rudder actuators are to be installed on foundations of strong construction so designed as to allow the transmission to the ship structure of the forces resulting from the torque applied by the rudder and/or by the actuator, considering the strength criteria defined in [2.5.3] and [5.3.1]. The structure of the ship in way of the foundations is to be suitably strengthened.

b) Where the rudder actuators are bolted to the hull, the grade of the bolts used is not to be less than 8.8. Unless the bolts are adjusted and fitted with a controlled tightening, strong shocks are to be fitted in order to prevent any lateral displacement of the rudder actuator.

5.3 Overload protections

5.3.1 Mechanical rudder stops

a) The steering gear is to be provided with strong rudder stops capable of mechanically stopping the rotation of the rudder at an angle slightly greater than its maximum working angle. Alternatively, these stops may be fitted on the ship to act on another point of the mechanical transmission system between the rudder actuator and the rudder blade. These stops may be built in with the actuator design.

b) The scantlings of the rudder stops and of the components transmitting to the ship's structure the forces applied on these stops are to be determined for the greater value of the torques T_R or T_G.

   Where $T_G \geq 1{,}5 T_R$, the rudder stops are to be fitted between the rudder actuator and the rudder stock, unless the rudder stock as well as all the components transmitting mechanical forces between the rudder actuator and the rudder blade are suitably strengthened.

5.3.2 Rudder angle limiters

a) Power-operated steering gear is to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

b) For power-operated steering gears and where the rudder may be oriented to more than 35° at very reduced speed, it is recommended to fit a limit system 35° for full speed. A notice is to be displayed at all steering wheel stations indicating that rudder angles of more than 35° are to be used only at very reduced speed.

5.3.3 Relief valves

Relief valves are to be fitted in accordance with [2.6.5].

5.3.4 Buffers

Buffers are to be provided on all ships fitted with mechanical steering gear. They may be omitted on hydraulic gear equipped with relief valves or with calibrated bypasses.

5.4 Means of communication

5.4.1 A means of communication is to be provided between the navigation bridge and the steering gear compartment.

If electrical, it is to be fed through the emergency switchboard or to be sound powered.

5.5 Operating instructions

5.5.1 For steering gear comprising two identical power units intended for simultaneous operation, both normally provided with their own (partly or mutually) separate control systems, the following standard notice is either to be placed on a signboard fitted at a suitable place on the steering control post on the bridge or incorporated into the operation manual:

CAUTION

IN SOME CIRCUMSTANCES WHEN 2 POWER UNITS ARE RUNNING SIMULTANEOUSLY, THE RUDDER MAY NOT RESPOND TO THE HELM. IF THIS HAPPENS STOP EACH PUMP IN TURN UNTIL CONTROL IS REGAINED.

6 Certification, inspection and testing

6.1 Type tests of hydraulic pumps

6.1.1 Each type of power unit pump is to be subjected in the workshop to a type test of not less than 100 hours' duration.

The test arrangements are to be such that the pump may run both:

- in idling conditions, and
- at maximum delivery capacity at maximum working pressure.

During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another is to occur at least as quickly as on board.

During the test, no abnormal heating, excessive vibration or other irregularities are permitted.

After the test, the pump is to be disassembled and inspected.

Note 1: Type tests may be waived for a power unit which has been proven to be reliable in marine service.

6.2 Testing of materials

6.2.1 Components subject to pressure or transmitting mechanical forces

a) Materials of components subject to pressure or transmitting mechanical forces, specifically:
   - cylindrical shells of hydraulic cylinders, rams and piston rods
   - tillers, quadrants
   - rotors and rotor housings for rotary vane steering gear
   - hydraulic pump casings
   - and hydraulic accumulators, if any,

   are to be duly tested, including examination for internal defects, in accordance with the requirements of NR216 Materials and Welding.

b) A works' certificate may be accepted for low stressed parts, provided that all characteristics for which verification is required are guaranteed by such certificate.

6.2.2 Hydraulic piping, valves and accessories

Tests for materials of hydraulic piping, valves and accessories are to comply with the provisions of Ch 1, Sec 10, [19.5].

6.3 Inspection and tests during manufacturing

6.3.1 Components subject to pressure or transmitting mechanical forces

a) The mechanical components referred to in [6.2.1] are to be subjected to appropriate non-destructive tests. For hydraulic cylinder shells, pump casings and accumulators, refer to Ch 1, Sec 3.

b) Defects may be repaired by welding only on forged parts or steel castings of weldable quality. Such repairs are to be conducted under the supervision of the Surveyor in accordance with the applicable requirements of NR216 Materials and Welding.

6.3.2 Hydraulic piping, valves and accessories

Hydraulic piping, valves and accessories are to be inspected and tested during manufacturing in accordance with Ch 1, Sec 10, [19], for a class I piping system.

6.4 Inspection and tests after completion

6.4.1 Hydrostatic tests

a) Hydraulic cylinder shells and accumulators are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 3.

b) Hydraulic piping, valves and accessories and hydraulic pumps are to be subjected to hydrostatic tests according to the relevant provisions of Ch 1, Sec 10, [19.6].

6.4.2 Shipboard tests

After installation on board the ship, the steering gear is to be subjected to the tests detailed in Ch 1, Sec 16, [3.9].

6.4.3 Sea trials

For the requirements of sea trials, refer to Ch 1, Sec 16.

Section 13 Thrusters

1 General

1.1 Application

1.1.1 The requirements of this Section apply to the following types of thrusters:

- transverse thrusters intended for manoeuvring developing power equal to 500 kW or more
- thrusters intended for propulsion, steering and dynamic positioning developing power equal to 220 kW or more; for power less than 220 kW the requirements apply only to the propeller and relevant shaft.

1.1.2 Thrusters developing power less than that indicated in [1.1.1] are to be built in accordance with sound marine practice and tested as required in [3.2] to the satisfaction of the Surveyor.

1.2 Definitions

1.2.1 Thruster

A thruster is a propeller installed in a revolving nozzle or in a special transverse tunnel in the ship, or a water-jet. A thruster may be intended for propulsion, manoeuvring and steering or any combination thereof. Propulsion propellers in fixed nozzles are not considered thrusters (see Ch 1, Sec 8, [1.1.1]).

1.2.2 Transverse thruster

A transverse thruster is an athwartship thruster developing a thrust in a transverse direction for manoeuvring purposes.

1.2.3 Azimuth thruster

An azimuth thruster is a thruster which has the capability to rotate through 360° in order to develop thrust in any direction.

1.2.4 Water-jet

A water-jet is equipment constituted by a tubular casing (or duct) enclosing an impeller. The shape of the casing is such as to enable the impeller to produce a water-jet of such intensity as to give a positive thrust. Water-jets may have means for deviating the jet of water in order to provide a steering function.

1.2.5 Continuous duty thruster

A continuous duty thruster is a thruster which is designed for continuous operation, such as a propulsion thruster.

1.2.6 Intermittent duty thruster

An intermittent duty thruster is a thruster designed for operation at full power for a period not exceeding 1 hour, followed by operation at reduced rating for a limited period of time not exceeding a certain percentage of the hours in a day and a certain (lesser) percentage of the hours in a year. In general, athwartship thrusters are intermittent duty thrusters.

1.3 Thrusters intended for propulsion

1.3.1 In general, at least two azimuth thrusters are to be fitted in ships where these are the sole means of propulsion. Single azimuth thruster installations will be specially considered by the Society on a case by case basis.

Single water-jet installations are permitted.

1.4 Documentation to be submitted

1.4.1 Plans to be submitted for athwartship thrusters and azimuth thrusters

For thrusters:

- intended for propulsion, steering and dynamic positioning
- intended for manoeuvring developing power equal to 500 kW or more,

the plans listed in Tab 1 are to be submitted. Plans as per item 6 of Tab 1 are also to be submitted for thrusters developing power less than 500 kW.

1.4.2 Plans to be submitted for water-jets

The plans listed in Tab 2 are to be submitted.

1.4.3 Additional data to be submitted

The data and documents listed in Tab 3 are to be submitted by the manufacturer together with the plans.

Table 1 : Plans to be submitted for athwartship thrusters and azimuth thrusters

No	A/I **(1)**	ITEM
GENERAL REQUIREMENTS FOR ALL THRUSTERS		
1	I	General arrangement of the thruster
2	A	Propeller, including the applicable details mentioned in Ch 1, Sec 8
3	A	Bearing details
4	A	Propeller and intermediate shafts
5	A	Gears, including the calculations according to Ch 1, Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears
SPECIFIC REQUIREMENTS FOR TRANSVERSE THRUSTERS		
6	A	Structure of the tunnel showing the materials and their thickness
7	A	Structural equipment or other connecting devices which transmit the thrust from the propeller to the tunnel
8	A	Sealing devices (propeller shaft gland and thruster-tunnel connection)
9	A	For the adjustable pitch propellers: pitch control device and corresponding monitoring system
SPECIFIC REQUIREMENTS FOR ROTATING AND AZIMUTH THRUSTERS		
10	A	Structural items (nozzle, bracing, etc.)
11	A	Structural connection to hull
12	A	Rotating mechanism of the thruster
13	A	Thruster control system
14	A	Piping systems connected to thruster
(1) A = to be submitted for approval I = to be submitted for information.		

Table 2 : Plans to be submitted for water-jets

No	A/I **(1)**	ITEM
1	I	General arrangement of the water-jet
2	A	Casing (duct) (location and shape) showing the materials and the thicknesses as well as the forces acting on the hull
3	A	Details of the shafts, flanges, keys
4	I	Sealing gland
5	A	Bearings
6	A	Impeller
7	A	Steering and reversing buckets and their control devices as well as the corresponding hydraulic diagrams
(1) A = to be submitted for approval I = to be submitted for information.		

Table 3 : Data and documents to be submitted for athwartship thrusters, azimuth thrusters and water-jets

No	A/I **(1)**	ITEM
1	I	Rated power and revolutions
2	I	Rated thrust
3	A	Material specifications of the major parts, including their physical, chemical and mechanical properties
4	A	Where parts of thrusters are of welded construction, all particulars on the design of welded joints, welding procedures, heat treatments and non-destructive examinations after welding
5	I	Where applicable, background information on previous operating experience in similar applications
(1) A = to be submitted for approval I = to be submitted for information.		

2 Design and construction

2.1 Materials

2.1.1 Propellers

For requirements relative to material intended for propellers, see Ch 1, Sec 8.

2.1.2 Other thruster components

For the requirements relative to materials intended for other parts of the thrusters, such as gears, shaft, couplings, etc., refer to the applicable Parts of the Rules.

2.2 Transverse thrusters and azimuth thrusters

2.2.1 Prime movers

a) Diesel engines intended for driving thrusters are to comply with the applicable requirements of Ch 1, Sec 2.

b) Electric motors intended for driving thrusters and their feeding systems are to comply with the requirements of Part C, Chapter 2. In particular:
   - Provisions are to be made to prevent starting of the motors whenever there are insufficient generators in operation.
   - Intermittent duty thrusters will be the subject of special consideration by the Society.

2.2.2 Propellers

a) For propellers of thrusters intended for propulsion, steering and dynamic positioning, the requirements of Ch 1, Sec 8 apply.

b) For propellers of thrusters intended for manoeuvring only, the requirements of Ch 1, Sec 8 also apply, although the increase in thickness of 10% required in Ch 1, Sec 8, [2.5] does not need to be applied.

2.2.3 Shafts

a) For propeller shafts of thrusters, the requirements of Ch 1, Sec 7 apply to the portion of propellershaft between the inner edge of the aftermost shaft bearing and the inner face of the propeller boss or the face of the integral propeller shaft flange for the connection to the propeller boss.

b) For other shafts of thrusters, the requirement of Ch 1, Sec 6, [4.4.2] apply.

2.2.4 Gears

a) Gears of thrusters intended for propulsion steering and dynamic positioning are to be in accordance with the applicable requirements of Ch 1, Sec 6 for cylindrical gears or standards recognised by the Society for bevel gears, applying the safety factors for propulsion gears.

b) Gears of thrusters intended for manoeuvring only are to be in accordance with the applicable requirements of Ch 1, Sec 6, for cylindrical gears or Standards recognised by the Society for bevel gears, applying the safety factors for auxiliary gears.

2.2.5 Nozzles and connections to hull for azimuth thrusters

a) For the requirements relative to the nozzle structure, see Part B, Chapter 9.

b) The scantlings of the nozzle connection to the hull and the welding type and size will be specially considered by the Society, which reserves the right to require detailed stress analysis in the case of certain high power installations.

c) For steerable thrusters, the equivalent rudder stock diameter is to be calculated in accordance with the requirements of Part B, Chapter 9.

2.2.6 Transverse thruster tunnel

a) The thickness of the tunnel is not to be less than the adjacent part of the hull.

b) Special consideration will be given by the Society to tunnels connected to the hull by connecting devices other than welding.

2.2.7 Bearings

Bearing are to be identifiable and are to have a life adequate for the intended purpose. However, their life cannot be less than:

- 40 000 hours for continuous duty thrusters. For ships with restricted service, a lesser value may be considered by the Society.
- 5 000 hours for intermittent duty thrusters.

2.3 Water-jets

2.3.1 Shafts

The diameter of the shaft supporting the impeller is not to be less than the diameter d_2, in mm, obtained by the following formula:

$$d_2 = 100 \cdot f \cdot h \cdot \left(\frac{P}{N}\right)^{1/3} \cdot \left(\frac{1}{1-Q^4}\right)^{1/3}$$

where:

P : Power, in kW

N : Rotational speed, in rpm

f : Calculated as follows:

$$f = \left(\frac{560}{R_m + 160}\right)^{1/3}$$

where R_m is the ultimate tensile strength of the shaft material, in N/mm^2

h : h = 1,0 when the shaft is only transmitting torque loads, and when the weight and thrust of the propeller are totally supported by devices located in the fixed part of the thruster

h = 1,2 where the impeller is fitted with key or shrink-fitted.

Q : Q = 0 in the case of solid shafts

Q = the ratio between the diameter of the hole and the external diameter of the shaft, in the case of hollow shafts. If Q ≤ 0,3, Q may be assumed equal to 0.

The shafts are to be protected against corrosion by means of either a continuous liner or an oil-gland of an approved type, or by the nature of the material of the shaft.

2.3.2 Guide vanes, shaft support

a) a) Guide vanes and shaft supports, if any, are to be fitted in accordance with direction of flow. Trailing and leading edges are to be fitted with rounded profiles.

b) b) Fillet radius are generally not be less than the maximum local thickness of the concerned element. Fatigue strength calculation is to be submitted.

2.3.3 Stator and impellers

a) Design is to take into account the loads developed in free going conditions and also in peculiar manoeuvres like crash stop.

b) Tip clearance is to take into account vibratory behaviours, displacements and any other expansion mode in all operating conditions of the water jet.

c) Fillet radii are generally not to be less than the maximum local thickness of the concerned element.

d) There is to be no natural frequency of stator blades or rotor blades in the vicinity of the excitation frequencies due to hydrodynamic interaction between stator blades and rotor blades. Calculations are to be submitted for maximum speed and any currently used speed.

2.3.4 Nozzle and reversing devices

Design of nozzle and reversing devices are to take into account the loads developed in all operating conditions of the water jet, including transient loads.

2.3.5 Steering performance

Steering performance and emergency steering availability are to be at least equivalent to the requirements in Ch 1, Sec 12, [4.2] and Ch 1, Sec 12, [4.3].

2.4 Alarm, monitoring and control systems

2.4.1 Steering thruster controls

a) Controls for steering are to be provided from the navigating bridge and locally, and also from the machinery control station when the thruster is the normal steering system of the ship.

b) Means are to be provided to stop any running thruster at each of the control stations.

c) A thruster angle indicator is to be provided at each steering control station. The angle indicator is to be independent of the control system.

2.4.2 Alarm and monitoring equipment

Tab 4 summarises the minimum alarm and monitoring requirements for propulsion and steering thrusters. See also Ch 1, Sec 12, [4].

Table 4 : Azimuth thrusters

Symbol convention H = High, HH = High high, G = group alarm L = Low, LL = Low low, I = individual alarm X = function is required, R = remote	Monitoring		Automatic control				
			Thruster			Auxiliary	
Identification of system parameter	Alarm	Indication	Slow-down	Shut-down	Control	Stand by Start	Stop
Steering oil pressure	L						
Oil tank level	L						

3 Testing and certification

3.1 Material tests

3.1.1 Propulsion and steering thrusters

All materials intended for parts transmitting torque and for propeller/impeller blades are to be tested in accordance with the applicable requirements of Ch 1, Sec 6, [6] or Ch 1, Sec 7, [4] or Ch 1, Sec 8, [4] in the presence of a Surveyor.

3.1.2 Transverse thrusters

Material testing for parts of athwartship thrusters does not need to be witnessed by a Surveyor, provided full test reports are made available to him.

3.2 Testing and inspection

3.2.1 Thrusters

Thrusters are to be inspected as per the applicable requirements given in the Rules for the specific components.

3.2.2 Prime movers

Prime movers are to be tested in accordance with the requirements applicable to the type of mover used.

3.3 Certification

3.3.1 Certification of thrusters

Thrusters are to be individually tested and certified by the Society.

3.3.2 Mass produced thrusters

Mass produced thrusters may be accepted within the framework of the type approval program of the Society.

Section 14 Refrigerating Installations

1 General

1.1 Application

1.1.1 Refrigerating installations on all ships

The minimum safety requirements addressed in this Section are to be complied with for any refrigerating plant installed on board a ship to be classed by the Society. These requirements do not cover any operation or availability aspect of the plants, which are not the subject of class requirements, unless an additional notation is requested.

1.1.2 Additional notations

Where the additional notation **REF-STORE** is requested, the requirements of Pt E, Ch 11, Sec 3 are to be complied with.

2 Minimum design requirements

2.1 Refrigerating installation components

2.1.1 General

In general, the specific requirements stated in Part C of the Rules for various machinery and equipment are also applicable to refrigerating installation components.

2.1.2 Pressure vessels and heat exchangers

a) Pressure vessels of refrigerating plants are to comply with the relevant requirements of Ch 1, Sec 3.

b) Vessels intended to contain toxic substances are to be considered as class 1 pressure vessels as indicated in Ch 1, Sec 3, [1.4].

c) The materials used for pressure vessels are to be appropriate to the fluid that they contain.

d) Notch toughness of steels used in low temperature plants is to be suitable for the thickness and the lowest design temperature. A check of the notch toughness properties may be required where the working temperature is below minus 40°C.

2.1.3 Piping systems

a) Refrigerant pipes are generally to be regarded as pressure pipes.

b) Refrigerant, brine and sea water pipes are to satisfy the requirements of Ch 1, Sec 10, as applicable.

c) Refrigerant pipes are to be considered as belonging to the following classes:
   - class I: where they are intended for toxic substances
   - class II: for other refrigerants
   - class III: for brine.

d) In general, the pipes conveying the cooling medium are not to come into direct contact with the ship's structure; they are to be carefully insulated on their run outside the refrigerated spaces, and more particularly when passing through bulkheads and decks.

e) The materials used for the pipes are to be appropriate to the fluids they convey.

f) Notch toughness of the steels used is to be suitable for the application concerned.

g) Where necessary, cooling medium pipes within refrigerated spaces or embedded in insulation are to be externally protected against corrosion; for steel pipes, this protection is to be ensured by galvanisation or equivalent. All useful precautions are to be taken to protect the joints of such pipes against corrosion.

h) The use of plastic pipes shall not be permitted.

2.2 Refrigerants

2.2.1 Prohibited refrigerants

In addition to the substances prohibited by the Montreal Protocol, the use of the following refrigerants is not allowed for shipboard installations:

- ethane
- ethylene
- ammonia
- other substances with lower explosion limit in air of less than 3,5%.

2.2.2 Statutory requirements

Particular attention is to be paid to any limitation on the use of refrigerants imposed by the Naval Authority.

2.2.3 Toxic or flammable refrigerants

The arrangement of refrigerating machinery spaces of plants using toxic or flammable refrigerants will be the subject of special consideration by the Society.

3 Instrumentation

3.1 Thermometers in refrigerated spaces

3.1.1 Number of thermometers

a) Each refrigerated space with a volume not exceeding 400 m^3 is to be fitted with at least 4 thermometers or temperature sensors. Where the volume exceeds 400 m^3, this number is to be increased by one for each additional 400 m^3.

b) Where the volume is not exceeding 60 m^3, this number may be reduced to 2 thermometers if the general shape of the refrigerating space is quite rectangular with no dead end.

c) Sensors for remote electric thermometers are to be connected to the instruments so that, in the event of failure of any one instrument, the temperature in any space can still be checked through half the number of sensors in this space.

3.1.2 Direct reading thermometers

The tubes intended to contain thermometers are to have a diameter not less than 50 mm and are to be carefully isolated from the ship's structure. If they pass through spaces other than those they serve, they are to be insulated when passing through those spaces. Joints and covers of such tubes are to be insulated from the plating to which they are attached and installed on open decks so that water will not collect and freeze in them when measuring temperatures. Local readings are to be provided in any adjacent corridor to refrigerating chambers.

3.1.3 Electric thermometer apparatus for remote reading

The apparatus is to provide the temperature indications, in any case in the damage control station and in manned stations, with the accuracy required in [3.1.5] in conditions of vibrations and inclinations expected on board and for all ambient temperatures, up to 45°C, to which indicating instruments and connection cables may be exposed.

3.1.4 Distant electric thermometer sensors

a) Sensing elements are to be placed in refrigerated spaces where they are not liable to be exposed to damage during goods' handling and well clear of heat sources such as, for instance, electric lamps, etc.

b) Sensing elements in air coolers are to be placed at a distance of at least 900 mm from coils or fan motors.

c) When arranged in ducts, they are to be placed at the centre of the air duct section, as far as possible.

d) Sensing elements are to be protected by a corrosion-resistant impervious covering. Conductors are to be permanently secured to sensing elements and to indicating instruments and connected accessories. Plug-and-socket connections are allowed only if they are of a type deemed suitable by the Society.

e) All sensing elements are to be easily accessible.

3.1.5 Accuracy

a) Direct reading thermometers are to permit reading with an accuracy of 0,1°C for temperatures between 0°C and 15°C. Temperatures given by remote reading are to have an accuracy of:
   - ± 0,3°C (at 0°C) for the carriage of fruit and vegetables, and
   - ± 0,5°C (at 0°C) for the carriage of frozen products.

b) The instrumental error, to be ascertained by means of calibration by comparison with a master-thermometer with officially certified calibration, is not to exceed the following values:
   - ± 0,15°C, in the range – 3°C to + 3°C
   - ± 0,25°C, in all other ranges of the scale.

c) In general, the scale range is to be within –30°C and +20°C; in any case it is to be ±5°C greater than the range of application of the instrument.

d) In the graduated scale, the space between each degree centigrade is not to be less than 5 mm.

3.1.6 Data-logger

a) When a data-logger is installed, at least one sensing element for each refrigerated space, both in the space itself and in its air circulating system, is to be connected to another independent indicating instrument, approved by the Society. The data-logger is to register to 0,1 of a degree. Indicating instruments are to be fed by two independent power sources. If they are fed by the network on board through a transformer and rectifier unit, a spare unit is also to be provided and is to be easily replaceable aboard. If they are fed by storage batteries, it will be sufficient to arrange easily changeable batteries.

b) A prototype apparatus is to be checked and tested by a Surveyor at an independent recognised laboratory, or at the Manufacturer's facilities, to verify by means of suitable tests that the degree of accuracy corresponds to the above provisions.

c) The capacity of the apparatus to withstand stipulated vibrations, impacts and temperature variations and its non-liability to alterations due to the salt mist atmosphere, typical of conditions on board, are to be verified.

4 Installations related to preservation of ships' victuals

4.1 Victuals chamber

4.1.1 The victuals chambers are to have the lining of stainless steel including surface joints.

4.1.2 The victuals chambers are not to be provided with scuppers for drainage. Drainage of victuals chambers is to be through their doors and the exterior antechamber door. A dripping-pan is to be located near such exterior door. The dripping-pan width is to be at least 200 mm greater than the exterior antichamber door. Pipes discharging from the dripping-pan are to be provided with liquid seal traps.

4.1.3 Only direct cooling systems are to be used.

4.1.4 No components of refrigerating installation are to be fitted inside the refrigerated chambers.

4.2 Instrumentation

4.2.1 In the adjacent corridor of the refrigerated chambers local reading of the temperatures both by a direct reading system and by a remote reading system (see [3.1.2] and [3.1.3]) is to be possible.

4.2.2 Data-logger (see [3.1.6]) is to be provided only for the frozen victuals at temperature minus 20°C.

Section 15 Turbochargers

1 General

1.1 Application

1.1.1 These Rules apply to turbochargers fitted on the diesel engines listed in Ch 1, Sec 2, [1.1.1] a), b) and c) having a power of 1000 kW and above.

1.1.2 Turbochargers not included in [1.1.1] are to be designed and constructed according to sound marine practice and delivered with the works' certificate (W) relevant to the bench running test as per [4.3.3] and the hydrostatic test as per [4.3.4].

1.1.3 In the case of special types of turbochargers, the Society reserves the right to modify the requirements of this Section, demand additional requirements in individual cases and require that additional plans and data be submitted.

1.2 Documentation to be submitted

1.2.1 The Manufacturer is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No	I/A **(1)**	Document
1	A	Longitudinal cross-sectional assembly with main dimensions
2	A	Rotating parts (shaft, wheels and blades)
3	A	Details of blade fixing
4	A	Technical specification of the turbocharger including the maximum operating conditions (maximum permissible rotational speed and maximum permissible temperature)
5	A	Material specifications for the main parts, including their physical, chemical and mechanical properties, values of tensile strength, average stress to produce creep, resistance to corrosion and heat treatments
6	I	Operation and service manual

(1) A = to be submitted for approval
I = to be submitted for information.

Note 1: Plans mentioned under items (2) and (3) are to be constructional plans with all main dimensions and are to contain any necessary information relevant to the type and quality of the materials employed. In the case of welded rotating parts, all relevant welding details are to be included in the above plans and the procedures adopted for welding or for any heat treatments will be subject to approval by the Society.

2 Design and construction

2.1 Materials

2.1.1 The requirements of Ch 1, Sec 5, [2.2.1] are to be complied with, as far as applicable, at the Society's discretion.

2.2 Design

2.2.1 The requirements of Ch 1, Sec 5, [2.4] are to be complied with, as far as applicable, at the Society's discretion.

2.3 Monitoring

2.3.1 General

In addition to those of this item, the general requirements given in Part C, Chapter 2 apply.

2.3.2 Indicators

The local indicators for turbochargers fitted on diesel engines having a power of 2000 kW and above to be installed on ships without automation notations are given in Ch 1, Sec 2, Tab 2.

3 Arrangement and installation

3.1 General

3.1.1 The arrangement and installation are to be such as to avoid any unacceptable load on the turbocharger.

4 Type tests, material tests, workshop inspection and testing, certification

4.1 Type tests

4.1.1 Turbochargers as per [1.1.1] admitted to an alternative inspection scheme are to be type approved.

The type test is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. Normally, the type test is to consist of a hot gas running test of one hour's duration at the maximum permissible speed and maximum permissible temperature. After the test the turbocharger is to be opened up and examined.

For Manufacturers who have facilities for testing the turbocharger unit on an engine for which the turbocharger is to be type approved, replacement of the hot running test by a test run of one hour's duration at overload (110% of the rated output) may be considered.

4.2 Material tests

4.2.1 Material tests (mechanical properties and chemical composition) are required for shafts and rotors, including blades (see [4.4.2] as regards the certificate required).

4.3 Workshop inspections and testing

4.3.1 Overspeed test

All wheels (impellers and inducers), when machine-finished and complete with all fittings and blades, are to undergo an overspeed test for at least 3 minutes at one of the following test speeds:

a) 20% above the maximum speed at room temperature

b) 10% above the maximum speed at the maximum working temperature.

Note 1: If each forged wheel is individually controlled by an approved non-destructive examination method no overspeed test may be required except for wheels of the type test unit.

4.3.2 Balancing

Each shaft and bladed wheel, as well as the complete rotating assembly, is to be dynamically balanced by means of equipment which is sufficiently sensitive in relation to the size of the rotating part to be balanced.

4.3.3 Bench running test

Each turbocharger is to undergo a mechanical running test at the bench for 20 minutes at maximum rotational speed at room temperature.

Subject to the agreement of the Society, the duration of the running test may be reduced to 10 minutes, provided that the Manufacturer is able to verify the distribution of defects found during the running tests on the basis of a sufficient number of tested turbochargers.

For Manufacturers who have facilities in their works for testing turbochargers on an engine for which they are intended, the bench test may be replaced by a test run of 20 minutes at overload (110% of the maximum continuous output) on such engine.

Where turbochargers are admitted to an alternative inspection scheme and subject to the satisfactory findings of a historical audit, the Society may accept a bench test carried out on a sample basis.

4.3.4 Hydrostatic tests

The cooling spaces of turbochargers are to be hydrostatically tested at a test pressure of 0,4 MPa or 1,5 times the maximum working pressure, whichever is the greater.

4.4 Certification

4.4.1 Type Approval Certificate and its validity

Subject to the satisfactory outcome of the type tests specified in [4.1], the Society will issue to the turbocharger Manufacturer a Type Approval Certificate valid for all turbochargers of the same type.

4.4.2 Testing certification

a) Turbochargers admitted to an alternative inspection scheme.

A statement, issued by the Manufacturer, is required certifying that the turbocharger conforms to the one type tested. The reference number and date of the Type Approval Certificate are also to be indicated in the statement (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.2]).

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) are required for material tests as per [4.2] and for works trials as per [4.3].

b) Turbochargers not admitted to an alternative inspection scheme.

Society's certificates (C) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.1]) are required for the bench running test as per [4.3.3] and the overspeed test as per [4.3.1], as well as for material and hydrostatic tests as per [4.2] and [4.3.4].

Works' certificates (W) (see NR216 Materials and Welding, Ch 1, Sec 1, [4.2.3]) may be accepted for material tests, in place of the Society's certificates, for turbochargers fitted on diesel engines having a cylinder diameter of 300 mm or less.

Section 16 Tests on Board

1 General

1.1 Application

1.1.1 This Section covers shipboard tests, both at the moorings and during sea trials. Such tests are additional to the workshop tests required in the other Sections of this Chapter.

For computerized Machinery systems, requirements contained in Part C, Chapter 3 shall be refered to.

1.2 Purpose of shipboard tests

1.2.1 Shipboard tests are intended to demonstrate that the main and auxiliary machinery and associated systems are functioning properly, in particular in respect of the criteria imposed by the Rules. The tests are to be witnessed by a Surveyor.

1.3 Documentation to be submitted

1.3.1 A comprehensive list of the shipboard tests intended to be carried out by the shipyard is to be submitted to the Society.

For each test, the following information is to be provided:

- scope of the test
- parameters to be recorded.

2 General requirements for shipboard tests

2.1 Trials at the moorings

2.1.1 Trials at the moorings are to demonstrate the following:

a) satisfactory operation of the machinery in relation to the service for which it is intended

b) quick and easy response to operational commands

c) safety of the various installations, as regards:
   - the protection of mechanical parts
   - the safeguards for personnel.

d) accessibility for cleaning, inspection and maintenance.

Where the above features are not deemed satisfactory and require repairs or alterations, the Society reserves the right to require the repetition of the trials at the moorings, either wholly or in part, after such repairs or alterations have been carried out.

2.2 Sea trials

2.2.1 Scope of the tests

Sea trials are to be conducted after the trials at the moorings and are to include the following:

a) demonstration of the proper operation of the main and auxiliary machinery, including monitoring, alarm and safety systems, under realistic service conditions

b) check of the propulsion capability when one of the essential auxiliaries becomes inoperative

c) detection of dangerous vibrations by taking the necessary readings when required

d) checks either deemed necessary for ship classification or requested by the interested parties and which are possible only in the course of navigation in open sea.

2.2.2 Exemptions

Exemption from some of the sea trials may be considered by the Society in the case of ships having a sister ship for which the satisfactory behaviour in service is demonstrated.

Such exemption is, in any event, to be agreed upon by the interested parties and is subject to the satisfactory results of trials at the moorings to verify the safe and efficient operation of the propulsion system.

3 Shipboard tests for machinery

3.1 Conditions of sea trials

3.1.1 Displacement of the ship

Except in cases of practical impossibility, or in other cases to be considered individually, the sea trials are to be carried out at a displacement as close as possible to the full load displacement or to the half load displacement.

3.1.2 Power of the machinery

a) The power developed by the propulsion machinery in the course of the sea trials is to be as close as possible to the power for which classification has been requested. In general, this power is not to exceed the maximum continuous power at which the weakest component of the propulsion system can be operated. In cases of diesel engines and gas turbines, it is not to exceed the maximum continuous power for which the engine type concerned has been approved.

b) Where the rotational speed of the shafting is different from the design value, thereby increasing the stresses in excess of the maximum allowable limits, the power developed in the trials is to be suitably modified so as to confine the stresses within the design limits.

3.1.3 Determination of the power and rotational speed

a) The rotational speed of the shafting is to be recorded in the course of the sea trials, preferably by means of a continuous counter.

b) In general, the power is to be determined by means of torsiometric readings, to be effected with procedures and instruments deemed suitable by the Society.

   As an alternative, for reciprocating internal combustion engines and gas turbines, the power may be determined by measuring the fuel consumption and on the basis of the other operating characteristics, in comparison with the results of bench tests of the prototype engine.

   For electric propulsion, the power may be determined by recording electrical data.

   Other methods of determining the power may be considered by the Society on a case by case basis.

3.2 Navigation and manoeuvring tests

3.2.1 Speed trials

a) Where required by the Rules, the speed of the ship is to be determined using procedures deemed suitable by the Society.

b) The ship speed is to be determined as the average of the speeds taken in not less than two pairs of runs in opposite directions.

3.2.2 Astern trials

a) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, and so to bring the ship to rest within reasonable distance from maximum ahead service speed, shall be demonstrated and recorded.

b) The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propellers or propulsion /steering systems to navigate and manoeuvre with one or more propellers or propulsion /steering systems inoperative, shall be available on board for the use of the Master or designated personnel.

c) Where the ship is provided with supplementary means for manoeuvring or stopping, the effectiveness of such means shall be demonstrated and recorded as referred to in paragraphs a) and b).

For electric propulsion systems, see [3.5].

3.2.3 Change of propulsion system configuration

a) Where several normal propulsion system configurations are possible, each of them are to be tested.

b) The normal transfers between these configurations are to be tested.

3.3 Tests of diesel engines

3.3.1 General

The scope of the trials of diesel engines may be expanded in consideration of the special operating conditions, such as towing, trawling, etc.

3.3.2 Main propulsion engines driving fixed propellers

Sea trials of main propulsion engines driving fixed propellers are to include the following tests:

a) operation at rated engine speed n_0 for at least 4 hours

b) operation at minimum load speed

c) starting and reversing manoeuvres

d) operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes

e) tests of the monitoring, alarm and safety systems.

Note 1: The test in d) may be performed during the dock or sea trials.

3.3.3 Main propulsion engines driving controllable pitch propellers or reversing gears

Sea trials of main propulsion engines driving controllable pitch propellers or reversing gear are to include the following tests:

a) operation at rated engine speed n_0 with nominal pitch of the propeller for at least 4 hours

b) test at various propeller pitches for engines driving controllable pitch propellers

c) operation in reverse thrust of propeller at the maximum torque or thrust allowed by the propulsion system for 10 minutes

d) tests of the monitoring, alarm and safety systems.

Note 1: The test in c) may be performed during the dock or sea trials.

3.3.4 Engines driving generators for electric propulsion

Sea trials of engines driving generators for electric propulsion are to include the following tests:

a) operation at 100% power (rated power) for at least 4 hours

b) operation at 110% power for 30 minutes

c) starting manoeuvres

d) tests of the monitoring, alarm and safety systems.

Note 1: The above tests a) to d) are to be performed at rated speed with a constant governor setting. The powers refer to the rated electrical powers of the driven generators.

3.3.5 Engines driving auxiliaries

a) Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for at least 2 hours.

b) It is to be demonstrated that the engine is capable of supplying 100% of its rated power and, in the case of shipboard generating sets, account is to be taken of the times needed to actuate the generator's overload protection system.

3.4 Tests of gas turbines

3.4.1 Main propulsion turbines

Main turbines are to be subjected during dock trials and subsequent sea trials to the following tests:

- operation at rated rpm for at least 3 hours
- ship reversing manoeuvres.

During the various operations, the pressures, temperatures and relative expansion are not to assume magnitudes liable to endanger the safe operation of the plant.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.4.2 Auxiliary turbines

Turbines driving electric generators or auxiliary machines are to be run for at least 4 hours at their rated power and for 30 minutes at 110% of rated power.

During the trials all safety, alarm, shut-off and control systems associated to the turbine are to be tested or properly simulated.

3.5 Tests of electric propulsion system

3.5.1 Dock trials

a) The dock trials are to include the test of the electrical production system, the power management system and the load limitation.

b) A test of the propulsion plant at a reduced power, in accordance with dock trial facilities, is to be carried out. During this test, the following are to be checked:
   - electric motor rotation speed variation
   - functional test, as far as practicable (power limitation is to be tested with a reduced value)
   - protection devices
   - monitoring and alarm transmission including interlocking system.

c) Prior to the sea trials, an insulation test of the electric propulsion plant is to be carried out.

3.5.2 Sea trials

Testing of the performance of the electric propulsion system is to be effected in accordance with an approved test program.

This test program is to include at least:

- speed rate of rise

- endurance test:
  - 4 hours at 100% rated output power
  - operation in reverse direction of propeller rotation at the maximum torque or thrust allowed by the propulsion system for 10 minutes

Note 1: The reverse test may be performed during the dock or sea trials.

- check of the crash astern operation in accordance with the sequence provided to reverse the speed from full ahead to full astern, in case of emergency. During this test, all necessary data concerning any effects of the reversing of power on the generators are to be recorded, including the power and speed variation
- test of functionality of electric propulsion, when manoeuvring and during the ship turning test
- test of power management performance: reduction of power due to loss of one or several generators to check, in each case, the power limitation and propulsion availability.

3.6 Tests of gears

3.6.1 Tests during sea trials

During the sea trials, the performance of reverse and/or reduction gearing is to be verified, both when running ahead and astern.

In addition, the following checks are to be carried out:

- check of the bearing and oil temperature
- detection of possible gear hammering, where required by Ch 1, Sec 9, [3.5.1]
- test of the monitoring, alarm and safety systems.

3.6.2 Check of the tooth contact

a) Prior to the sea trials, the tooth surfaces of the pinions and wheels are to be coated with a thin layer of suitable coloured compound.

   Upon completion of the trials, the tooth contact is to be inspected. The contact marking is to appear uniformly distributed without hard bearing at the ends of the teeth and without preferential contact lines.

   The tooth contact is to comply with Tab 1.

b) The verification of tooth contact at sea trials by methods other than that described above will be given special consideration by the Society.

Table 1 : Tooth contact for gears

Heat treatment and machining	Percentage of tooth contact	
	across the whole face width	of the tooth working depth
quenched and tempered, cut	70	40
• quenched and tempered, shaved or ground • surface-hardened	90	40

3.7 Tests of main propulsion shafting and propellers

3.7.1 Shafting alignment

Where alignment calculations are required to be submitted in pursuance of Ch 1, Sec 7, [3.3.1], the alignment conditions are to be checked on board as follows:

a) shafting installation and intermediate bearing position, before and during assembling of the shafts:
   - optical check of the relative position of bushes after fitting
   - check of the flanged coupling parameters (gap and sag)
   - check of the centring of the shaft sealing glands

b) engine (or gearbox) installation, with floating ship:
   - check of the engine (or gearbox) flanged coupling parameters (gap and sag)
   - check of the crankshaft deflections before and after the connection of the engine with the shaft line, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine

Note 1: The ship is to be in the loading conditions defined in the alignment calculations.

c) load on the bearings:
   - check of the intermediate bearing load by means of jack-up load measurements
   - check of the bearing contact area by means of coating with an appropriate compound.

3.7.2 Shafting vibrations

Torsional, bending and axial vibration measurements are to be carried out where required by Ch 1, Sec 9. The type of the measuring equipment and the location of the measurement points are to be specified.

3.7.3 Bearings

The temperature of the bearings is to be checked under the machinery power conditions specified in [3.1.2].

3.7.4 Stern tube sealing gland

The stern tube oil system is to be checked for possible oil leakage through the stern tube sealing gland.

3.7.5 Propellers

a) For controllable pitch propellers, the functioning of the system controlling the pitch from full ahead to full astern position is to be demonstrated. It is also to be checked that this system does not induce any overload of the engine.

b) The proper functioning of the devices for emergency operations is to be tested during the sea trials.

3.8 Tests of piping systems

3.8.1 Functional tests

During the sea trials, piping systems serving propulsion and auxiliary machinery, including the associated monitoring and control devices, are to be subjected to functional tests at the nominal power of the machinery. Operating parameters (pressure, temperature, consumption) are to comply with the values recommended by the equipment manufacturer.

3.8.2 Performance tests

The Society reserves the right to require performance tests, such as flow rate measurements, should doubts arise from the functional tests.

3.9 Tests of steering gear

3.9.1 General

a) The steering gear is to be tested during the sea trials under the conditions stated in [3.1] in order to demonstrate, to the Surveyor's satisfaction, that the applicable requirements of Ch 1, Sec 12 are fulfilled.

b) For controllable pitch propellers, the propeller pitch is to be set at the maximum design pitch approved for the maximum continuous ahead rotational speed.

c) If the ship cannot be tested at the deepest draught, alternative trial conditions will be given special consideration by the Society on the basis of Naval Authority determinations. In such case, the ship speed corresponding to the maximum continuous number of revolutions of the propulsion machinery may apply.

3.9.2 Tests to be performed

Tests of the steering gear are to include at least:

a) functional test of the main and auxiliary steering gear with demonstration of the performances required by Ch 1, Sec 12, [2.3]

b) test of the steering gear power units, including transfer between steering gear power units and between main and auxiliary

c) test of the isolation of one power actuating system, checking the time for regaining steering capability for both main and auxiliary steering gear operation

d) test of the hydraulic fluid refilling system

e) test of the alternative power supply required by Ch 1, Sec 12, [2.7.2], item e)

f) test of the steering gear controls, including transfer of controls and local control

g) test of the means of communication between the navigation bridge, the engine room and the steering gear compartment and other position of emergency steering

h) test of the alarms and indicators

i) where the steering gear design is required to take into account the risk of hydraulic locking, a test is to be performed to demonstrate the efficiency of the devices intended to detect this.

Note 1: Tests d) to i) may be carried out either during the mooring trials or during the sea trials.

Note 2: Azimuth thrusters are to be subjected to the above tests, as far as applicable.

4 Inspection of machinery after sea trials

4.1 General

4.1.1

a) For all types of propulsion machinery, those parts which have not operated satisfactorily in the course of the sea trials, or which have caused doubts to be expressed as to their proper operation, are to be disassembled or opened for inspection.

   Machinery or parts which are opened up or disassembled for other reasons are to be similarly inspected.

b) Should the inspection reveal defects or damage of some importance, the Society may require other similar machinery or parts to be opened up for inspection.

c) An exhaustive inspection report is to be submitted to the Society for information.

4.2 Diesel engines

4.2.1

a) In general, for all diesel engines, the following items are to be verified:
   - the deflection of the crankshafts, by measuring the variation in the distance between adjacent webs in the course of one complete revolution of the engine
   - the cleanliness of the lubricating oil filters.

b) In the case of propulsion engines for which power tests have not been carried out in the workshop, some parts, agreed upon by the interested parties, are to be disassembled for inspection after the sea trials.

Appendix 1 Check of the Scantlings of Crankshafts for Diesel Engines

1 General

1.1 Application

1.1.1

a) The requirements for the check of scantlings of crankshafts given in this Appendix apply to diesel engines as per Ch 1, Sec 2, [1.1.1] a), b) and c), capable of continuous operation at their maximum continuous power P, (as defined in Ch 1, Sec 2, [1.3.2]), at the nominal maximum speed n.

Crankshafts which cannot satisfy these requirements will be subject to special consideration by the Society as far as detailed calculations or measurements can be submitted.

The following cases:

- surface treated fillets;
- when fatigue parameter influences are tested; and
- when working stresses are measured;

will be also specially considered by the Society.

b) The requirements of this Appendix apply only to solid-forged and semi-built crankshafts of forged or cast steel, with one crank throw between two adjacent main bearings.

1.2 Documentation to be submitted

1.2.1 Required data for the check of the scantlings are indicated in the specific Society form as per Ch 1, Sec 2, Tab 1, item 1.

1.3 Principles of calculation

1.3.1 The scantlings of crankshafts as per this Appendix are based on an evaluation of safety against fatigue failure in the highly stressed areas.

The calculation is also based on the assumption that the fillet transitions between the crankpin and web as well as between the journal and web are the areas exposed to the highest stresses.

The outlets of oil bores into crankpins and journals are to be formed in such a way that the safety margin against fatigue at the oil bores is not less than that acceptable in the fillets.

The engine manufacturer, where requested by the Society, is to submit documentation supporting his oil bore design.

Calculation of crankshaft strength consists initially in determining the nominal alternating bending and nominal alternating torsional stresses which, multiplied by the appropriate stress concentration factors using the theory of constant energy of distortion (von Mises' Criterion), result in an equivalent alternating stress (uni-axial stress). This equivalent alternating stress is then compared with the fatigue strength of the selected crankshaft material. This comparison will then show whether or not the crankshaft concerned is dimensioned adequately.

1.4 Symbols

1.4.1

B : Width of the web, in mm; see Fig 2

d_{BC} : Diameter of bore in crankpin, in mm; see Fig 2

d_{BJ} : Diameter of bore in journal, in mm; see Fig 2

d_C : Crankpin diameter, in mm; see Fig 2

d_J : Journal diameter, in mm; see Fig 2

D_E : The minimum value between:

- the outside diameter of web, in mm, or
- the value, in mm, equal to twice the minimum distance x between centre-line of journals and outer contour of web (see Fig 3)

d_S : Shrink-fit diameter, in mm; see Fig 3

E : Pin eccentricity, in mm; see Fig 2

E_W : Value of the modulus of elasticity of the web material, in N/mm²; see [7.2.2]

F : Area, in mm^2, related to cross-section of web, given by the following formula:

$$F = B \cdot W$$

K : Crankshaft manufacturing process factor; see [6.1.1] a)

K_E : Empirical factor for the modification of the alternating bending stress, which considers to some extent the influence of adjacent cranks and bearing restraint, whose value may be taken as follows:

- $K_E = 0,8$ for 2-stroke engines
- $K_E = 1,0$ for 4-stroke engines

L_S : Axial length of the shrink-fit, in mm; see Fig 3

M_B : Bending moment in the web centre, in N·m

$M_{B,MAX}$: Maximum value of the bending moment M_B, in N·m

$M_{B,MIN}$: Minimum value of the bending moment M_B, in N·m

M_{BN} : Nominal alternating bending moment, in Nm; for the determination of M_{BN} see [2.1.2] b)

$M_{T,MAX}$: Maximum value of the torque, in N·m, with consideration of the mean torque

$M_{T,MIN}$: Minimum value of the torque, in N·m, with consideration of the mean torque

M_{TN} : Nominal alternating torque, in N·m, given by the following formula:

$$M_{TN} = \pm 0,5 \cdot (M_{T,MAX} - M_{T,MIN})$$

Q_1 : Acceptability factor for the crankpin fillet; see [8.1.1]

Q_2 : Acceptability factor for the journal fillet; see [8.1.1]

Q_{MAX} : Maximum value of the alternating shearing force Q, in N

Q_{MIN} : Minimum value of the alternating shearing force Q, in N

Q_N : Nominal alternating shearing force, in N; for the determination of Q_N see [2.1.2] c)

r_C : Fillet radius of crankpin, in mm; see Fig 2

r_J : Fillet radius of journal, in mm; see Fig 2

R_m : Value of the minimum specified tensile strength of crankshaft material, in N/mm^2

$R_{S,MIN}$: Specified value, in N/mm^2, of the minimum yield strength (R_{eH}), or 0,2% proof stress ($R_{p\,0,2}$), of the crank web material.

S : Pin overlap, in mm, (see Fig 2) whose value may be calculated by the following formula:

$$S = \frac{d_C + d_J}{2} - E$$

Where pins do not overlap, the negative value of S calculated by the above formula is to be considered.

T_C : Recess of crankpin, in mm; see Fig 2

T_J : Recess of journal, in mm; see Fig 2

W : Axial web thickness, in mm; see Fig 2

W_{EQ} : Equatorial moment of resistance, in mm^3, related to cross-sectional area of web, whose value may be calculated as follows:

$$W_{EQ} = \frac{B \cdot W^2}{6}$$

W_{PC} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of crankpin; for the determination of W_{PC} see [2.2.2]

W_{PJ} : Value, in mm^3, of the polar moment of resistance related to cross-sectional area of journal; for the determination of W_{PJ} see [2.2.2]

y : Distance, in mm, between the adjacent generating lines of journal and pin connected to the same web (see Fig 3).

In general y is not to be less than 0,05 d_s.

Where y is less than 0,1 d_S, special consideration will be given by the Society in each case, to the effect of the stress due to the shrink on the fatigue strength of the web at the crankpin fillet

β_{BC} : Stress concentration factor for bending in crankpin fillet; for the determination of β_{BC} see [3.1.2] a)

β_{BJ} : Stress concentration factor for bending in journal fillet; for the determination of β_{BJ} see [3.1.3] a)

β_{QJ} : Stress concentration factor for shearing in journal fillet; for the determination of β_{QJ} see [3.1.3] b)

β_{TC} : Stress concentration factor for torsion in crankpin fillet; for the calculation of β_{Tc} see [3.1.2] b)

β_{TJ} : Stress concentration factor for torsion in journal fillet; for the calculation of β_{TJ} see [3.1.3] c)

$\sigma_{B,ADD}$: Additional bending stress, in N/mm^2, due to misalignment; see [4.1.1]

σ_{BN} : Nominal alternating bending stress, in N/mm^2; for the determination of σ_{BN} see [2.1.2] b)

σ_{BC} : Alternating bending stress in crankpin fillet, in N/mm^2; for the determination of σ_{BC} see [2.1.3] a)

σ_{BJ} : Alternating bending stress in journal fillet, in N/mm^2; for the determination of σ_{BJ} see [2.1.3] b)

σ'_E : Equivalent alternating stress in way of the crankpin fillet, in N/mm^2; for the determination of σ'_E see [5.2.1] a)

σ''_E : Equivalent alternating stress in way of the journal fillet, in N/mm²; for the determination of σ''_E see [5.2.1] b)

$\sigma'_{F,ALL}$: Allowable alternating bending fatigue strength in way of the crankpin fillet, in N/mm²; for the determination of $\sigma'_{F,ALL}$ see [6.1.1] a)

$\sigma''_{F,ALL}$: Allowable alternating bending fatigue strength in way of the journal fillet, in N/mm²; for the determination of $\sigma''_{F,ALL}$ see [6.1.1] b)

σ_{QN} : Nominal alternating shearing stress, in N/mm²; for the determination of σ_{QN} see [2.1.2] c)

τ_C : Alternating torsional stress in way of crankpin fillet, in N/mm²; for the determination of τ_C see [2.2.3] a)

τ_J : Alternating torsional stress in way of journal fillet, in N/mm²; for the determination of τ_J see [2.2.3] b)

τ_{NC} : Nominal alternating torsional stress referred to crankpin, in N/mm²; for the determination of τ_{NC} see [2.2.2]

τ_{NJ} : Nominal alternating torsional stress referred to journal, in N/mm²; for the determination of τ_{NJ} see [2.2.2].

2 Calculation of alternating stresses

2.1 Calculation of alternating stresses due to bending moments and shearing forces

2.1.1 Assumptions

The calculation of alternating stresses is based on the assumptions specified below.

a) The calculation is based on a statically determined system, so that only one single crank throw is considered with the journals supported in the centre of adjacent bearings and the throw subjected to gas and inertia forces. The bending length is taken as the length L_3 between the centre of two adjacent main bearings (see Fig 1(a) and (b)).

b) The nominal bending moment is taken as the bending moment in the crank web cross-section in the centre of the solid web (distance L_1 from the centre of the nearest main bearing) based on a triangular bending moment load due to the radial components of the connecting rod force. For crank throws with two connecting rods acting upon one crankpin, the nominal bending moment is taken as a bending moment obtained by superimposing the two triangular bending moment loads due to the radial components of the connecting rod forces, according to phase.

c) The nominal alternating stresses due to bending moments and shearing forces are to be related to the cross-sectional area of the crank web, at the centre of the overlap S in cases of overlap of the pins and at the centre of the distance y between the adjacent generating lines of the two pins in cases of pins which do not overlap (see Fig 2 and Fig 3).

   Nominal mean bending stresses are neglected.

2.1.2 Calculation of nominal alternating bending and shearing stresses

a) As a rule the calculation is carried out in such a way that the individual radial forces acting upon the crank pin owing to gas and inertia forces will be calculated for all crank positions within one working cycle. A simplified calculation of the radial forces may be used at the discretion of the Society.

b) The time curve of the bending moment M_B in the web centre is to be calculated by means of the radial forces variable in time within one working cycle, and taking into account the axial distance from the bearing center as defined in [2.1.1] a) to the acting position of the forces on the pin. The nominal alternating bending moment M_{BN}, in N·m, and, from this, the nominal alternating bending stress σ_{BN}, in N/mm², will then be calculated by the following formulae:

$$M_{BN} = \pm 0{,}5 \cdot (M_{B,MAX} - M_{B,MIN})$$

$$\sigma_{BN} = \pm \frac{M_{BN}}{W_{EQ}} \cdot K_E \cdot 10^3$$

   In the case of V-type engines, the bending moments, progressively calculated for the various crank angles and due to the gas and inertia forces of the two cylinders acting on one crank throw, are to be superimposed according to phase, the differing designs of the connecting rods (forked connecting rod, articulated-type connecting rod or adjacent connecting rods) being taken into account.

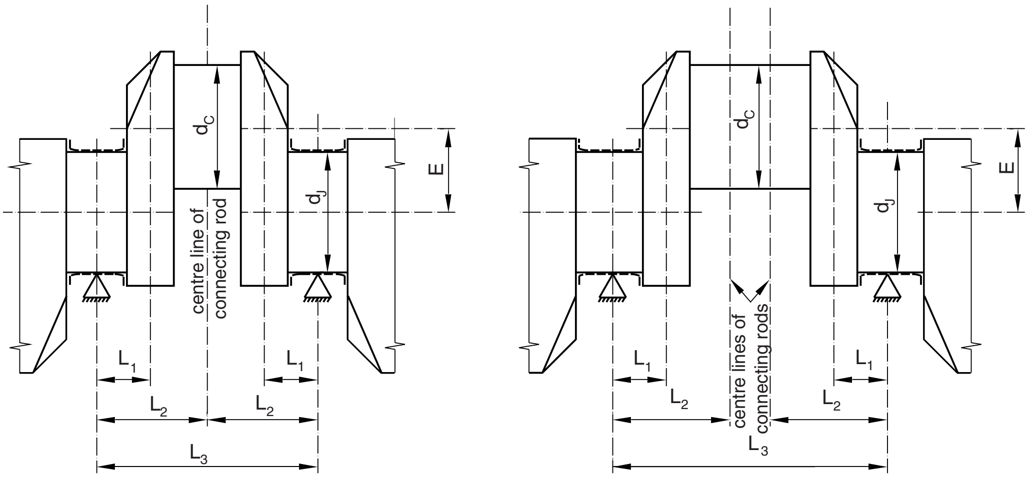
   Where there are cranks of different geometrical configuration (e.g., asymmetric cranks) in one crankshaft, the calculation is to cover all crank variants.

c) The nominal alternating shearing force Q_N, in N, and, from this, the nominal alternating shearing stress σ_{QN}, in N/mm², may be calculated by the following formulae:

$$Q_N = \pm 0{,}5 \cdot (Q_{MAX} - Q_{MIN})$$

$$\sigma_{QN} = \pm \frac{Q_N}{F} \cdot K_E$$

Figure 1 : Crank throw of solid crankshaft



(a) Crank throw for in-line engine

(b) Crank throw for engine with two adjacent connecting rods

Figure 2 : Crank dimensions necessary for the calculation of stress concentration factors

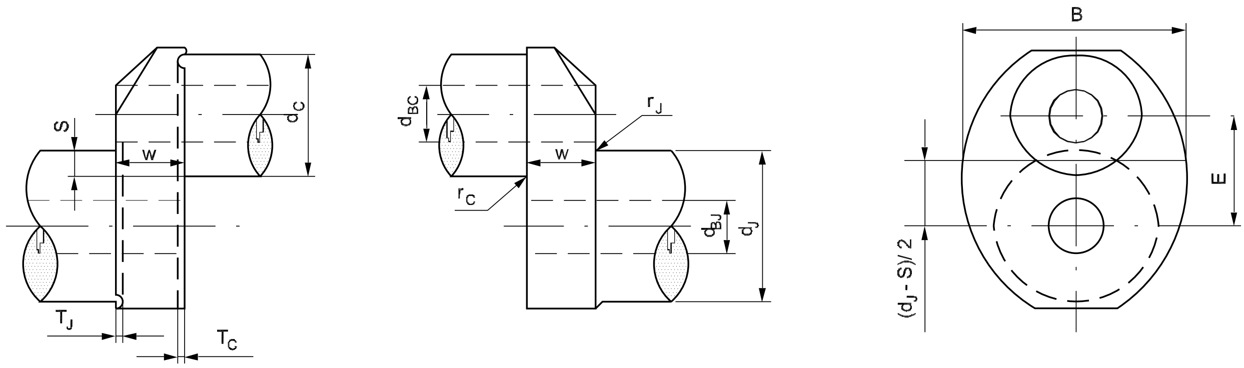
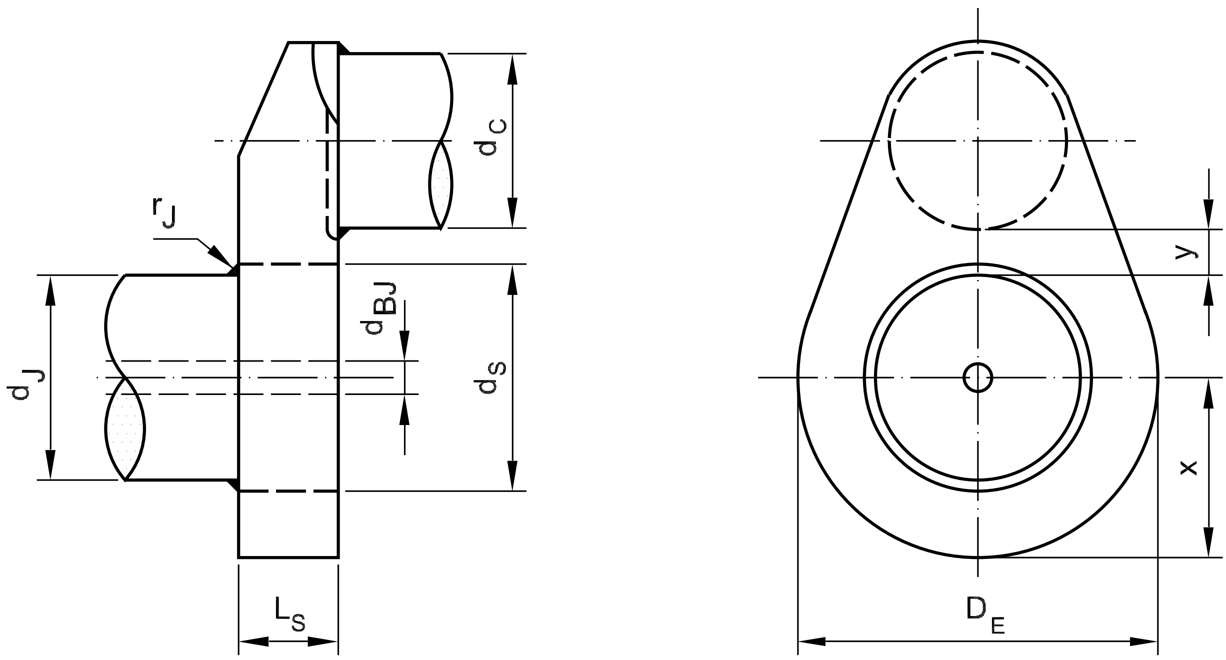


Figure 3 : Crank throw of semi-built crankshaft



2.1.3 Calculation of alternating bending stresses in way of crankpin and journal fillets

The calculation of the alternating bending stresses is to be carried out in way of crankpin and journal fillets, as specified below.

a) The alternating bending stress in crankpin fillet is to be taken equal to the value σ_{BC}, in N/mm², obtained by the following formula:

$$\sigma_{BC} = \pm (\beta_{BC} \cdot \sigma_{BN})$$

b) The alternating bending stress in journal fillet is to be taken equal to the value σ_{BJ}, in N/mm², obtained by the following formula:

$$\sigma_{BJ} = \pm (\beta_{BJ} \cdot \sigma_{BN} + \beta_{QJ} \cdot \sigma_{QN})$$

2.2 Calculation of alternating torsional stresses

2.2.1 General

The calculation for nominal alternating torsional stresses is to be undertaken by the engine manufacturer according to the information contained in [2.2.2].

The maximum value obtained from such calculations will be used by the Society when determining the equivalent alternating stress according to the provisions of [5].

In the absence of such a maximum value, the Society reserves the right to incorporate a fixed value in the calculation for the crankshaft dimensions, to be established at its discretion in each case.

In the event of the Society being entrusted to carry out a forced vibration calculation on behalf of the engine manufacturer to determine the torsional vibration stresses expected in the engine and where relevant in the shafting, the following data are to be submitted in addition to those required in [1.2.1]:

a) equivalent dynamic system of the engine, comprising:
   1) mass moment of inertia of every mass point, in kg·m²
   2) inertialess torsional stiffnesses, in N·m/rad, of all crankshaft parts between two mass points
b) vibration dampers, specifying:
   1) type designation
   2) mass moments of inertia, in kg·m²
   3) inertialess torsional stiffnesses, in N·m/rad
   4) values of the damping coefficients, in N·m·s
c) flywheels, specifying:
   1) mass moment of inertia, in kg·m².

Where the whole propulsion system is to be considered, the following information is also to be submitted:

a) elastic couplings, specifying:
   1) dynamic characteristics and damping data, as well as the permissible value of alternating torque
b) gearing and shafting, specifying:
   1) shaft diameters of gear shafts, thrust shafts, intermediate shafts and propeller shafts, mass moments of inertia, in kg·m², of gearing or important mass points, gear ratios and, for gearboxes of complex type, the schematic gearing arrangement
c) propellers, specifying:
   1) propeller diameter
   2) number of blades
   3) pitch and developed area ratio
   4) mass moment of inertia of propeller in air and with entrained water, in kg·m², (for controllable pitch propellers both the values at full pitch and at zero pitch are to be specified)
   5) damping characteristics, if available and documented
d) natural frequencies with their relevant modes of vibration and the vector sums for the harmonics of the engine excitation
e) estimated torsional vibration stresses in all important elements of the system with particular reference to clearly defined resonance speeds of rotation and continuous operating ranges.

2.2.2 Calculation of nominal alternating torsional stresses

The maximum and minimum values of the alternating torques are to be ascertained for every mass point of the system and for the entire speed range by means of a harmonic synthesis of the alternating stresses due to the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines, and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines.

In performing this calculation, allowance is to be made for the dampings that exist in the system and for unfavourable conditions (e.g., misfiring in one of the cylinders).

The speed stages is to be selected for the forced vibration calculations in such a way that the transient response can be recorded with sufficient accuracy at various speeds.

The values received from such calculation are to be submitted to the Society for consideration.

The nominal alternating torsional stresses, referred to crankpin and journal, in every mass point which is essential to the assessment, may be taken equal to the values τ_{NC} and τ_{NJ}, in N/mm², calculated by the following formulae:

$$\tau_{NC} = \pm \frac{M_{TN}}{W_{PC}} \cdot 10^3$$

$$\tau_{NJ} = \pm \frac{M_{TN}}{W_{PJ}} \cdot 10^3$$

where:

a) For unbored crankpins or journals:

$$W_{PC} = \frac{\pi \cdot d_C^3}{16}$$

$$W_{PJ} = \frac{\pi \cdot d_J^3}{16}$$

b) For bored crankpins or journals:

$$W_{PC} = \frac{\pi}{16} \cdot \frac{d_C^4 - d_{BC}^4}{d_C}$$

$$W_{PJ} = \frac{\pi}{16} \cdot \frac{d_J^4 - d_{BJ}^4}{d_J}$$

For the symbols d_C, d_J, d_{BC} and d_{BJ} see [3.1.1] and Fig 2.

For the calculation of the polar moments of resistance W_{PC} and W_{PJ}, bored crankpins and journals having bore diameter not exceeding 0,3 times the outer diameter of crankpins or journals may be considered as unbored.

Bored crankpins and journals whose bore longitudinal axis does not coincide with the axis of the said crankpins and journals, will be considered by the Society in each case.

The assessment of the proposed crankshaft dimensions is based on the alternating torsional stress which, in conjunction with the associated bending stress, results in the lowest acceptability factor F_A, as specified in [8.1].

Where barred speed ranges are necessary, the alternating torsional stresses within these ranges are to be neglected in the calculation of the above acceptability factor.

Barred speed ranges are to be so arranged that satisfactory operation is possible despite their existence.

There are to be no barred speed ranges for values of the speed ratio $\lambda \geq 0,8$, λ being the ratio between the rotational speed considered and the rotational speed corresponding to the maximum continuous power.

The approval of the proposed crankshaft dimensions will be based on the installation having the lowest value of the above-mentioned acceptability factor.

Thus, for each installation, it is to be ensured by suitable calculation that the nominal alternating torsional stress accepted for the purpose of checking the crankshaft scantlings is not exceeded.

This calculation is to be submitted for assessment to the Society (see Ch 1, Sec 9).

2.2.3 Calculation of alternating torsional stresses in crankpin and journal fillets

The calculation of alternating torsional stresses is to be carried out both in way of crankpin and journal fillets, as specified below:

a) The alternating torsional stress in way of crankpin fillet is to be taken equal to the value τ_C, in N/mm², given by the following formula:

$$\tau_C = \pm (\beta_{TC} \cdot \tau_{NC})$$

b) The alternating torsional stress in way of journal fillet is to be taken equal to the value τ_J, in N/mm², given by the following formula:

$$\tau_J = \pm (\beta_{TJ} \cdot \tau_{NJ})$$

3 Calculation of stress concentration factors

3.1 General

3.1.1 The stress concentration factors for bending (β_{BC} and β_{BJ}) are defined as the ratio of the maximum value of the bending stress occurring in the fillets under bending load acting in the central cross-section of a crank, to the value of the nominal alternating bending stress related to the web cross-section.

The value of the above nominal stress is to be determined under the bending moment in the middle of the solid web.

The stress concentration factors for torsion (β_{TC} and β_{TJ}) are defined as the ratio of the maximum value of the torsional stress occurring under torsional load in the fillets to the value of the nominal alternating torsional stress related to the crankpin or journal cross-section, taking account of the relevant bores, if any.

The stress concentration factor for shearing β_{QJ} is defined as the ratio of the maximum value of the shear stress occurring in the journal fillet under bending load to the value of the nominal shear stress related to the web cross-section.

Where the above stress concentration factors cannot be obtained by reliable measurements, their values may be evaluated by means of the formulae in [3.1.2] and [3.1.3], which are applicable to crankpin fillets and journal fillets for solid-forged crankshafts, and to the crankpin fillets only for semi-built crankshafts.

Fig 2 shows the dimensions necessary for the calculation of the above-mentioned stress concentration factors.

For the calculation of stress concentration factors for bending, torsion and shearing, the related dimensions shown in Tab 1 will be applied.

The values of the stress concentration factors, calculated as follows, are valid for the following ranges of related dimensions for which investigations have been carried out:

$-0{,}50 \leq s \leq 0{,}70$

$0{,}20 \leq w \leq 0{,}80$

$1{,}20 \leq b \leq 2{,}20$

$0{,}03 \leq r_1 \leq 0{,}13$

$0{,}03 \leq r_2 \leq 0{,}13$

$0 \leq d_1 \leq 0{,}80$

$0 \leq d_2 \leq 0{,}80$

The factor f(t,s), which accounts for the influence of a recess in the web in way of the crankpin and journal fillets, is valid if the related dimensions t_1 and t_2 meet the following conditions:

$t_1 \leq r_1 \quad t_2 \leq r_2$

and is to be applied for the values of the related dimension s within the range:

$-0{,}30 \leq s \leq 0{,}50$

Table 1 :

Crankpin fillets	Journal fillets
$r_1 = r_C / d_C$	$r_2 = r_J / d_C$
$s = S / d_C$	$s = S / d_C$
$w = W / d_C$	$w = W / d_C$
$b = B / d_C$	$b = B / d_C$
$d_1 = d_{BC} / d_C$	$d_2 = d_{BJ} / d_C$
$t_1 = T_C / d_C$	$t_2 = T_J / d_C$

3.1.2 Crankpin fillets

a) The value of the stress concentration factor for bending β_{BC} may be calculated by the following formula:

$$\beta_{BC} = 2{,}6914 \cdot f_1(s,w) \cdot f_1(w) \cdot f_1(b) \cdot f_1(r_1) \cdot f_1(d_1) \cdot f_1(d_2) \cdot f(t,s)$$

where:

$f_1(s,w)$: $-4{,}1883 + 29{,}2004 \cdot w - 77{,}5925 \cdot w^2 + 91{,}9454 \cdot w^3 - 40{,}0416 \cdot w^4 + (1-s) \cdot (9{,}5440 - 58{,}3480 \cdot w + 159{,}3415 \cdot w^2 - 192{,}5846 \cdot w^3 + 85{,}2916 \cdot w^4) + (1-s)^2 \cdot (-3{,}8399 + 25{,}0444 \cdot w - 70{,}5571 \cdot w^2 + 87{,}0328 \cdot w^3 - 39{,}1832 \cdot w^4)$

$f_1(w)$: $2{,}1790 \cdot w^{0{,}7171}$

$f_1(b)$: $0{,}6840 - 0{,}0077 \cdot b + 0{,}1473 \cdot b^2$

$f_1(r_1)$: $0{,}2081 \cdot r_1^{-0{,}5231}$

$f_1(d_1)$: $0{,}9978 + 0{,}3145 \cdot d_1 - 1{,}5241 \cdot d_1^2 + 2{,}4147 \cdot d_1^3$

$f_1(d_2)$: $0{,}9993 + 0{,}27 \cdot d_2 - 1{,}0211 \cdot d_2^2 + 0{,}5306 \cdot d_2^3$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1{,}8 + 3{,}2\ s)$

b) The value of the stress concentration factor for torsion β_{TC} may be calculated by the following formula:

$\beta_{TC} = 0{,}8 \cdot f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$

where:

$f_2(r_1,s)$: $r_1^{\,x}$ with $x = -0{,}322 + 0{,}1015 \cdot (1 - s)$

$f_2(b)$: $7{,}8955 - 10{,}654 \cdot b + 5{,}3482 \cdot b^2 - 0{,}857 \cdot b^3$

$f_2(w)$: $w^{-0{,}145}$

3.1.3 Journal fillets

a) The value of the stress concentration factor for bending β_{BJ} may be calculated by the following formula:

$\beta_{BJ} = 2{,}7146 \cdot f_3(s,w) \cdot f_3(w) \cdot f_3(b) \cdot f_3(r_2) \cdot f_3(d_1) \cdot f_3(d_2) \cdot f(t,s)$

where:

$f_3(s,w)$: $-1{,}7625 + 2{,}9821 \cdot w - 1{,}5276 \cdot w^2$
$+ (1 - s) \cdot (5{,}1169 - 5{,}8089 \cdot w + 3{,}1391 \cdot w^2)$
$+ (1 - s)^2 \cdot (-2{,}1567 + 2{,}3297 \cdot w - 1{,}2952 \cdot w^2)$

$f_3(w)$: $2{,}2422 \cdot w^{0{,}7548}$

$f_3(b)$: $0{,}5616 + 0{,}1197 \cdot b + 0{,}1176 \cdot b^2$

$f_3(r_2)$: $0{,}1908 \cdot r_2^{\,-0{,}5568}$

$f_3(d_1)$: $1{,}0022 - 0{,}1903 \cdot d_1 + 0{,}0073 \cdot d_1^{\,2}$

$f_3(d_2)$: $1{,}0012 - 0{,}6441 \cdot d_2 + 1{,}2265 \cdot d_2^{\,2}$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1{,}8 + 3{,}2\ s)$

b) The value of the stress concentration factor for shearing β_{QJ} may be calculated by the following formula:

$\beta_{QJ} = 3{,}0128 \cdot f_4(s) \cdot f_4(w) \cdot f_4(b) \cdot f_4(r_2) \cdot f_4(d_1) \cdot f(t,s)$

where:

$f_4(s)$: $0{,}4368 + 2{,}1630 \cdot (1 - s) - 1{,}5212 \cdot (1 - s)^2$

$f_4(w)$: $\dfrac{w}{0{,}0637 + 0{,}9369 \cdot w}$

$f_4(b)$: $-0{,}5 + b$

$f_4(r_2)$: $0{,}5331 \cdot r_2^{\,-0{,}2038}$

$f_4(d_1)$: $0{,}9937 - 1{,}1949 \cdot d_1 + 1{,}7373 \cdot d_1^{\,2}$

$f(t,s)$: $1 + (t_1 + t_2) \cdot (1{,}8 + 3{,}2\ s)$

c) The value of the stress concentration factor for torsion β_{TJ} may be calculated by the following formulae:

- where $d_J = d_C$ and $r_J = r_C$:

  $\beta_{TJ} = \beta_{TC}$

- where $d_J \neq d_C$ and/or $r_J \neq r_C$:

  $\beta_{TJ} = 0{,}8 \cdot f_2(r_1,s) \cdot f_2(b) \cdot f_2(w)$

  and $f_2(r_1,s)$, $f_2(b)$ and $f_2(w)$ are to be determined in accordance with [3.1.2], but taking:

  $r_1 = r_J / d_J$

  instead of $r_1 = r_C / d_C$ for the calculation of $f_2(r_1,s)$.

4 Additional bending stresses

4.1

4.1.1 In addition to the alternating bending stresses in fillets (see [2.1.3]), further bending stresses due to misalignment, bedplate deformation and axial and bending vibrations are also to be considered.

The values of such additional bending stresses may be taken equal to the values $\sigma_{B,ADD}$, in N/mm², as shown in Tab 2.

Table 2 : Additional bending stresses

Type of engine	$\sigma_{B,ADD}$, in N/mm²
Crosshead engine	± 30
Trunk piston engine	± 10

5 Calculation of the equivalent alternating stress

5.1 General

5.1.1 The equivalent alternating stress is to be calculated for the crankpin fillet as well as for the journal fillet.

For this calculation the theory of constant energy of distorsion (von Mises's Criterion) is to be used.

Here it is assumed that the maximum alternating bending stresses and maximum alternating torsional stresses within a crankshaft occur simultaneously and at the same point.

5.2 Equivalent alternating stress

5.2.1 The equivalent alternating stress is to be taken as the greater of the two values σ'_E and σ''_E, calculated according to the formulae of a) and b) below.

a) The equivalent alternating stress in way of the crankpin fillet is to be taken equal to the value σ'_E, in N/mm², calculated by the following formula:

$$\sigma'_E = \pm[(\sigma_{BC} + \sigma_{B,ADD})^2 + 3\tau_C{}^2]^{0,5}$$

b) The equivalent alternating stress in way of the journal fillet is to be taken equal to the value σ''_{ID}, in N/mm², calculated by the following formula:

$$\sigma''_E = \pm[(\sigma_{BJ} + \sigma_{B,ADD})^2 + 3\tau_J{}^2]^{0,5}$$

6 Calculation of the fatigue strength

6.1

6.1.1 The fatigue strength is to be understood as that value of alternating bending stress which a crankshaft can permanently withstand at the most highly stressed points of the fillets between webs and pins.

Where the fatigue strength for a crankshaft cannot be ascertained by reliable measurements, it may be taken equal to the lower of the values $\sigma'_{F, ALL}$ and $\sigma''_{F, ALL}$ evaluated by means of the formulae in a) and b) below.

a) The value of the allowable alternating bending fatigue strength in way of the crankpin fillet may be taken equal to the value $\sigma'_{F.ALL}$ in N/mm², calculated by the following formula:

$$\sigma'_{F,ALL} = \pm\ K.R'_m.(0{,}264 + 1{,}073.d_C^{-0,2} + R''_m + R'''_m.r_C^{-0,5})$$

where:

K	:	Factor for different types of forged and cast steel crankshafts without surface treatment of pins, whose value may be taken as follows: • 1,05 for continuous grain flow forged or drop-forged steel crankshafts • 1,00 for free form forged steel crankshafts • 0,93 for cast steel crankshafts
R'_m	:	$0{,}42 \cdot R_m + 39{,}3$
R''_m	:	$\dfrac{785 - R_m}{4900}$
R'''_m	:	$196 / R_m$

b) The value of the allowable alternating bending fatigue strength in way of the journal fillet may be taken equal to the value $\sigma''_{F,.ALL}$, in N/mm², calculated by the following formula:

$$\sigma''_{F,ALL} = \pm\ K.R'_m.(0{,}264 + 1{,}073.d_J^{-0,2} + R''_m + R'''_m.r_J^{-0,5})$$

For calculation of $\sigma'_{F,ALL}$ and $\sigma''_{F,ALL}$, the values of r_C and r_J are not to be taken less than 2 mm.

Where results of the fatigue tests conducted on full size crank throws or crankshafts whose pins have been subjected to surface treatment are not available, the factor K for crankshafts without surface treatment of pins is to be used.

In all cases the experimental values of fatigue strength carried out with full size crank throws or crankshafts is to be submitted to the Society for consideration.

The survival probability for fatigue strength values derived from testing is to be to the satisfaction of the Society and in principle not less than 80%.

7 Calculation of shrink-fit of semi-built crankshafts

7.1 General

7.1.1 Considering the radius of the transition r_J from the journal diameter d_J to the shrink diameter d_S, both the following equations are to be respected:

$r_J \geq 0,015 d_J$

$r_J \geq 0,5 \cdot (d_S - d_J)$

The actual oversize h of the shrink-fit must be within the limits h_{MIN} and h_{MAX} calculated in accordance with [7.2] and [7.3] or according to recognized standards.

7.2 Minimum required oversize of shrink-fit

7.2.1 The minimum oversize required for the shrink-fit is determined by the greater of the values calculated in accordance with [7.2.2] and [7.2.3].

7.2.2 The value of the minimum required oversize of the shrink-fit h_{MIN}, in mm, is to be not less than that calculated by the following formula for the crank throw with the absolute maximum torque $M_{T,MAX}$.

The above torque $M_{T,MAX}$, in N·m, corresponds to the maximum value of the torque for the various mass points of the crankshaft

$$h_{MIN} = \frac{4 \cdot 10^3}{\pi \cdot \mu} \cdot \frac{s_F \cdot M_{T,MAX}}{E_W \cdot d_S \cdot L_S} \cdot f(Z)$$

where:

s_F : safety factor against slipping; in no case is a value less than 2 to be taken

μ : coefficient for static friction between the journal and web surfaces, to be taken equal to 0,20, if $L_S / d_S \geq 0,40$

f (Z) : $\dfrac{1 - Z_A^2 \cdot Z_S^2}{(1 - Z_A^2) \cdot (1 - Z_S^2)}$

Z_A : d_S / D_E

Z_S : d_{BJ} / d_S

7.2.3 In addition to the provisions of [7.2.2], the minimum required oversize value h_{MIN}, in mm, is not to be less than that calculated according to the following formula:

$$h_{MIN} = \frac{R_{S,MIN} \cdot d_S}{E_W}$$

7.3 Maximum permissible oversize of shrink-fit

7.3.1 The value of the maximum permissible oversize of shrink-fit is not to be exceeded the value h_{MAX}, in mm, calculated in accordance with the following formula:

$$h_{MAX} = \frac{R_{S,MIN} \cdot d_S}{E_W} + \frac{0,8 d_S}{1000}$$

This condition concerning the maximum permissible oversize serves to restrict the shrinkage induced mean stress in the journal fillet.

8 Acceptability criteria

8.1

8.1.1 In order for the proposed crankshaft scantlings to be acceptable, the equivalent alternating stresses, calculated both at crankpin and journal fillets, are to be such as to satisfy the following conditions:

$$Q_1 = \frac{\sigma'_{F,ALL}}{\sigma'_E} \geq 1,15$$

$$Q_2 = \frac{\sigma''_{F,ALL}}{\sigma''_E} \geq 1,15$$

Appendix 2 Plastic Pipes

1 General

1.1 Application

1.1.1 These requirements are applicable to pipes / piping systems made of plastic or made predominantly of other material than metal. The installation of plastic pipes is to be avoided on naval ships if not agreed by the Society and the Naval Authority.

1.1.2 The use of mechanical joints approved for the use in metallic piping system only is not permitted.

1.1.3 Piping systems intended for non-essential services are only required to meet the requirements of recognized standards and [2.1.3], item b); [2.5.2]; [3.1.2]; [3.1.3]; [3.1.4]; [3.1.5]; [3.1.6]; [3.1.7] and Article [4].

1.2 Use of plastic pipes

1.2.1 Plastic may be used in piping systems in accordance with the provisions of Ch 1, Sec 10, [2.1.3], provided the requirements of this Appendix are complied with.

1.2.2 Plastic pipes are to be type approved by the Society.

1.3 Specifications

1.3.1 The specification of the plastic piping is to be submitted in accordance with the provisions of Ch 1, Sec 10, [1.2.2]. It is to comply with a recognised national or international standard approved by the Society. In addition, the requirements stated in this Appendix are to be complied with.

1.4 Terms and conditions

1.4.1 Plastic(s)

Plastic(s) includes both thermoplastic and thermosetting plastic materials with or without reinforcement, such as PVC and fibre reinforced plastic (FRP). Plastic includes synthetic rubber and materials of similar thermo/mechanical properties.

1.4.2 Pipes / piping systems

Pipes / piping systems means those made of plastic(s) and include the pipes, fittings, system joints, method of joining and any internal or external liners, coverings and coatings required to comply with the performance criteria.

1.4.3 Joint

Joint means the location at which two pieces of pipe or a pipe and a fitting are connected together. The joint may be made by adhesive bonding, laminating, welding, flanges and mechanical joints according to Ch 1, Sec 10, Fig 2.

1.4.4 Fitting

Fittings means bends, elbows, fabricated branch pieces etc. of plastic materials.

1.4.5 Nominal pressure

Nominal pressure means the maximum permissible working pressure which is to be determined in accordance with the requirements in [2.1.3].

1.4.6 Design pressure

Design pressure means the maximum working pressure which is expected under operation conditions or the highest set pressure of any safety valve or pressure relief device on the system, if fitted.

1.4.7 Fire endurance

Fire endurance means the capability of piping to maintain its strength and integrity (i.e. capable of performing its intended function) for some predetermined period of time while exposed to fire.

1.4.8 Essential to the safety of ships

Essential to the safety of ships means all piping systems that in event of failure will pose a threat to personnel and the ship.

1.4.9 Essential services

Essential services are those services essential to propulsion and steering and safety of the ship as specified in Ch 2, Sec 1, [3.2].

Note: Examples for piping systems essential to the safety are provided by Tab 1.

2 General requirements

2.1 Strength

2.1.1 The strength of the pipes is to be determined by a hydrostatic test failure pressure of a pipe specimen under the standard conditions: atmospheric pressure equal to 100 kPa, relative humidity 30%, environmental and carried fluid temperature 298 kPa (25°C).

2.1.2 The strength of fittings and joints is to be not less than that of the pipes.

2.1.3 The nominal pressure P_N is to be determined from the following conditions:

a) Internal pressure

For an internal pressure $P_{N\ int}$, the following is to be taken whichever is smaller:

- $P_{N\ int} \leq P_{sth} / 4$
- $P_{N\ int} \leq P_{lth} / 2,5$

where:

P_{sth} : Short-term hydrostatic test pipe failure pressure

P_{lth} : Long-term hydrostatic test pipe failure pressure (>100 000 hours)

b) External pressure $P_{N\ ext}$, (for any installation which may be subject to vacuum conditions inside the pipe or a head of liquid acting on the outside of the pipe; and for any pipe installation required to remain operational in case of flooding damage, as per SOLAS Chapter II-1, Regulation 8-1, as amended, or for any pipes that would allow progressive flooding to other compartments through damaged piping or through open ended pipes in the compartments)

$P_{N\ ext} \leq P_{col} / 3$

where P_{col} is the collapse pressure.

In no case is the pipe collapse pressure to be less than 0,3 MPa

The maximum working external pressure is the sum of the vacuum inside the pipe and the static pressure head outside the pipe.

2.1.4 Notwithstanding the requirements of items a) or b) as applicable, the pipe or pipe layer minimum wall thickness is to follow recognized standards. In the absence of standards for pipes not subject to external pressure, the requirements of item a) above are to be met.

2.1.5 The maximum permissible working pressure is to be specified with due regard for maximum possible working temperatures in accordance with Manufacturer's recommendations.

2.2 Axial strength

2.2.1 The sum of the longitudinal stresses due to pressure, weight and other loads is not to exceed the allowable stress in the longitudinal direction.

2.2.2 In the case of fibre reinforced plastic pipes, the sum of the longitudinal stresses is not to exceed half of the nominal circumferential stress derived from the nominal internal pressure condition (see [2.1.3]).

2.3 Impact resistance

2.3.1 Plastic pipes and joints are to have a minimum resistance to impact in accordance with a recognised national or international standard.

After the test the specimen is to be subjected to hydrostatic pressure equal to 2,5 times the design pressure for at least 1 hour.

2.4 Temperature

2.4.1 The permissible working temperature depending on the working pressure is to be in accordance with Manufacturer's recommendations, but in each case it is to be at least 20ºC lower than the minimum heat distortion/deflection temperature of the pipe material, determined according to ISO 75-2:2013 method A, or equivalent e.g. ASTM D648-18.

The minimum heat distortion/deflection temperature is to be not less than 80ºC.

2.5 Requirements depending on service and/or location

2.5.1 Fire endurance

Pipes and their associated joints and fittings whose integrity is essential to the safety of ships are required to meet the minimum fire endurance requirements of Appendix 1 or 2, as applicable, of IMO Resolution A.753(18), as amended.

Unless instructed otherwise by the Naval Authority, fire endurance tests are to be carried out with specimen representative for pipes, joints and fittings:

a) Pipes:
- for sizes with outer diameter < 200 mm the minimum outer diameter and wall thickness
- for sizes with outer diameter ≥ 200 mm one test specimen for each category of t/d, with:

  D= outer diameter,

  t = structural wall thickness.

A scattering of ±10% for t/D is regarded as the same group. Minimum size approved is equal to the diameter of specimen successfully tested.

b) Joints:

Each type of joint applicable for applied fire endurance level tested on pipe to pipe specimen

Note 1: A test specimen incorporating several components of a piping system may be tested in a single test.

Note 2: Test conditions are most demanding for minimum wall thickness and thus larger wall thickness is covered. A key factor determining the fire performance of a pipe component variant is the thickness-to-diameter (t/D) ratio and whether it is larger or smaller than that of the variant which has been fire-tested.

If fire-protective coatings or layers are included in the variant used in the fire test, only variants with the same or greater thickness of protection, regardless of the (t/D) ratio, are to be qualified by the fire test.

Means are to be provided to ensure a constant media pressure inside the test specimen during the fire test as specified in Appendix 1or 2 of the IMO Resolution A.753(18), as amended. During the test it is not permitted to replace media drained by fresh water or nitrogen.

Depending on the capability of a piping system to maintain its strength and integrity, there exist three different levels of fire endurance for piping systems:

a) Level 1. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of one hour without loss of integrity in the dry condition is considered to meet level 1 fire endurance standard (L1).

Level 1W - Piping systems similar to Level 1 systems except these systems do not carry flammable fluid or any gas and a maximum 5% flow loss in the system after exposure is acceptable (L1W).

b) Level 2. Piping having passed the fire endurance test specified in Appendix 1 of IMO Resolution A.753(18), as amended, for a duration of a minimum of 30 minutes in the dry condition is considered to meet level 2 fire endurance standard (L2).

Level 2W - Piping systems similar to Level 2 systems except a maximum 5% flow loss in the system after exposure is acceptable (L2W).

c) Level 3. Piping having passed the fire endurance test specified in Appendix 2 of IMO Resolution A.753(18) for a duration of a minimum of 30 minutes in the wet condition is considered to meet level 3 fire endurance standard (L3).

Permitted use of piping depending on fire endurance, location and piping system is given in Tab 1.

Table 1 : Fire endurance of piping systems

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A **(12)**	Other machinery spaces and pump rooms **(13)**	Cargo pump rooms **(14)**	Ro-Ro cargo holds **(15)**	Other dry cargo holds **(16)**	Cargo tanks **(17)**	Fuel oil tanks **(18)**	Ballast water tanks **(19)**	Cofferdams, void spaces, pipe tunnels and ducts **(20)**	Accommodation, service and control spaces **(21)**	Open decks **(22)**
CARGO (FLAMMABLE CARGOES WITH FLASH POINT ≤ 60°C)											
Cargo lines	NA	NA	L1	NA	NA	0	NA	0 **(9)**	0	NA	L1 **(2)**
Crude oil washing lines	NA	NA	L1	NA	NA	0	NA	0 **(9)**	0	NA	L1 **(2)**
Vent lines	NA	NA	NA	NA	NA	0	NA	0 **(9)**	0	NA	X
INERT GAS											
Water seal effluent line	NA	NA	0 **(1)**	NA	NA	0 **(1)**	0 **(1)**	0 **(1)**	0 **(1)**	NA	0
Scrubber effluent line	0 **(1)**	0 **(1)**	NA	NA	NA	NA	NA	0**(1)**	0 **(1)**	NA	0
Main line	0	0	L1	NA	NA	NA	NA	NA	0	NA	L1 **(6)**
Distribution line	NA	NA	L1	NA	NA	0	NA	NA	0	NA	L1 **(2)**
FLAMMABLE LIQUIDS (FLASH POINT > 60°C)											
Cargo lines	X	X	L1	X	X	NA**(3)**	0	0 **(9)**	0	NA	L1
Fuel oil	X	X	L1	X	X	NA**(3)**	0	0	0	L1	L1

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A (12)	Other machinery spaces and pump rooms (13)	Cargo pump rooms (14)	Ro-Ro cargo holds (15)	Other dry cargo holds (16)	Cargo tanks (17)	Fuel oil tanks (18)	Ballast water tanks (19)	Cofferdams, void spaces, pipe tunnels and ducts (20)	Accommodation, service and control spaces (21)	Open decks (22)
Lubricating oil	X	X	L1	X	X	NA	NA	NA	0	L1	L1
Hydraulic oil	X	X	L1	X	X	0	0	0	0	L1	L1
SEA WATER **(1)**											
Bilge main and branches	X	X	L1	X	X	NA	0	0	0	NA	L1
Fire main and water spray	L1	L1	L1	X	NA	NA	NA	0	0	X	L1
Foam system	L1W	L1W	L1W	NA	NA	NA	NA	NA	0	L1W	L1W
Sprinkler system	L1W	L1W	L3	X	NA	NA	NA	0	0	L3	L3
Ballast	L3	L3	L3	L3	X	0 **(9)**	0	0	0	L2W	L2W
Cooling water, essential services	L3	L3	NA	NA	NA	NA	NA	0	0	NA	L2W
Tank cleaning services, fixed machines	NA	NA	L3	NA	NA	0	NA	0	0	NA	L3 **(2)**
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
FRESH WATER											
Cooling water, essential services	L3	L3	NA	NA	NA	NA	0	0	0	L3	L3
Condensate return	L3	L3	L3	0	0	NA	NA	NA	0	0	0
Non-essential systems	0	0	0	0	0	NA	0	0	0	0	0
SANITARY, DRAINS, SCUPPERS											
Deck drains (internal)	L1W**(4)**	L1W**(4)**	NA	L1W**(4)**	0	NA	0	0	0	0	0
Sanitary drains (internal)	0	0	NA	0	0	NA	0	0	0	0	0
Scuppers and discharges (over-board)	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0 **(1)(7)**	0	0	0	0	0 **(1)(7)**	0
SOUNDING, AIR											
Water tanks, dry spaces	0	0	0	0	0	0**(9)**	0	0	0	0	0
Oil tanks (flash point > 60°C)	X	X	X	X	X	X**(3)**	0	0**(9)**	0	X	X
MISCELLANEOUS											
Control air	L1 **(5)**	L1 **(5)**	L1 **(5)**	L1**(5)**	L1**(5)**	NA	0	0	0	L1 **(5)**	L1**(5)**
Service air (non-essential)	0	0	0	0	0	NA	0	0	0	0	0
Brine	0	0	NA	0	0	NA	NA	NA	0	0	0
Auxiliary low steam pressure (≤ 0,7 MPa)	L2W	L2W	0 **(8)**	0 **(8)**	0 **(8)**	0	0	0	0	0 **(8)**	0 **(8)**
Urea transfer / supply system (SCR installations)	L1**(11)**	L1**(11)**	NA	NA	NA	NA	NA	NA	0	L3 **(1)(10)** NA	0

PIPING SYSTEM	LOCATION										
	Machinery spaces of category A (12)	Other machinery spaces and pump rooms (13)	Cargo pump rooms (14)	Ro-Ro cargo holds (15)	Other dry cargo holds (16)	Cargo tanks (17)	Fuel oil tanks (18)	Ballast water tanks (19)	Cofferdams, void spaces, pipe tunnels and ducts (20)	Accommodation, service and control spaces (21)	Open decks (22)

Note 1:

- L1 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 60 min
- L1W : Fire endurance test (see [2.5.1])
- L2 : Fire endurance test (appendix 1 of IMO Resolution A.753(18), as amended) in dry conditions, 30 min
- L2W : Fire endurance test (see [2.5.1])
- L3 : Fire endurance test (appendix 2 of IMO Resolution A.753(18), as amended) in wet conditions, 30 min
- 0 : No fire endurance test required
- NA : Not applicable
- X : Metallic materials having a melting point greater than 925°C

(1) Where non-metallic piping is used, remote controlled valves to be provided at ship side (valve is to be controlled from outside space).
(2) Remote closing valves to be provided at the cargo tanks.
(3) When cargo tanks contain flammable liquids with flash point > 60 °C, “0” may replace “NA” or “X”.
(4) For drains serving only the space concerned, “0” may replace “L1W”.
(5) When controlling functions are not required by the Rules, “0” may replace “L1”.
(6) For pipes between machinery space and deck water seal, “0” may replace “L1”.
(7) Scuppers serving open decks in positions 1 and 2, as defined in Pt B, Ch 1, Sec 2, [9], are to be “X” throughout unless fitted at the upper end with a means of closing capable of being operated from a position above the damage control deck in order to prevent downflooding.
(8) For essential services, such as fuel oil tank heating and ship’s whistle, “X” is to replace “0”.
(9) For tankers, “NA” is to replace “0”.
(10) L3 in service spaces, NA in accommodation and control spaces.
(11) Type approved plastic piping without fire endurance test (0) is acceptable downstream of the tank valve, provided this valve is metal seated and arranged as fail-to-closed or with quick closing from a safe position outside the space in the event of fire.
(12) Machinery spaces of category A are defined in Ch 4, Sec 1, [2.22].
(13) Spaces, other than category A machinery spaces and cargo pumps rooms, containing propulsion machinery, boilers, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
(14) Spaces containing cargo pumps, and entrances and trunks to such spaces.
(15) Ro-ro and vehicle spaces are defined in Ch 4, Sec 1, [2]
(16) All spaces other than ro-ro cargo holds used for non-liquid cargo and trunks to such spaces.
(17) All spaces used for liquid cargo and trunks to such spaces.
(18) All spaces used for fuel oil (excluding cargo tanks) and trunks to such spaces.
(19) All spaces used for ballast water and trunks to such spaces.
(20) Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
(21) Accommodation spaces, service spaces and control stations are defined in Ch 4, Sec 1, [2].
(22) Open decks are defined in Ch 4, Sec 5, [1.2.3].

2.5.2 Flame spread

a) All pipes, except those fitted on open decks and within tanks, cofferdams, pipe tunnels, and ducts if separated from accommodation, permanent manned areas and escape ways by means of an A class bulkhead are to have low surface flame spread characteristics not exceeding average values listed in Appendix 3 of IMO Resolution A.753(18), as amended.

b) Surface flame spread characteristics are to be determined using the procedure given in the 2010 FTP Code, Annex 1, Part 5 with regard to the modifications due to the curvilinear pipe surfaces as also listed in Appendix 3 of IMO Resolution A.753(18), as amended.

c) Surface flame spread characteristics may also be determined using the test procedures given in ASTM D635-18, or in other national equivalent standards. Under the procedure of ASTM D635-18 a maximum burning rate of 60 mm/min applies. In case of adoption of other national equivalent standards, the relevant acceptance criteria are to be defined.

2.5.3 Fire protection coating

Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance level required, it is to meet the following requirements:

- The pipes are generally to be delivered from the manufacturer with the protective coating on.

- The fire protection properties of the coating are not to be diminished when exposed to salt water, oil or bilge slops. It is to be demonstrated that the coating is resistant to products likely to come into contact with the piping.
- In considering fire protection coatings, such characteristics as thermal expansion, resistance against vibrations and elasticity are to be taken into account.
- The fire protection coatings are to have sufficient resistance to impact to retain their integrity.

2.5.4 Electrical conductivity

Where electrical conductivity is to be ensured, the resistance of the pipes and fittings is not to exceed $1\cdot10^5$ Ohm/m.

3 Material approval and quality control during manufacture

3.1 General

3.1.1 Except as required in [1.1.3], prototypes of pipes and fittings are to be tested to determine short-term and long-term design strength, fire endurance and low surface flame spread characteristics (if applicable), electrical resistance (for electrically conductive pipes), impact resistance in accordance with the requirements of this Appendix.

3.1.2 For prototype testing representative samples of pipes and fittings are to be selected to the satisfaction of the Society.

3.1.3 The Manufacturer is to have quality system that meets ISO 9001:2015 standards or equivalent. The quality system is to consist of elements necessary to ensure that pipes and fittings are produced with consistent and uniform mechanical and physical properties.

3.1.4 Each pipe and fitting is to be tested by the Manufacturer at a hydrostatic pressure not less than 1,5 times the nominal pressure. Alternatively, for pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test may be carried out in accordance with the hydrostatic testing requirements stipulated in the recognised national or international standard to which the pipe or fittings are manufactured, provided that there is an effective quality system in place.

3.1.5 Piping and fittings are to be permanently marked with identification. Identification is to include pressure ratings, the design standards that the pipe or fitting is manufactured in accordance with, and the material of which the pipe or fitting is made.

3.1.6 In case the Manufacturer does not have an approved quality system complying with ISO 9001:2015 or equivalent, pipes and fittings are to be tested in accordance with this Appendix to the satisfaction of the Surveyor for every batch of pipes.

3.1.7 Depending upon the intended application a Society may require the pressure testing of each pipe and/or fitting.

4 Arrangement and installation of plastic pipes

4.1 Supports

4.1.1 Selection and spacing of pipe supports in shipboard systems are to be determined as a function of allowable stresses and maximum deflection criteria. Support spacing is not to be greater than the pipe Manufacturer's recommended spacing. The selection and spacing of pipe supports are to take into account pipe dimensions, length of the piping, mechanical and physical properties of the pipe material, mass of pipe and contained fluid, external pressure, operating temperature, thermal expansion effects, loads due to external forces, thrust forces, water hammer, vibrations, maximum accelerations to which the system may be subjected.

Combination of loads is to be considered.

4.1.2 Each support is to evenly distribute the load of the pipe and its content over the full width of the support. Measures are to be taken to minimise wear of the pipes where they are in contact with the supports.

4.1.3 Heavy components in the piping system such as valves and expansion joints are to be independently supported.

4.2 Expansion

4.2.1 Suitable provision is to be made in each pipeline to allow for relative movement between pipes made of plastic and the steel structure, having due regard to:

- the high difference in the coefficients of thermal expansion
- deformations of the ship’s structure.

4.2.2 Calculations of the thermal expansions are to take into account the system working temperature and the temperature at which the assembly is performed.

4.3 External loads

4.3.1 When installing the piping, allowance is to be made for temporary point loads, where applicable. Such allowance is to include at least the force exerted by a load (person) of 100 kg at mid-span on any pipe of more than 100 mm nominal outside diameter.

4.3.2 Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with [2.1], may be increased taking into account the conditions encountered during service on board ships.

4.3.3 Pipes are to be protected from mechanical damage where necessary.

4.4 Strength of connections

4.4.1 General

a) The strength of connections is not to be less than that of the piping system in which they are installed.

b) Pipes and fittings may be assembled using adhesive-bonded, welded, flanged or other joints.

c) When used for joint assembly, adhesives are to be suitable for providing a permanent seal between the pipes and fittings throughout the temperature and pressure range of the intended application.

d) Tightening of joints, where required, is to be performed in accordance with the manufacturer's instructions.

4.5 Installation of conductive pipes

4.5.1 In piping systems for fluids with conductivity less than 1000 pico siemens per metre (pS/m) such as refined products and distillates use is to be made of conductive pipes.

Regardless of the fluid being conveyed, plastic piping is to be electrically conductive if the piping passes through a hazardous area. The resistance to earth from any point in the piping system is not to exceed 1 x 10^6 Ohm. It is preferred that pipes and fittings be homogeneously conductive. Pipes and fittings having conductive layers are to be protected against a possibility of spark damage to the pipe wall. Satisfactory earthing is to be provided.

After completion of the installation, the resistance to earth is to be verified. Earthing wires are to be accessible for inspection

4.6 Application of fire protection coatings

4.6.1 Where necessary for the required fire endurance as stated in [2.5.3], fire protection coatings are to be applied on the joints, after performing hydrostatic pressure tests of the piping system.

4.6.2 The fire protection coatings are to be applied in accordance with the manufacturer's recommendations, using a procedure approved in each case.

4.7 Penetration of fire divisions and watertight bulkheads or decks

4.7.1 Where plastic pipes pass through "A" or "B" class divisions, arrangements are to be made to ensure that fire endurance is not impaired. These arrangements are to be tested in accordance with 'Recommendations for Fire Test Procedures for "A", "B" and "F" Bulkheads' 2010 FTP Code, annex 1, part 3, as amended.

4.7.2 When plastic pipes pass through watertight bulkheads or decks, the watertight integrity of the bulkhead or deck is to be maintained. For pipes not able to satisfy the requirements in [2.1.3] item b), a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

4.7.3 If the bulkhead or deck is also a fire division and destruction by fire of plastic pipes may cause the inflow of liquid from tanks, a metallic shut-off valve operable from above the freeboard deck is to be fitted at the bulkhead or deck.

4.8 Control during installation

4.8.1 General

a) Installation is to be in accordance with the Manufacturer's guidelines.

b) Prior to commencing the work, joining techniques are to be approved by the Society.

c) The tests and explanations specified in the present Appendix are to be completed before shipboard piping installation commences.

d) The personnel performing this work are to be properly qualified and certified to the satisfaction of the Society.

e) The procedure for making bonds is to be submitted to the Society for qualification. It is to include the following:
   - materials used
   - tools and fixtures
   - joint preparation requirements
   - cure temperature
   - dimensional requirements and tolerances
   - acceptance criteria for the test of the completed assembly

f) Any change in the bonding procedure which will affect the physical and mechanical properties of the joint is to require the procedure to be requalified.

4.8.2 Bonding qualification test

a) A test assembly is to be fabricated in accordance with the procedure to be qualified. It is to consist of at least one pipe-to-pipe joint and one pipe-to-fitting joint.

b) When the test assembly has been cured, it is to be subjected to a hydrostatic test pressure at a safety factor of 2,5 times the design pressure of the test assembly, for not less than one hour. No leakage or separation of joints is allowed. The test is to be conducted so that the joint is loaded in both longitudinal and circumferential directions.

c) Selection of the pipes used for the test assembly is to be in accordance with the following:
   - when the largest size to be joined is 200 mm nominal outside diameter or smaller, the test assembly is to be the largest piping size to be joined.
   - when the largest size to be joined is greater than 200 mm nominal outside diameter, the size of the test assembly is to be either 200 mm or 25% of the largest piping size to be joined, whichever is the greater.

d) When conducting performance qualifications, each bonder and each bonding operator are to make up test assemblies, the size and number of which are to be as required above.

4.9 Testing after installation on board

4.9.1 Piping systems for essential services are to be subjected to a test pressure not less than 1,5 times the design pressure or 4 bar whichever is greater. Notwithstanding the requirement above, the requirement in [4.9.2] may be applied to open ended pipes (drains, effluent, etc.).

4.9.2 Piping systems for non-essential services are to be checked for leakage under operational conditions.

4.9.3 For piping required to be electrically conductive, earthing is to be checked and random resistance testing is to be conducted.

5 Test specification for plastic pipes

5.1 Scope

5.1.1 This Article contains requirements for the type approval of plastic pipes. It is applicable to piping systems, including pipe joints and fittings, made predominately of other material than metal.

5.2 Documentation

5.2.1 The following information for the plastic pipes, fittings and joints is to be submitted for consideration and approval:

a) General information
   - pipe and fitting dimensions
   - maximum internal and external working pressure
   - working temperature range
   - intended services and installation locations
   - the level of fire endurance
   - electrically conductive
   - intended fluids
   - limits on flow rates
   - serviceable life
   - installation instructions
   - details of marking.

b) Drawings and supporting documentation

- certificates and reports for relevant tests previously carried out
- details of relevant standards
- all relevant design drawings, catalogues, data sheets, calculations and functional descriptions
- fully detailed sectional assembly drawings showing pipe, fittings and pipe connections.

c) Materials (as applicable)

- the resin type
- catalyst and accelerator types, and concentration employed in the case of reinforced polyester resin pipes or hardeners where epoxide resins are employed
- a statement of all reinforcements employed where the reference number does not identify the mass per unit area or the tex number of a roving used in a filament winding process, these are to be detailed
- full information regarding the type of gel-coat or thermoplastic liner employed during construction, as appropriate
- cure/post-cure conditions. The cure and post-cure temperatures and times employ resin/reinforcement ratio
- winding angle and orientation
- Joint bonding procedures and qualification tests results, see [4.8.1], item e).

5.3 Testing

5.3.1 Testing is to demonstrate compliance of the pipes, fittings and joints for which type approval is sought with the present Appendix.

Pipes, joints and fittings are to be tested for compliance with the requirements of recognized standards acceptable to the Society. In that order, recommended standards are given in Tab 2 and Tab 3.

Table 2 : Typical requirements for all systems

No	Test	Typical standard	Notes
1	Internal pressure **(1)**	the present [2.1.3], item a) ASTM D 1599 ASTM D 2992 ISO 15493 or equivalent	Top, middle, bottom (of range) Tests are to be carried out on pipe spools made of different pipe sizes, fittings and pipe connections
2	External pressure **(1)**	the present [2.1.3], item b) ISO 15493 or equivalent	As above, for straight pipes only
3	Axial strength	the present [2.2]	As above
4	Load deformation	ASTM D 2412 or equivalent	Top, middle, bottom (of each pressure range)
5	Temperature limitations	ISO 75-2:2013 method A GRP piping system: HDT test on each type of resin according to ISO 75-2:2013 method A Thermoplastic piping systems: ISO 75:2-2013 method A ISO 306 - Thermoplastic materials - Determination of Vicat softening temperature (VST) VICAT test according to ISO 2507 Polyesters with an HDT below 80°C are not to be used	Each type of resin
6	Impact resistance	ISO 9854, ISO 9653, ISO 15493, ASTM D 2444, or equivalent	Representative samples of each type of construction
7	Ageing	Manufacturer's standard ISO 9142	Each type of construction
8	Fatigue	Manufacturer's standard or service experience	Each type of construction
9	Fluid absorption	ISO 8361	
10	Material compatibility **(2)**	ASTM C581 Manufacturer's standard	

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable.

Table 3 : Typical additional requirements depending on service and/or locations of piping

No	Test	Typical standard	Notes
1	Fire endurance**(1)(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 1, 2	Representative samples of each type of construction and type of pipe connection
2	Flame spread**(1)(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
3	Smoke generation**(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
4	Toxicity**(2)(3)**	IMO Resolution A.753(18), as amended, Appendix 3	Representative samples of each type of construction
5	Electrical conductivity **(1)(2)(3)**	ASTM F1173-95 or ASTM D 257, NS 6126 § 11.2 or equivalent	Representative samples of each type of construction

(1) Test to be witnessed by a Surveyor of the Society.
(2) If applicable
(3) Optional. However, if the test is not carried out, the range of approved applications for the pipes is to be limited accordingly.

Appendix 3 Independent Fuel Oil Tanks

1 General

1.1 Application

1.1.1

a) The provisions of this Appendix apply to fuel oil tanks and bunkers which are not part of the ship's structure.

b) Requirements for scantling apply only to steel tanks. Scantling of tanks not made of steel will be given special consideration.

1.2 Documents to be submitted

1.2.1 Constructional drawings of the tanks are to be submitted, showing the height of the overflow and air pipe above the top of the tank.

1.3 Symbols and units

1.3.1 Tanks

The meaning of the symbols used for tanks is given in Fig 1.

L : Greater length of the considered plating element, in m

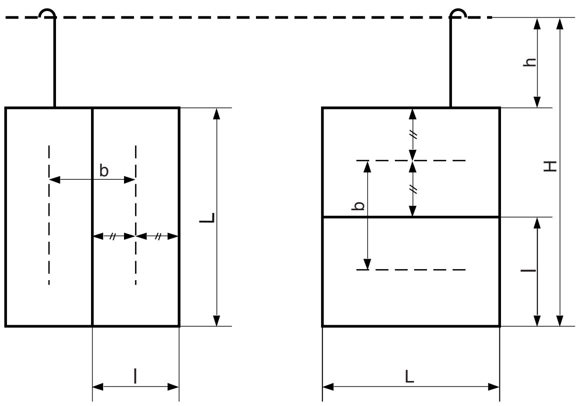
l : Smaller length of the considered plating element, in m

H : Height, in m, of the overflow or air pipe above the lower edge of the considered plating element

h : Height, in m, of overflow or air pipe above the top of the tank, subject to a minimum of:

- 3,60 m for fuel oil having a flash point below 60°C
- 2,40 m otherwise.

Figure 1 : Symbols used for tanks



1.3.2 Stiffeners

The following symbols and units are used for the stiffeners:

b : Width of the plating element supported by the stiffener, in m

w : Section modulus of the stiffeners, in cm^3.

2 Design and installation of tanks

2.1 Materials

2.1.1 General

Independent fuel oil tanks are to be made of steel except where permitted in [2.1.2].

2.1.2 Use of materials other than steel

a) On ships of less than 100 gross tonnage, independent fuel oil tanks may be made of:

- aluminium alloys or equivalent material, provided that the tanks are located outside the propulsion machinery spaces or, when located within such spaces, they are insulated to A-60 class standard

- glass reinforced plastics (GRP), provided:
  - the total volume of tanks located in the same space does not exceed 4,5 m^3, and
  - the properties of GRP including fire resistance comply with the relevant provisions of Ch 1, App 3.

b) On ships of 100 gross tonnage or more, the use of independent fuel oil tanks made of aluminium alloys or GRP will be given special consideration.

2.2 Scantling of steel tanks

2.2.1 General

a) The scantling of tanks whose dimensions are outside the range covered by the following provisions will be given special consideration.

b) The scantling of the tanks is to be calculated assuming a minimum height h of the overflow or air pipe above the top of the tank of:

- 3,60 m for fuel oil having a flash point below 60°C,
- 2,40 m otherwise.

c) All tanks having plating elements of a length exceeding 2,5 m are to be fitted with stiffeners.

2.2.2 Thickness of plating

The thickness of the plates is not to be less than the value given in Tab 1 for the various values of l, L/l and H. However, for tanks having a volume of more than 1 m^3, the thickness of the plates is not to be less than 5 mm.

2.2.3 Scantlings of stiffeners

a) This requirement applies only to stiffeners which are all vertical or all horizontal and attached according to the types shown in Fig 2. Other cases will be given special consideration.

b) The minimum values of the ratio w/b required for stiffeners are given in:

- Tab 2 for vertical stiffeners
- Tab 3 for horizontal stiffeners

for the different types of attachments shown in Fig 2.

Table 1 : Thickness of plating (mm)

		H (m)													
l (m)	L / l	2,4 - 2,7	2,7 - 3,0	3,0 - 3,3	3,3 - 3,6	3,6 - 4,0	4,0 - 4,4	4,4 - 4,8	4,8 - 5,2	5,2 - 5,8	5,8 - 6,4	6,4 - 7,0	7,0 - 8,0	8,0 - 9,0	9,0 - 10,0
0,40	< 2	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5
	≥ 2	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5
0,45	< 2	3,0	3,0	3,0	3,0	3,0	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	5,0
	≥ 2	3,5	3,5	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	6,0	6,0
0,50	< 2	3,0	3,0	3,5	3,5	3,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
	≥ 2	3,5	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5	7,0
0,55	< 2	3,5	3,5	3,5	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0
	≥ 2	4,0	4,5	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0	7,5
0,60	< 2	3,5	4,0	4,0	4,0	4,0	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,5
	≥ 2	4,5	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0
0,65	< 2	4,0	4,0	4,0	4,0	4,5	4,5	5,0	5,0	5,5	5,5	6,0	6,0	6,5	7,0
	≥ 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,5	8,5
0,70	< 2	4,0	4,0	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,5
	≥ 2	5,0	5,0	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	–
0,75	< 2	4,5	4,5	5,0	5,0	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	8,0
	≥ 2	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	–	–
0,80	< 2	4,5	5,0	5,0	5,0	5,5	6,0	6,0	6,0	6,5	7,0	7,0	7,5	8,0	8,5
	≥ 2	5,5	6,0	6,0	6,5	6,5	7,0	7,5	7,5	8,0	8,5	9,0	–	–	–
0,85	< 2	5,0	5,0	5,5	5,5	5,5	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0
	≥ 2	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,0	8,5	9,0	–	–	–	–
0,90	< 2	5,0	5,5	5,5	6,0	6,0	6,5	6,5	7,0	7,0	7,5	8,0	8,5	9,0	–
	≥ 2	6,5	6,5	7,0	7,0	7,5	8,0	8,5	8,5	9,0	–	–	–	–	–
0,95	< 2	5,5	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	–	–
	≥ 2	6,5	7,0	7,0	7,5	8,0	8,5	9,0	9,0	–	–	–	–	–	–
1,00	< 2	5,5	6,0	6,0	6,5	7,0	7,0	7,5	7,5	8,0	8,5	9,0	–	–	–
	≥ 2	7,0	7,5	7,5	8,0	8,5	8,5	9,0	–	–	–	–	–	–	–

Figure 2 : Type of stiffener end attachments

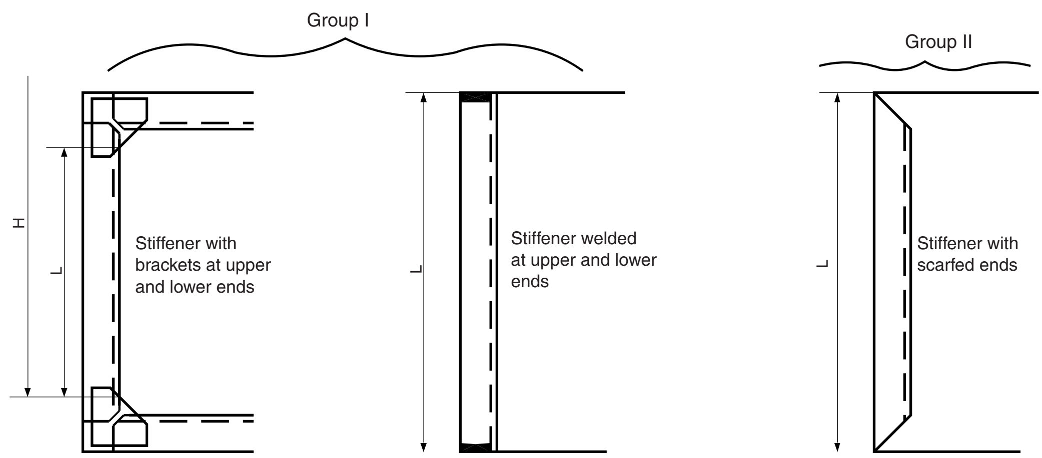


Table 2 : Values of w/b ratio for vertical stiffeners (cm^3/m)

L (m)	end attachment	H, in m **(1)**												
		3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I	5,0	5,5	6,0	6,5	7,5	8,0	9,0	9,5	10,5	11,5	14,0	16,0	18,0
	II	8,0	9,0	10,0	11,0	12,0	12,5	13,0	15,0	16,0	19,0	22,0	25,0	28,0
0,8	I	8,5	9,5	10,5	11,5	13,0	14,0	15,0	16,5	18,0	22,0	25,0	28,0	31,5
	II	13,0	15,0	16,0	18,0	20,0	21,5	24,0	25,5	28,5	34,0	38,0	43,0	48,0
1,0	I		14,5	16,0	17,5	19,5	21,0	23,0	26,0	28,5	34,0	38,0	43,0	49,0
	II		22,0	24,0	27,0	30,0	32,5	36,0	39,0	43,0	51,0	58,0	67,0	75,0
1,2	I			22,5	24,5	28,0	30,0	33,0	37,0	40,5	48,0	55,0	63,0	71,0
	II			34,0	30,7	42,5	46,0	50,0	55,0	61,0	73,0	84,0	96,0	107
1,4	I			30,0	32,5	37,0	40,0	44,0	49,0	55,0	65,0	75,0	85,0	96,0
	II			45,0	49,0	56,0	61,0	67,0	74,0	82,0	98,0	113,0	129,0	144,0
1,6	I				47,0	53,0	57,0	64,0	71,0	79,0	94,0	110,0	125,0	140,0
	II				71,0	80,0	87,0	96,0	107,0	118,0	141,0	165,0	187,0	
1,8	I				58,0	65,0	71,0	79,0	88,0	98,0	117,0	136,0	156,0	175,0
	II				87,0	98,0	107,0	118,0	132,0	147,0	176,0	204,0		
2,0	I					78,0	85,0	95,0	107,0	119,0	142,0	166,0	190,0	
	II					118,0	129,0	142,0	160,0	178,0				
2,2	I						100,0	112,0	126,0	140,0	170,0	198,0		
	II						151,0	168,0	190,0					
2,5	I						124,0	139,0	158,0					
	II						187,0							

(1) H is to be taken equal to the height of the tank top above the lower end of the stiffener, plus h.

2.3 Installation

2.3.1 Securing

Independent tanks are to be securely fixed to hull structures and are to be so arranged as to permit inspection of adjacent structures.

2.3.2 Protection against spillage

Where permitted, independent fuel oil tanks are to be placed in an oil-tight spill tray of ample size with a suitable drain pipe leading to a suitably sized spill oil tank.

Table 3 : Values of w/b ratio for horizontal and top and bottom stiffeners (cm^3/m)

L (m)	end attachment	H, in m **(1)**															
		2,4	2,6	2,8	3,0	3,3	3,6	3,9	4,3	4,6	5,0	5,5	6,0	7,0	8,0	9,0	10,0
0,6	I	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,5	9,0	10,0	11,0	12,0	13,5	15,0	17,0	19,0
	II	7,0	8,0	8,5	9,0	10,0	11,0	11,5	12,5	13,5	15,0	16,0	17,5	21,0	24,0	27,0	30,0
0,8	I	8,0	9,0	9,5	10,0	11,0	12,0	13,0	14,5	15,5	17,0	18,5	20,0	23,5	27,0	30,0	33,5
	II	13,0	15,0	15,5	16,5	18,0	19,5	21,5	23,5	25,0	27,0	30,0	34,0	38,0	44,0	49,0	55,0
1,0	I	13,0	15,0	15,5	16,5	18,0	19,5	21,5	23,5	25,0	27,0	30,0	34,0	38,0	44,0	49,0	55,0
	II	20,0	22,0	23,5	25,0	28,0	30,0	33,0	36,0	39,0	42,0	46,0	50,0	59,0	67,0	75,0	84,0
1,2	I	18,0	20,0	21,0	22,5	25,0	26,5	29,5	32,5	34,5	37,5	41,5	45,0	52,5	60,0	67,5	75,0
	II	28,0	31,0	33,0	35,0	39,0	42,0	46,0	51,0	54,0	59,0	65,0	70,0	82,0	93,0	105	117
1,4	I	26,0	28,0	30,5	32,5	36,0	39,0	42,5	46,5	50,0	54,5	59,5	65,0	76,0	87,0	97,0	108
	II	39,0	43,0	45,5	49,0	54,0	58,5	63,5	70,0	75,0	81,0	89,0	97,0	113	130	146	162
1,6	I	36,0	39,0	42,0	45,0	50,0	54,0	59,0	65,0	69,0	75,0	82,0	90,0	105	120	135	150
	II	56,0	61,0	66,0	70,0	77,0	84,0	91,0	100	107	117	128	140	163	186		
1,8	I	46,0	50,0	54,0	58,0	63,0	69,0	75,0	82,0	88,0	95,0	105	115	134	153	172	191
	II	70,0	76,0	82,0	88,0	96,0	105	113	125	134	146	160	175	204			
2,0	I	57,0	62,0	67,0	72,0	78,0	85,0	92,0	102	109	118	130	142	166	190		
	II	87,0	95,0	102	109	120	130	141	155	166	181	198					
2,2	I	70,0	76,0	82,0	88,0	96,0	105	113	125	134	145	160	175	204			
	II	107	116	125	134	147	160	174	192	205							
2,5	I	92,0	100	108	115	127	138	150	165	176	191						
	II	140	152	163	175	192											

(1) For horizontal stiffeners, H is to be measured from the horizontal stiffener immediately below the stiffener considered.
For top stiffeners, H = h.

Appendix 4 Special Approval of Alloy Steel used for Intermediate Shaft Material

1 General

1.1 Application

1.1.1 This Appendix is applied to the approval of alloy steel which has a minimum specified tensile strength greater than 800 N/mm², but less than 950 N/mm² intended for use as intermediate shaft material.

1.2 Torsional fatigue test

1.2.1 A torsional fatigue test is to be performed to verify that the material exhibits similar fatigue life as conventional steels. The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_C given by the formula of τ_1 in Ch 1, Sec 9, [3.4.2], item b).

The test is to be carried out with notched and unnotched specimens respectively. For calculation of the stress concentration factor of the notched specimen, fatigue strength reduction factor β should be evaluated in consideration of the severest torsional stress concentration in the design criteria.

Note 1: The stress concentration factor (scf) at the end of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{t(hole)} + 0{,}8\frac{(l-e)/d}{\sqrt{\left(1-\frac{d_i}{d}\right)\frac{e}{d}}}$$

This formula applies to:

- slots at 120 or 180 or 360 degrees apart
- slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula
- slots with no edge rounding (except chamfering), as any edge rounding increases the scf slightly.

where:

l	:	Slot length
e	:	Slot width
d	:	Shaft outside diameter
d_i	:	Shaft inside diameter
$\alpha_{t(hole)}$	:	Stress concentration of radial holes (in this context e = hole diameter) and can be determined as:

$$\alpha_{t(hole)} = 2{,}3 - 3\frac{e}{d} + 15\left(\frac{e}{d}\right)^2 + 10\left(\frac{e}{d}\right)^2\left(\frac{d_i}{d}\right)^2$$

or simplified to $\alpha_{t(hole)} = 2{,}3$

For unnotched specimen, scf = 1

1.2.2 Test conditions

Test conditions are to be in accordance with Tab 1. Mean surface roughness, in µm, is to be less than 0,2 Ra with the absence of localised machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352:2011.

Test procedures are to be in accordance with Section 10 of ISO 1352:2011.

Table 1 : Test condition

Loading type	Torsion
Stress ratio	R = –1
Load waveform	Constant-amplitude sinusoidal
Evaluation	S-N curve
Number of cycles for test termination	1 x 10^7 cycles

1.2.3 Acceptance criteria

Measured high-cycle torsional fatigue strength τ_{C1} and low-cycle torsional fatigue strength τ_{C2} are to be equal to or greater than the values given by the following formulae:

$$\tau_{C1} \geq \tau_{C, \lambda = 0} = \frac{\sigma_B + 160}{6} C_K C_D$$

$$\tau_{C2} \geq 1,7 \frac{1}{\sqrt{C_K}} \tau_{C1}$$

where:

C_K : Factor for the particular shaft design features, see Ch 1, Sec 9, Tab 1

C_D : Size factor, see Ch 1, Sec 9, [3.3.2]

σ_B : Specified minimum tensile strength in N/mm^2 of the shaft material.

1.3 Cleanliness requirements

1.3.1 The steels are to have a degree of cleanliness as shown in Tab 2 when tested according to ISO 4967:2013 method A. Representative samples are to be obtained from each heat of forged or rolled products.

The steels are generally to comply with the minimum requirements of NR216, Ch 5, Sec 2, Tab 1, with particular attention given to minimising the concentrations of sulphur, phosphorus and oxygen in order to achieve the cleanliness requirements. The specific steel composition is required to be approved by the Society.

1.4 Inspection

1.4.1 The ultrasonic testing required by NR216, Ch 5, Sec 1, [10.3.1] is to be carried out prior to acceptance. The acceptance criteria are to be in accordance with IACS Recommendation No. 68 or a recognized national or international standard.

Table 2 : Cleanliness requirements

Inclusion group	Series	Limiting chart diagram index I
Type A	Fine	1,0
	Thick	1,0
Type B	Fine	1,5
	Thick	1,0
Type C	Fine	1,0
	Thick	1,0
Type D	Fine	1,0
	Thick	1,0
Type DS	–	1,0

Part C
Machinery, Systems and Fire Protection

CHAPTER 2
ELECTRICAL INSTALLATIONS

Section 1 General

1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to electrical installations on ships. In particular, they apply to the components of electrical installations for essential services.

The other parts of the installation are to be so designed as not to introduce any malfunction to the ship and hazard to personnel.

1.2 References to other regulations and standards

1.2.1 The Society may refer to other regulations and standards when deemed necessary. These include the IEC publications, notably the IEC 60092 series.

It is to be noted however that, where the prescriptive requirements in the present Rules and such standards are not aligned, the prescriptive requirements in the present Rules take precedence and are to be applied.

1.2.2 When referred to by the Society, publications by the International Electrotechnical Commission (IEC) or other internationally recognized standards, are those currently in force at the date of agreement for ship classification.

2 Documentation to be submitted

2.1

2.1.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documents to be submitted

No	I/A **(1)**	Document
1	A	Single line diagram of main power and lighting systems
2	A	Electrical power balance
3	A	Calculation of short-circuit currents for each installation in which the sum of rated power of the energy sources which may be connected contemporaneously to the network is greater than 500 kVA (kW)
4	A	List of circuits including, for each supply and distribution circuit, data concerning the nominal current, the cable type, length and cross-section, nominal and setting values of the protective and control devices
5	A	Single line diagram and detailed diagram of the main switchboard
6	A	Single line diagram and detailed diagram of the emergency switchboards
7	A	Diagram of the most important section boards and motor control centres (above 100 kW)
8	A	Diagram of the supply, monitoring and control systems of propulsion motors and generator prime movers
9	A	Diagram of the supply, monitoring and control systems of the rudder propellers
10	A	Diagram of the supply, monitoring and control systems of controllable pitch propellers
11	A	Diagram of the general emergency alarm system and of the intercommunication systems requested in Ch 4, Sec 8, [1.1.2]
12	A	Detailed diagram of the navigation-light switchboard
13	A	Diagram of the remote stop system (ventilation, fuel pump, fuel valves, etc.)
14	A **(2)**	Selectivity and coordination of the electrical protection
15	A	Single line diagram of electrical propulsion system
16	A	Principles of control system and power supply of electrical propulsion system
17	A	Alarm and monitoring system including, for electrical propulsion system: • list of alarms and monitoring points • power supply diagram.

(1) A = to be submitted for approval ; I = to be submitted for information.
(2) For high voltage installations.
(3) For electric propulsion installations.

No	I/A **(1)**	Document
18	A	Safety system including, for electrical propulsion system: • list of monitored parameters for safety system • power supply diagram.
19	I **(3)**	Arrangements and details of the propulsion control consoles and panels
20	I **(3)**	Arrangements and details of electrical coupling
21	I **(3)**	Arrangements and details of the frequency converters together with the justification of their characteristics
22	I **(3)**	Arrangements of the cooling system provided for the frequency converters and motor enclosure
23	I **(3)**	Measurements of voltage signal form for converters directly connected to high voltage (HV) network
24	I **(3)**	Computation of permanent and transitory voltage drops of LV and HV networks
25	A **(3)**	Test program for converters and rotating machines having rated power > 1 MW, dock and sea trials
(1) A = to be submitted for approval ; I = to be submitted for information. **(2)** For high voltage installations. **(3)** For electric propulsion installations.		

3 Definitions

3.1 General

3.1.1 Unless otherwise stated, the terms used in this Chapter have the definitions laid down by the IEC standards.

The definitions given in the following requirements also apply.

3.2 Essential services

3.2.1 Essential services are defined in Pt A, Ch 1, Sec 1, [1.2.1]. They are subdivided in primary and secondary essential services defined in [3.3] [3.4].

3.3 Primary essential services

3.3.1 Primary essential services are those which need to be maintained in continuous operation.

Primary essential services are services such as:

- steering gear
- actuating systems of controllable pitch propellers
- scavenging air blowers, fuel oil supply pumps, fuel valve cooling pumps, lubricating oil pumps and cooling water pumps for main and auxiliary engines and turbines necessary for the propulsion
- forced draught fans, feed water pumps, water circulating pumps, condensate pumps, oil burning installations, for steam plants or steam turbines ship, and also for auxiliary boilers on ship where steam is used for equipment supplying primary essential services
- azimuth thrusters which are the sole means for propulsion/steering with lubricating oil pumps, cooling water pumps
- electrical equipment for electric propulsion plant with lubricating oil pumps and cooling water pumps
- electric generators and associated power sources supplying the above equipment
- hydraulic pumps supplying the above equipment
- viscosity control equipment for heavy fuel oil
- control, monitoring and safety devices/systems for equipment for primary essential services
- speed regulators dependent on electrical energy for main or auxiliary engines necessary for propulsion
- starting equipment of diesel engines and gas turbines
- at least one fire pump, when required to be permanently in operation.

The main lighting system for those parts of the ship normally accessible to and used by personnel is also considered as a primary essential service.

3.4 Secondary essential services

3.4.1 Secondary essential services are those services which need not necessarily be in continuous operation.

Secondary essential services are services such as:

- windlasses
- fuel oil transfer pumps and fuel oil treatment equipment
- lubrication oil transfer pumps and lubrication oil treatment equipment

- preheaters for heavy fuel oil
- sea water pumps
- starting air and control air compressors
- bilge, ballast and heeling pumps
- fire pumps and other fire-extinguishing medium pumps
- ventilation fans for engine and boiler rooms
- services considered necessary to maintain dangerous cargo in a safe condition
- navigation lights, aids and signals
- internal safety communication equipment
- fire detection and alarm systems
- electrical equipment for watertight closing appliances
- electric generators and associated power supplying the above equipment
- hydraulic pumps supplying the above equipment
- control, monitoring and safety for cargo containment systems
- control, monitoring and safety devices/systems for equipment for secondary essential services
- ammunition elevators
- cooling system of environmentally controlled spaces, see Ch 2, Sec 12, [1.4].

3.5 Services for habitability

3.5.1 Services for habitability are those intended for minimum comfort conditions for people on board, and specially in engine control room, safety room and operation control room.

Examples of equipment for maintaining conditions of habitability:

- cooking
- heating
- domestic refrigeration
- mechanical ventilation
- sanitary and fresh water
- electric generators and associated power sources supplying the above equipment.

3.6 Safety voltage

3.6.1 A voltage which does not exceed 50 V a.c. r.m.s. between conductors, or between any conductor and earth, in a circuit isolated from the supply by means such as a safety isolating transformer.

3.6.2 A voltage which does not exceed 50 V d.c. between conductors or between any conductor and earth in a circuit isolated from higher voltage circuits.

3.7 Low-voltage systems

3.7.1 Alternating current systems with rated voltages greater than 50 V r.m.s. up to 1000 V r.m.s. inclusive and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 50 V up to 1500 V inclusive.

3.8 High-voltage systems

3.8.1 Alternating current systems with rated voltages greater than 1000 V r.m.s. and direct current systems with a maximum instantaneous value of the voltage under rated operating conditions greater than 1500 V.

3.9 Basic insulation

3.9.1 Insulation applied to live parts to provide basic protection against electric shock.

Note 1: Basic insulation does not necessarily include insulation used exclusively for functional purposes.

3.10 Supplementary insulation

3.10.1 Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

3.11 Double insulation

3.11.1 Insulation comprising both basic insulation and supplementary insulation.

3.12 Reinforced insulation

3.12.1 A single insulation system applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation.

Note 1: The term "single insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

3.13 Earthing

3.13.1 The earth connection to the general mass of the hull of the ship in such a manner as will ensure at all times an immediate discharge of electrical energy without danger.

3.14 Normal operational and habitable condition

3.14.1 A condition under which the ship as a whole, the machinery, services, means and aids ensuring propulsion, ability to steer, safe navigation, pay load, fire and flooding safety, internal and external communications and signals, means of escape, and emergency boat winches, as well as the designed comfortable conditions of habitability are in working order and functioning normally.

3.15 Emergency condition

3.15.1 A condition under which any services needed for normal operational and habitable conditions are not in working order due to failure of the main source of electrical power.

3.16 Main source of electrical power

3.16.1 A source intended to supply electrical power to a main switchboard for distribution to all services necessary for maintaining the ship in normal operational and habitable condition.

3.17 Dead ship condition

3.17.1 The condition under which the main propulsion plant, boilers and auxiliaries are not in operation due to the absence of power.

Note 1: Dead ship condition is a condition in which the entire machinery installation, including the power supply, is out of operation and the auxiliary services such as compressed air, starting current from batteries etc., for bringing the main propulsion into operation and for the restoration of the main power supply are not available.

3.18 Main generating station

3.18.1 The space in which a main source of electrical power is situated.

3.19 Main switchboard

3.19.1 A switchboard which is directly supplied by a main source of electrical power and is intended to distribute electrical energy to the ship's services.

3.20 Emergency switchboard

3.20.1 A switchboard which in the event of failure of the main electrical power supply system is directly supplied by the emergency source of electrical power or the transitional source of emergency electrical power and is intended to distribute electrical energy to the emergency services.

3.21 Emergency source of electrical power

3.21.1 A source of electrical power, intended to supply the emergency switchboard in the event of failure of the supply from the main electrical power supply system.

3.22 Section boards

3.22.1 A switchgear and controlgear assembly which is supplied by another assembly and arranged for the distribution of electrical energy to other section boards or distribution boards.

3.23 Distribution board

3.23.1 A switchgear and controlgear assembly arranged for the distribution of electrical energy to final sub-circuits.

3.24 Final sub-circuit

3.24.1 That portion of a wiring system extending beyond the final required overcurrent protective device of a board.

3.25 Hazardous areas

3.25.1 Areas in which an explosive atmosphere is present, or may be expected to be present due to the presence of vapours, gases, flammable dusts or explosives in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

3.25.2 Hazardous areas are classified in zones based upon the frequency and the duration of the occurrence of explosive atmosphere.

3.25.3 Hazardous areas for explosive gas atmosphere are classified in the following zones:
- zone 0: an area in which an explosive gas atmosphere is present continuously or is present for long periods
- zone 1: an area in which an explosive gas atmosphere is likely to occur in normal operation
- zone 2: an area in which an explosive gas atmosphere is not likely to occur in normal operation and if it does occur, is likely to do only infrequently and will exist for a short period only.

3.26 High fire risk areas

3.26.1 The high fire risk areas are defined as follows:

a) machinery spaces as defined in Ch 4, Sec 1, [2.21], except spaces having little or no fire risk as defined by category (10) of Ch 4, Sec 5, [1.2.3], item b) 2)

b) spaces containing fuel treatment equipment and other highly flammable substances

c) galleys and pantries containing cooking appliances

d) laundry with drying equipment

e) spaces as defined in Ch 4, Sec 5, [1.2.3], item b) 2), as:
   - (8) accommodation spaces of greater fire risk
   - (12) machinery spaces and main galleys
   - (14) special purpose spaces
   - (15) ammunition spaces or other equivalent spaces

f) enclosed or semi-enclosed hazardous spaces, in which certified safe type electric equipment is required.

3.27 Certified safe-type equipment

3.27.1 Certified safe-type equipment is electrical equipment of a type for which a national or other appropriate authority has carried out the type verifications and tests necessary to certify the safety of the equipment with regard to explosion hazard when used in an explosive gas atmosphere.

3.28 Environmental categories

3.28.1 Electrical equipment is classified into environmental categories according to the temperature range, vibration levels, and resistance to chemically active substances and to humidity.

The designation of the environmental categories is indicated by the EC Code i Tab 2.

The first characteristic numeral indicates the temperature range in which the electrical equipment operates satisfactorily, as specified in Tab 3.

The second characteristic numeral indicates the vibration level in which the electrical equipment operates satisfactorily, as specified in Tab 4.

3.28.2 The tests for verifying the additional and supplementary letters and the characteristic numeral of the environmental categories are defined in Ch 3, Sec 6.

Table 2 : EC Code

Code letter	First characteristic numeral	Second characteristic numeral	Additional letter	Supplementary letter
EC	(numerals 1 to 4)	(numerals 1 to 3)	(letter S) **(1)**	(letter C) **(2)**

(1) The additional letter S indicates the resistance to salt mist (exposed decks, masts) of the electrical equipment.
(2) The supplementary letter C indicates the relative humidity up to 80% (air conditioned areas) in which the electrical equipment operates satisfactorily.

Table 3 : First characteristic numeral

First characteristic numeral	Brief description of location	Temperature range °C	
1	Air conditioned areas	+ 5	+ 40
2	Enclosed spaces	+ 5	+ 45
3	Inside consoles or close to combustion engines and similar	+ 5	+ 55
4	Exposed decks, masts	– 25	+ 45

Table 4 : Second characteristic numeral

Second characteristic numeral	Brief description of location	Frequency r ange Hz	Displacement amplitude (mm)	Acceleration amplitude g
1	Machinery spaces, command and control stations, accommodation spaces, exposed decks, cargo spaces	from 2,0 to 13,2 from 13,2 to 100	1,0 –	– 0,7
2	Masts	from 2,0 to 13,2 from 13,2 to 50	3,0 –	– 2,1
3	On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 –	– 4,0

Section 2 General Design Requirements

1 Environmental conditions

1.1 General

1.1.1 The electrical components of installations are to be designed and constructed to operate satisfactorily under the environmental conditions on board.

In particular, the conditions shown in the tables in this Article are to be taken into account.

Note 1: The environmental conditions are characterised by:

- one set of variables including climatic conditions (e.g. ambient air temperature and humidity), biological conditions, conditions dependent upon chemically active substances (e.g. salt mist) or mechanically active substances (e.g. dust or oil), mechanical conditions (e.g. vibrations or inclinations) and conditions dependent upon electromagnetic noise and interference, and
- another set of variables dependent mainly upon location on vessels, operational patterns and transient conditions.

1.2 Ambient air temperatures

1.2.1 For ships classed for unrestricted navigation, the ambient air temperature ranges shown in Tab 1 are applicable in relation to the various locations of installation.

Table 1 : Ambient air temperature

Location	Temperature range (°C)	
Enclosed spaces	+ 5	+ 45
Inside consoles or fitted on combustion engines and similar	+ 5	+ 55
Air conditioned areas	+ 5	+ 40
Exposed decks	– 25	+ 45

1.2.2 For ships classed for service in specific zones, the Society may accept different ranges for the ambient air temperature (e.g. for ships operating outside the tropical belt, the maximum ambient air temperature may be assumed as equal to + 40°C instead of + 45°C).

1.3 Humidity

1.3.1 For ships classed for unrestricted service, the humidity ranges shown in Tab 2 are applicable in relation to the various locations of installation.

Table 2 : Humidity

Location	Humidity
General	95% at 55°C
Air conditioned areas	Different values may be considered on a case by case basis

1.4 Cooling water temperatures

1.4.1 The temperatures shown in Tab 3 are applicable to ships classed for unrestricted service.

Table 3 : Water temperature

Coolant	Temperature range (°C)	
Sea water	0	+ 32

1.4.2 For ships classed for service in specific zones, the Society may accept different values for the cooling water temperature (e.g. for ships operating outside the tropical belt, the maximum cooling water temperature may be assumed as equal to + 25°C instead of + 32°C).

1.5 Salt mist

1.5.1 The applicable salt mist content in the air is to be 1 mg/m^3.

1.6 Inclinations

1.6.1 The inclinations applicable are those shown in Tab 4.

The Society may consider deviations from these angles of inclination taking into consideration the type, size and service conditions of the ships.

1.7 Vibrations

1.7.1 In relation to the location of the electrical components, the vibration levels given in Tab 5 are to be assumed. The necessary damping elements on machinery supports will be fitted to reach this level.

1.7.2 The natural frequencies of the equipment, their suspensions and their supports are to be outside the frequency ranges specified.

Where this is not possible using a suitable constructional technique, the equipment vibrations are to be dumped so as to avoid unacceptable amplifications.

1.8 Shock

1.8.1 When required by the Naval Authority and in general for front line ships, shock levels are to be evaluated.

1.8.2 Electrical components are to be so designed, manufactured and installed that they are capable of operating satisfactorily under shock conditions.

1.8.3 This capability may be achieved through their own characteristics or through particular installation arrangements.

Table 4 : Inclination of ship

Type of machinery, equipment or component	Angles of inclination, in degrees **(1)**			
	Athwartship		Fore-and-aft	
	static	dynamic **(3)**	static	dynamic **(4)**
Machinery and equipment relative to main electrical power installation	15,0	22,5	5,0	7,5
Machinery and equipment relative to the emergency power installation, safety systems of the ship (e.g. emergency source of power, emergency fire pumps, etc.)	22,5	22,5	10,0	10,0
Switchgear and associated electrical and electronic components and remote control systems **(2)**	22,5	22,5	10,0	10,0

(1) Athwartship and fore-and-aft angles may occur simultaneously in their most unfavourable combination.
(2) No undesired switching operations or functional changes may occur up to an angle of inclination of 45°.
(3) The period of dynamic inclination may be assumed equal to 10 s.
(4) The period of dynamic inclination may be assumed equal to 5 s.

Table 5 : Vibration levels

Location	Frequency range (Hz)	Displacement amplitude (mm)	Acceleration amplitude g
Machinery spaces, command and control stations, accommodation spaces, exposed decks	from 2,0 to 13,2 from 13,2 to 100	0,25 –	– 0,2
On air compressors, on diesel engines and similar	from 2,0 to 25,0 from 25,0 to 100	1,6 –	– 4,0
Masts	from 2,0 to 13,2 from 13,2 to 50	1,0 –	– 0,7

Table 6 : Voltage and frequency variations of power supply in a.c.

Parameter	Variations	
	Continuous	Transient
Voltage	+ 6% – 10%	± 20% (recovery time: 1,5 s)
Frequency	± 5%	± 10% (recovery time: 5 s)

Note 1: For alternating current components supplied by emergency generating sets, different variations may be considered.

2 Quality of power supply

2.1 General

2.1.1 All electrical components are to be so designed and manufactured that they are capable of operating satisfactorily under the variations of voltage, frequency and harmonic distortion of the power supply specified from [2.2] to [2.4].

2.2 A.c. distribution systems

2.2.1 For alternating current components the voltage and frequency variations of power supply shown in Tab 6 are to be assumed.

2.3 D.c. distribution systems

2.3.1 For direct current components voltage variations of power supply shown in Tab 7 are to be assumed.

Table 7 : Voltage variations of power supply in d.c.

Parameters	Variations
Voltage tolerance (continuous)	± 10%
Voltage cyclic variation	5%
Voltage ripple (a.c. r.m.s. over steady d.c. voltage)	10%

2.3.2 For direct current components supplied by electrical battery the following voltage variations are to be assumed:

- + 30% to – 25% for components connected to the battery during charging (see Note 1)
- + 20% to – 25% for components not connected to the battery during charging.

Note 1: Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered.

2.4 Harmonic distortions

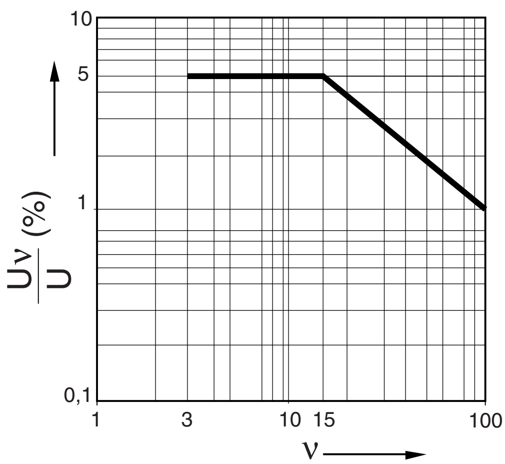
2.4.1 For components intended for systems without substantially static converter loads and supplied by synchronous generators, it is assumed that the total voltage harmonic distortion does not exceed 5%, and the single harmonic does not exceed 3% of the nominal voltage.

2.4.2 For components intended for systems fed by static converters, and/or systems in which the static converter load predominates, it is assumed that:

- the single harmonics do not exceed 5% of the nominal voltage up to the 15th harmonic of the nominal frequency, decreasing to 1% at the 100th harmonic (see Fig 1), and that
- the total harmonic distortion does not exceed 8%.

2.4.3 Higher values for the harmonic content (e.g. in electric propulsion plant systems) may be accepted on the basis of correct operation of all electrical devices.

Figure 1 :



3 Electromagnetic susceptibility

3.1

3.1.1 For electronic type components such as sensors, alarm panels, automatic and remote control equipment, protective devices and speed regulators, the conducted and radiated disturbance levels to be assumed are those given in Part C, Chapter 3.

Note 1: See also IEC Publication 60533 - "Electromagnetic Compatibility of Electrical and Electronic Installations in Ships and of Mobile and Fixed Offshore Units".

4 Materials

4.1 General

4.1.1 In general, and unless it is adequately protected, all electrical equipment is to be constructed of durable, flame-retardant, moisture-resistant materials which are not subject to deterioration in the atmosphere and at the temperatures to which they are likely to be exposed. Particular consideration is to be given to sea air and oil vapour contamination.

Note 1: The flame-retardant and moisture-resistant characteristics may be verified by means of the tests cited in IEC Publication 60092-101 or in other recognised standards.

4.1.2 Where the use of incombustible materials or lining with such materials is required, the incombustibility characteristics may be verified by means of the test cited in IEC Publication 60092-101 or in other recognized standards.

4.2 Insulating materials for windings

4.2.1 Insulated windings are to be resistant to moisture, sea air and oil vapour unless special precautions are taken to protect insulants against such agents.

4.2.2 The insulation classes given in Tab 8 may be used in accordance with IEC Publication 60085.

Table 8 : Insulation Classes

Class	Maximum continuous operating temperature (°C)
A	105
E	120
B	130
F	155
H	180

4.3 Insulating materials for cables

4.3.1 See Ch 2, Sec 9, [1.3].

5 Construction

5.1 General

5.1.1 All electrical apparatus is to be so constructed as not to cause injury when handled or touched in the normal manner.

5.1.2 The design of electrical equipment is to allow accessibility to each part that needs inspection or adjustment, also taking into account its arrangement on board.

5.1.3 Enclosures are to be of adequate mechanical strength and rigidity.

5.1.4 Enclosures for electrical equipment are generally to be of metal; other materials may be accepted for accessories such as connection boxes, socket-outlets, switches and luminaires. Other exemptions for enclosures or parts of enclosures not made of metal will be specially considered by the Society.

5.1.5 Cable entrance are not to impair the degree of protection of the relevant enclosure (see Ch 2, Sec 3, Tab 3).

5.1.6 All nuts and screws used in connection with current-carrying parts and working parts are to be effectively locked.

5.1.7 All equipment is generally to be provided with suitable, fixed terminal connectors in an accessible position for convenient connection of the external cables.

5.2 Degree of protection of enclosures

5.2.1 Electrical equipment is to be protected against the ingress of foreign bodies and water.

The minimum required degree of protection, in relation to the place of installation, is generally that specified in Ch 2, Sec 3, Tab 3.

5.2.2 The degrees of protection are to be in accordance with:

- IEC Publication No. 60529 for equipment in general
- IEC Publication No. 60034-5 for rotating machines.

5.2.3 For cable entries see [5.1.5].

6 Protection against explosion hazard

6.1 Protection against explosive gas or vapour atmosphere hazard

6.1.1 Electrical equipment intended for use in areas where explosive gas or vapour atmospheres may occur, is to be of a "safe type" suitable for the relevant flammable atmosphere and for shipboard use.

6.1.2 The following “certified safe type” equipment is considered:

- intrinsically-safe: Ex(ia) - Ex(ib)
- flameproof: Ex(d)
- increased safety: Ex(e)
- pressurised enclosure: Ex(p)
- encapsulated: Ex(m)
- sand filled: Ex(q)
- special protection: Ex(s)
- oil-immersed apparatus (see Note 1): Ex(o)

Note 1: Only when required by the application.

6.1.3 Other equipment complying with types of protection other than those in [6.1.2] may be considered by the Society, such as:

- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules
- electrical apparatus specifically designed and certified by the appropriate authority for use in Zone 0 or specially tested for Zone 2 (e.g. type “n” protection)
- equipment the type of which ensures the absence of sparks and arcs and of “hot spots” during its normal operation
- pressurised equipment
- equipment having an enclosure filled with a liquid dielectric, or encapsulated.

6.2 Protection against combustible dust hazard

6.2.1 Electrical appliances intended for use in areas where a combustible dust hazard may be present are to be arranged with enclosures having a degree of protection and maximum surface temperature suitable for the dust to which they may be exposed.

Note 1: Where the characteristics of the dust are unknown, the appliances are to have a degree of protection IP6X. For most dusts a maximum surface temperature of 135°C is considered adequate.

Section 3 System Design

1 Supply systems and characteristics of the supply

1.1 Supply systems

1.1.1 The following distribution systems may be used:

a) on d.c. installations:
- two-wire insulated
- two-wire with one pole earthed

b) on a.c. installations:
- three-phase three-wire with neutral insulated
- three-phase three-wire neutral directly earthed or through impedance
- three-phase four-wire neutral directly earthed or through impedance
- single-phase two-wire insulated
- single-phase two-wire with one phase earthed.

1.1.2 The hull return system of distribution is not to be used.

1.1.3 The requirement of [1.1.2] does not preclude under conditions approved by the Society the use of:

a) impressed current cathodic protective systems

b) insulation level monitoring devices provided the circulation current does not exceed 30 mA under the most unfavourable conditions.

1.1.4 For the supply systems in HV installations, see Ch 2, Sec 13.

1.1.5 When required by the Naval Authority, for the supply of weapon system and shore supply, the STANAG standard 1008 NAV is to be applied. Mainly, the distribution systems to be of the three phase three wires with neutral insulated.

1.2 Maximum voltages

1.2.1 The maximum voltages for both alternating current and direct current low-voltage systems of supply for the ship's services are given in Tab 1.

Table 1 : Maximum voltages for various ship services

Use		Maximum voltage V
For permanently installed and connected to fixed wiring	Power equipment Cooking equipment Lighting Space heaters in accommodation spaces Control**(1)**, communication (including signal lamps) and instrumentation equipment	1000 500 250 250 250
For permanently installed and connected by flexible cable	Power and heating equipment, where such connection is necessary because of the application (e.g. for moveable cranes or other hoisting gear)	1000
For socket-outlets supplying	Portable appliances which are not hand-held during operation (e.g. refrigerated containers) by flexible cables Portable appliances and other consumers by flexible cables Equipment requiring extra precaution against electric shock where an isolating transformer is used to supply one appliance **(2)(3)** Equipment requiring extra precaution against electric shock with or without a safety transformer **(2)(3)**	1000 250 250 50

(1) For control equipment which is part of a power and heating installation (e.g. pressure or temperature switches for starting/stopping motors), the same maximum voltage as allowed for the power and heating equipment may be used provided that all components are constructed for such voltage. However, the control voltage to external equipment is not to exceed 500 V.
(2) Both conductors in such systems are to be insulated from earth.
(3) Equipment located in narrow and wet spaces such as machinery spaces provided with bilge spaces.

1.2.2 Voltages exceeding those shown will be specially considered in the case of specific systems.

1.2.3 For high voltage systems see Ch 2, Sec 13.

2 Sources of electrical power

2.1 General

2.1.1 Electrical installations are to be such that:

a) All electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions will be assured without recourse to the emergency source of electrical power

b) Electrical services essential for safety will be assured under various emergency conditions

c) When a.c. generators are involved, attention is to be given to the starting of squirrel-cage motors connected to the system, or other pay load consumers having pulse loads, particularly with regard to the effect of the magnitude and duration of the transient voltage change produced due to the maximum starting or pulse currents and the power factor. The voltage drop due to such currents is not to cause any motor already operating to stall or have any adverse effect on other equipment in use.

2.2 Main source of electrical power

2.2.1 A main source of electrical power is to be provided, of sufficient capability to supply all electrical auxiliary services necessary for maintaining the ship in normal operational and habitable conditions without recourse to the emergency source of electrical power.

2.2.2 For vessels propelled by electrical power and having two or more constant voltage propulsion generating sets which constitute the source of electrical energy for the ship's auxiliary services, see Ch 2, Sec 14.

2.2.3 When only one main source of electrical power is provided, it is to consist of at least two generating sets.

The capacity of the main generating sets is to be such that in the event of any one generating set being stopped it will still be possible to supply those services necessary to provide normal operational conditions.

Such capacity is, in addition, to be sufficient to start the largest motor and to supply pay-load consumers having pulse loads without causing any other motor to stop or having any adverse effect on other equipment in operation.

2.2.4 For the purpose of calculating the necessary capacity, it is essential to consider which consumers can be expected to be in use simultaneously, in the various operational conditions of the ship.

For a duplicated service, one being supplied electrically and the other non-electrically (see Note 1) (e.g. driven by the main engine), the electrical capacity is not included in the above calculation.

Note 1: It is assumed that the consumers not electrically driven are capable to operate satisfactorily in all conditions.

2.2.5 The services in [2.2.4] do not include:

- thrusters not forming part of the main propulsion or dynamic positioning system
- refrigerators for air conditioning other than air refrigerator systems for satisfactory operation of essential services.

2.2.6 Further to the provisions above, the generating sets shall be such as to ensure that with any one generator or its primary source of power out of operation, the remaining generating sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a "dead ship" condition.

2.2.7 The arrangement of the ship's main sources of electrical power shall be such that essential services can be maintained regardless of the speed and direction of rotation of the main propulsion machinery or shafting.

2.2.8 Generators driven by the propulsion plant (shaft generators) which are intended to operate at constant speed (e.g. a system where vessel speed and direction are controlled by varying propeller speed) may be accepted as forming part of the main source of electrical power if, in all sailing and manoeuvring conditions, and including the propeller being stopped, the capacity of these generators is sufficient to provide the electrical power to comply with [2.2.3] and all further requirements, especially those of [2.2.6]. They are to be not less effective and reliable than the independent generating sets.

2.2.9 Shaft generator installations which do not comply with the provisions of [2.2.8] may be used as additional sources of electrical power with respect to the power balance provided that:

a) in the event of a loss of power from the shaft generator(s), e.g. due to a sudden stopping of the propulsion plant, a standby generating set is started automatically

b) the capacity of the standby set is sufficient for the loads necessary for propulsion and safety of the vessel

c) the time required to restore these services is not longer than 45 s.

2.2.10 Where transformers, converters or similar appliances constitute an essential part of the electrical supply system, the system is to be so arranged as to ensure the same continuity of supply as stated in this sub-article.

This may be achieved by arranging at least two three-phase or three single-phase transformers so that with any one transformer not in operation, the remaining transformer(s) is (are) sufficient to ensure the supply to the services stated in [2.2.3].

Each transformer required is to be located as a separate unit with separate enclosure or equivalent.

Where single phase transformers are used, only one spare element is required for each different type of transformer if special precautions are taken to rapidly replace the faulty one.

2.2.11 For ships having qualified automation systems, see Part E, Chapter 4.

2.2.12 For starting arrangements for main generating sets, see Ch 1, Sec 2, [3.1].

2.2.13 Generators and generator systems, having the ship propulsion machinery as their prime mover but not forming part of the ship main source of electrical power, may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that:

a) there are sufficient and adequately rated additional generators fitted, which constitute the main source of electrical power required by [2.2.1]

b) arrangements are fitted to automatically start one or more of the generators, constituting the main source of electrical power required by [2.2.1], upon the frequency variations exceeding 10% of the limits specified below

c) within the declared operating range of the generators and/or generator systems the specified limits for the voltage variations and the frequency variations in Ch 2, Sec 2 can be met

d) the short circuit current of the generator and/or generator system is sufficient to trip the generator/generator system circuit-breaker taking into account the selectivity of the protective devices for the distribution system

e) where considered appropriate, load shedding arrangements are to be fitted

f) on ships having remote control of the ship's propulsion machinery from the navigating bridge, means are provided, or procedures be in place, so as to ensure that supplies to essential services are maintained during manoeuvring conditions in order to avoid a blackout situation.

2.3 Emergency source of electrical power

2.3.1 A self-contained emergency source of electrical power shall be provided, except where:

a) The main sources of electrical power are located in two or more compartments that are not contiguous with each other and separated in such a way to ensure the supply to the emergency services also in case of flooding of the maximum number of contiguous compartments according to stability regulation (see Part B), and

b) Each source has its own independent self contained systems, including power distribution and control systems such that a fire in any one of the compartments or other casualty including the flooding of the maximum number of contiguous compartments according to stability regulation as above, will not affect the power distribution from the other main sources, or to the services required by [3.5.3], and

c) There is at least one generating set complying with the requirements from [2.3.4] to [2.3.14] and of sufficient capacity to meet the requirements of [3.5.3] in at least two non-contiguous (as prescribed above) compartments, and

d) The generator sets referred to in item c) and their self contained systems are installed such that one of them remains operable after damage or flooding in any one compartment.

2.3.2 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

Exceptionally is understood to mean conditions, while the vessel is at sea, such as:

a) blackout situation

b) dead ship situation

c) routine use for testing

d) short-term parallel operation with the main source of electrical power for the purpose of load transfer.

Unless otherwise instructed by the Society, the emergency generator may be used during lay time in port for the supply of the ship mains, provided the requirements of [2.4] are complied with.

2.3.3 The electrical power available shall be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously.

2.3.4 The emergency source of electrical power shall be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the services stated in [3.5.3] for the period specified, if they depend upon an electrical source for their operation.

2.3.5 The transitional source of emergency electrical power, where required, is to be of sufficient capacity to supply at least the services for the time stated in [3.5.6], if they depend upon an electrical source for their operation.

2.3.6 An indicator shall be mounted in a suitable place, in a continuously manned control position (e.g. platform control room), to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged.

2.3.7 If the services which are to be supplied by the transitional source receive power from an accumulator battery by means of semiconductor convertors, means are to be provided for supplying such services also in the event of failure of the convertors (e.g. providing a bypass feeder or a duplication of convertors).

2.3.8 Where electrical power is necessary to restore propulsion, the capacity of the emergency source shall be sufficient to restore propulsion to the ship in conjunction to other machinery as appropriate, from a dead ship condition within 30 min. after blackout.

For the purpose of this requirement only, the dead ship condition and blackout are both understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation and in restoring the propulsion, no stored energy for starting the propulsion plant, the main source of electrical power and other essential auxiliaries is to be assumed available. It is assumed that means are available to start the emergency generator at all times.

The emergency generator and other means needed to restore the propulsion are to have a capacity such that the necessary propulsion starting energy is available within 30 minutes of blackout/dead ship condition as defined above. Emergency generator or the other means stored starting energy is not to be directly used for starting the propulsion plant.

For steam ships, the 30 minute time limit given can be interpreted as time from blackout/dead ship condition defined above to light-off the first boiler.

2.3.9 Provision shall be made for the periodic testing of the complete emergency system and shall include the testing of automatic starting arrangements, where provided.

2.3.10 For starting arrangements for emergency generating sets, see Ch 1, Sec 2, [3.1].

2.3.11 The emergency source of electrical power may be either a generator or an accumulator battery which shall comply with the requirements of [2.3.12] or [2.3.13], respectively.

2.3.12 Where the emergency source of electrical power is a generator, it shall be:

a) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43°C

b) started automatically upon failure of the electrical supply to the emergency switchboard from the main source of electrical power and shall be automatically connected to the emergency switchboard; those services referred to in [3.5.6] shall then be transferred automatically to the emergency generating set. The automatic starting system and the characteristic of the prime mover shall be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 s, and

c) provided with a transitional source of emergency electrical power according to [2.3.14].

2.3.13 Where here the emergency source of electrical power is an accumulator battery, it shall be capable of:

a) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage

b) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power, and

c) immediately supplying at least those services specified in [3.5.6].

2.3.14 The transitional source of emergency electrical power required by [2.3.12] c) shall consist of an accumulator battery which shall operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage and be so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power at least the services in [3.5.6] if they depend upon an electrical source for their operation.

2.4 Use of emergency generator in port

2.4.1 To prevent the generator or its prime mover from becoming overloaded when used in port, arrangements are to be provided to shed sufficient non-emergency loads to ensure its continued safe operation.

2.4.2 The prime mover is to be arranged with fuel oil filters and lubrication oil filters, monitoring equipment and protection devices as requested for the prime mover for main power generation and for unattended operation.

2.4.3 The fuel oil supply tank to the prime mover is to be provided with a low level alarm, arranged at a level ensuring sufficient fuel oil capacity for the emergency services for the period of time as required in [3.5].

2.4.4 The prime mover is to be designed and built for continuous operation and should be subjected to a planned maintenance scheme ensuring that it is always available and capable of fulfilling its role in the event of an emergency at sea.

2.4.5 Fire detectors are to be installed in the location where the emergency generator set and emergency switchboard are installed.

2.4.6 Means are to be provided to readily change over to emergency operation.

2.4.7 Control, monitoring and supply circuits for the purpose of the use of the emergency generator in port are to be so arranged and protected that any electrical fault will not influence the operation of the main and emergency services.

When necessary for safe operation, the emergency switchboard is to be fitted with switches to isolate the circuits.

2.4.8 Instructions are to be provided on board to ensure that, even when the vessel is underway, all control devices (e.g. valves, switches) are in a correct position for the independent emergency operation of the emergency generator set and emergency switchboard.

These instructions are also to contain information on the required fuel oil tank level, position of harbour/sea mode switch, if fitted, ventilation openings, etc.

3 Distribution

3.1 Earthed distribution systems

3.1.1 System earthing is to be effected by means independent of any earthing arrangements of the non-current-carrying parts.

3.1.2 Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance or insulation resistance measurements.

3.1.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage wave form of each generator does not exceed 5%.

3.1.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

3.1.5 Where for final sub-circuits it is necessary to locally connect a pole (or phase) of the sub-circuits to earth after the protective devices (e.g. in automation systems or to avoid electromagnetic disturbances), provision (e.g. d.c./d.c. convertors or transformers) is to be made such that current unbalances do not occur in the individual poles or phases.

3.1.6 For high voltage systems see Ch 2, Sec 13.

3.2 Insulated distribution systems

3.2.1 Every insulated distribution system, whether primary or secondary (see Note 1), for power, heating or lighting, shall be provided with a device capable of continuously monitoring the insulation level to earth (i.e. the values of electrical insulation to earth) and of giving an audible and visual indication of abnormally low insulation values (see Ch 2, Sec 15).

Note 1: A primary system is one supplied directly by generators. Secondary systems are those supplied by transformers or convertors.

3.2.2 For high voltage systems see Ch 2, Sec 13.

3.3 General requirements for distribution systems

3.3.1 The distribution system is to be such that the failure of any single circuit will not endanger or impair essential services.

3.3.2 No common switchgear (e.g. contactors for emergency stop) is to be used between the switchboard's bus-bars and two duplicated essential services.

3.3.3 The system shall be so arranged that the electrical supply will be maintained or immediately restored in the case of loss of any one of the generators in service. Automatic restart of equipment necessary for propulsion and steering and to ensure safety of the ship is also to be provided.

3.3.4 Arrangements are to be provided to prevent overloading of the generating set(s) supplying the electrical power that is/are required to maintain the ship in a normal operational and habitable condition.

On loss of electrical power, arrangements are to be made for a standby generator set to be automatically started, automatically connected to the switchboard within 30 seconds after loss of power, and essential services restarted in as short a time as is practicable.

These load restart functions may be achieved by the actions of suitably trained personnel but in ships with **AUT-QAS**, **AUT-IAS** notations the arrangements are to be automatic.

Where prime movers with longer starting time are used, this starting and connection time may be exceeded upon approval from the Society.

3.3.5 Automatic load shedding or other equivalent arrangements are to be provided to protect the generators against sustained over-load.

3.3.6 The non-essential services, service for habitable conditions may be shed to ensure the connected generator set or generator sets are not overloaded.

3.4 Main distribution of electrical power

3.4.1 Where more than one main generator is connected to a main switchboard, the main bus-bar is to be divided into at least two parts which are normally to be connected by circuit breakers or other approved means such as circuit breakers without tripping mechanisms or disconnecting switches by means of which bus-bars can be split safely and easily.

The connection of generating sets, associated auxiliaries and other duplicated equipment is to be equally divided between the parts as far as practicable, so that in the event of damage to one section of the switchboard the remaining parts are still supplied.

The same applies in case of main switchboards supplied by one generating set and connected to another main switchboard, being this connection considered as a connection of a second generator.

3.4.2 Two or more units serving the same consumer (e.g. main and standby lubricating oil pumps) are to be supplied by individual separate circuits without the use of common feeders, protective devices or control circuits. This requirement is satisfied when such units are supplied by separate cables from the a main switchboard or from two independent section boards.

3.4.3 A main electric lighting system, which is to provide illumination throughout those parts of the ship normally accessible to and used by personnel, is to be supplied from the main sources of electrical power.

3.5 Emergency distribution of electrical power

3.5.1 The emergency switchboard shall be supplied during normal operation from the main switchboard by an interconnector feeder which shall be adequately protected at the main switchboard against overload and short-circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power.

Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short-circuit.

3.5.2 In order to ensure ready availability of the emergency source of electrical power, arrangements shall be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that power shall be available to the emergency circuits.

3.5.3 The emergency source of electrical power shall be capable of supplying simultaneously at least the following services for the periods specified hereafter, if they depend upon an electrical source for their operation:

a) for a period of 3 hours, emergency lighting at every muster and embarkation station and over the sides;

b) for a period of 18 hours, emergency lighting unless, when an electrical distribution by zones is adopted, alternative arrangements are provided by movable lamps having their own dedicated accumulator batteries for at least 3 hours operation that in normal condition are continuously charged:

   1) in all service and accommodation alleyways, stair-ways and exits, personnel lift cars and personnel lift trunks

   2) in the machinery spaces and main generating stations including their control positions

   3) in all control stations including platform control room and combat system control rooms, machinery control rooms, and at each main and emergency switchboard

   4) at all stowage positions for firemen’s outfits

   5) at the steering gear, and

   6) at the fire pump referred to in e) below, at the sprinkler pump, if any, at the emergency bilge pump, if any, and at the starting positions of their motors

c) for a period of 18 hours:

   1) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force and/or by the Naval Authority

   2) the radio installation and external communication systems required by SOLAS and or by the Naval Authority

d) for a period of 18 hours:

   1) all internal communication equipment as required in an emergency [3.5.4]

   2) the shipborne navigational equipment as required by SOLAS and or by the Naval Authority, including those for flight assistance

   3) the fire detection and fire alarm systems, and

   4) intermittent operation of the daylight signalling lamp, the ship’s whistle, the manually operated call points and all internal signals (see [3.5.5]) that are required in an emergency, unless such services have an independent supply for the period of 18 hours from an accumulator battery suitably located for use in an emergency

e) for a period of 18 hours:
   1) One or more of the fire pumps listed in Ch 4, Sec 6, [1.3] allowing to face a fire in any machinery space
   2) the automatic sprinkler pump, if any, and
   3) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves
f) for the period of time required in Ch 1, Sec 12, the steering gear where it is required to be so supplied
g) for a period of half an hour, any watertight doors required to be power operated together with their indicators and warning signals
h) equipment necessary for ship's self defence or a selection of apparatus of the pay load to be defined case by case by the Naval Authority.

3.5.4 Internal communication equipment required in an emergency generally includes:

a) the means of communication between the navigating bridge and the steering gear compartment
b) the means of communication between the navigating bridge and the position in the machinery space or control room from which the engines are normally controlled
c) the means of communication for fire fighting and damage control
d) the means of communication for combat system operation
e) the public address system.

3.5.5 Internal signals required in an emergency generally include:

a) general alarm
b) watertight door alarm and indication system.

3.5.6 The transitional source of emergency electrical power shall supply for half an hour at least the following services if they depend upon an electrical source for their operation:

a) the lighting required by [3.5.3], items a), b) and c)1), for this transitional phase, the required emergency electric lighting, in respect of the machinery space and the accommodation and service spaces may be provided by individual, automatically charged, relay operated accumulator lamps, and
b) all services required by [3.5.3], items d) 1), d) 3) and d) 4) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

It is also to supply power to close the watertight doors, but not necessarily all of them simultaneously, unless an independent temporary source of stored energy is provided and powers the control, indication and alarm circuits, for half an hour.

3.6 Shore/Ship supply

3.6.1 Arrangements are to be made for supplying the electrical installation from a source on shore or elsewhere. At least a suitable connection box is to be installed on the ship in a convenient location to receive the flexible cable from outside.

3.6.2 Permanently fixed cables of adequate rating are to be provided for connecting the box to the main distribution system.

3.6.3 Where necessary for systems with earthed neutrals, the box is to be provided with an earthed terminal for connection between the shore's/ship's and ship's neutrals or for connection of a protective conductor.

3.6.4 The connection box is to contain a circuit-breaker or a switch-disconnector and fuses.

The shore connection is to be protected against short-circuit and overload; however, the overload protection may be omitted in the connection box if provided on the main switchboard.

3.6.5 Means are to be provided for checking the phase sequence of the incoming supply in relation to the ship's system.

3.6.6 The cable connection to the box is to be provided with at least one switch-disconnector on the main switch-board.

3.6.7 The shore connection is to be provided with an indicator at the main switchboard in order to show when the cable is energized.

3.6.8 At the connection box a notice is to be provided giving full information on the nominal voltage and frequency of the installation.

3.6.9 The switch-disconnector on the main switchboard is to be interlocked with the main generator circuit-breakers in order to prevent its closure when any generator is supplying the main switchboard.

3.6.10 Adequate means are to be provided to equalize the potential between the hull and the shore when the electrical installation of the ship is supplied from shore.

3.7 Supply of motors

3.7.1 A separate final sub-circuit is to be provided for every motor required for an essential service (and for every motor rated at 1 kW or more).

3.7.2 Each motor is to be provided with controlgear ensuring its satisfactory starting.

Depending on the capacity of the generating plant or the cable network, it may be necessary to limit the starting current to an acceptable value.

Direct on line starters are accepted if the voltage drop does not exceed 15% of the network voltage.

3.7.3 Efficient means are to be provided for the isolation of the motor and its associated control gear from all live poles of the supply.

Where the control gear is mounted on or adjacent to a switchboard, a disconnecting switch in the switchboard may be used for this purpose.

Otherwise, a disconnecting switch within the control gear enclosure or a separate enclosed disconnecting switch is to be provided.

3.7.4 Where the starter or any other apparatus for disconnecting the motor is remote from the motor itself, one of the following is to be arranged:

a) provision for locking the circuit disconnecting switch in the OFF position
b) an additional disconnecting switch fitted near the motor
c) provision such that the fuses in each live pole or phase can be readily removed and retained by persons authorized to have access to the motor.

3.8 Specific requirements for special power services

3.8.1 For the supply and characteristics of the distribution of the following services see the requirements listed:

- steering gear: Ch 1, Sec 12
- fire-extinguishing and detecting systems: Ch 4, Sec 13
- permanently installed submerged bilge pump: [9.7]
- ventilation fans: Ch 4, Sec 2, [2.1.2]
- fuel pumps: Ch 1, Sec 10
- pumps discharging overboard above the lightest waterline and in way of the area of lifeboat and liferaft launching: Ch 1, Sec 10, [5.2.4].

3.8.2 All power circuits terminating in a bunker or cargo space are to be provided with a multiple-pole switch out-side the space for disconnecting such circuits.

3.9 Power supply to heaters

3.9.1 Each heater rated more than 16 A is to be connected to a separate final circuit.

3.10 Power supply to lighting installations

3.10.1 Final sub-circuits for lighting supplying more than one lighting point and socket outlets are to be fitted with protective devices having a current rating not exceeding 16 A.

3.10.2 Final sub-circuits for socket-outlets are to be fitted with protective devices having a current rating not exceeding 10 A.

3.11 Special lighting services

3.11.1 In spaces such as:

- main and large machinery spaces
- large galleys
- passageways
- stairways leading to boat-decks
- public spaces
- operation control room.

there is to be more than one final sub-circuit for lighting such that failure of any one circuit does not reduce the lighting to an insufficient level.

3.11.2 Where the emergency installation is required, one of the circuits in [3.11.1] may be supplied from the emergency source of power.

3.11.3 All lighting circuits terminating in a bunker or dry holds are to be provided with a multiple-pole switch outside the space for disconnecting such circuits.

3.11.4 A vessel is to be designed so as, at night, without fog or rain, when observed 500 meters away from a vessel:

- no light is to be seen with bare eye
- direct or indirect lighted surface is not to be more visible than the non lighted hull surface.

In addition, when observed 500 meters away from a aircraft, in the same condition as above:

- no light is to be seen with bare eye
- all lighted surface is not to be more visible than the lighted deck
- no part of the sea surface in the vicinity of the hull is to be more lighted than the hull.

3.11.5 A red lighting is to be provided in the following locations:

- all alleyways leading to outside spaces, and used for personnel on duty
- all rooms and acces leading directly to the outside spaces without airlock
- all airlocks for external access.

The red lighting is to be maximum 2 Lux on the floor in passageway and 5 lux where reading is necessary.

3.12 Navigation and signalling lights

3.12.1 Navigation and signalling lights are to be connected separately to a distribution board specially reserved for this purpose.

3.12.2 The distribution board in [3.12.1] is to be supplied from two alternative circuits, one from the main source of power and one from the emergency source of power; see also [3.5].

The transfer of supply is to be practicable from the bridge, for example by means of a switch.

3.12.3 Each navigation light is to be controlled and protected in each insulated pole by a double-pole switch and a fuse or, alternatively, by a double-pole circuit-breaker, fitted on the distribution board referred to in [3.12.1].

3.12.4 Where there are double navigation lights, i.e. lights with two lamps or where for every navigation light a spare is also fitted, the connections to such lights may run in a single cable provided that means are foreseen in the distribution board to ensure that only one lamp or light may be supplied at any one time.

3.12.5 Each navigation light is to be provided with an automatic indicator giving audible and/or visual warning in the event of failure of the light. If an audible device alone is fitted, it is to be connected to a separate source of supply from that of the navigation lights, for example an accumulator (storage) battery.

If a visual signal is used connected in series with the navigation light, means are to be provided to prevent the extinction of the navigation light due to the failure of the visual signal.

A minimum level of visibility is to be assured in the case of use of dimmer devices on the signalling panel. On request of the Naval Authority, dimmering of navigation and signalling lights may be accepted.

3.13 General emergency alarm system

3.13.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal, is to comply with the requirements of this sub-article. General emergency alarm systems installed on ships having the service notation **aircraft carrier** are also to comply with the requirements of Pt D, Ch 2, Sec 4, [4.1].

3.13.2 The general emergency alarm system is to be supplemented by either a public address system complying with the requirements in [3.14] or other suitable means of communication.

3.13.3 Entertainment sound system is to be automatically turned off when the general alarm system is activated.

3.13.4 The system is to be continuously powered and is to have an automatic change-over to a standby power supply in case of loss of normal power supply.

An alarm is to be given in the event of failure of the normal power supply.

3.13.5 The system is to be powered by means of two circuits, one from the ship's main supply and the other from the emergency source of electrical power required by [2.3] and [3.5].

3.13.6 The system is to be capable of operation from the navigation bridge and, except for the ship's whistle, also from other strategic points

Note 1: Other strategic points are taken to mean those locations, other than the navigation bridge, from where emergency situations are intended to be controlled and the general alarm system can be activated. A fire control station or a platform control room should normally be regarded as strategic points.

3.13.7 The alarm is to continue to function after it has been triggered until it is manually turned off or is temporarily interrupted by a message on the public address system.

3.13.8 The alarm system is to be audible throughout all the accommodation and normal crew working spaces during normal operational condition.

3.13.9 For cables used for the general emergency alarm system, see [9.6].

3.14 Public address system

3.14.1 The public address system is to be a loudspeaker installation enabling the broadcast of messages into all spaces where people on board are normally present.

If not feasible, adequate additional visual indication is to be provided to indicate that a message is being broadcasted.

3.14.2 Where the public address system is used to supplement the general emergency alarm system as per [3.13.2], it is to be continuously powered from the emergency source of electrical power required by [2.3] and [3.5].

3.14.3 The system is to allow for the broadcast of messages from the navigation bridge and from other strategic points as above.

3.14.4 The system is not to require any action from the addressee.

3.14.5 Where an individual loudspeaker has a device for local silencing, an override arrangement from the control station(s), including the navigating bridge, is to be in place.

3.15 Combined general emergency alarm - public address system

3.15.1 Where the public address system is the only means for sounding the general emergency alarm signal and the fire alarm, in addition to the requirements of [3.13] and [3.14], the following are to be satisfied:

- the system automatically overrides any other input system when an emergency alarm is required
- the system automatically overrides any volume control provided to give the required output for the emergency mode when an emergency alarm is required
- the system is arranged to prevent feedback or other interference
- the system is arranged to minimize the effect of a single failure so that the alarm signal is still audible (above ambient noise levels) also in the case of failure of any one circuit or component, by means of the use of:
  - multiple amplifiers
  - segregated cable routes to public rooms, alleyways, stairways and control stations
  - more than one device for generating electronic sound signal
  - electrical protection for individual loudspeakers against short-circuits.

3.16 Control and indication circuits

3.16.1 For the supply of automation systems, including control, alarm and safety system, see the requirements of Part C, Chapter 3.

3.16.2 Control and indicating circuits relative to essential services are to be branched off from the main circuit in which the relevant equipment is installed. Equivalent arrangements may be accepted by the Society.

3.16.3 Control and indicating circuits relative to non-essential services may be supplied by distribution systems reserved for the purpose to the satisfaction of the Society.

3.17 Power supply to the speed control systems of main propulsion engines

3.17.1 Electrically operated speed control systems of main engines are to be fed from the main source of electrical power.

3.17.2 Where more than one main propulsion engine is foreseen, each speed control system is to be provided with an individual supply by means of separate wiring from the main switchboard or from two independent section boards.

Being the main busbars divided into two sections, the governors are, as far as practicable, to be supplied equally from the two sections.

3.17.3 In the case of propulsion engines which do not depend for their operation on electrical power, i.e. pumps driven from the main engine, the speed control systems are to be fed both from the main source of electrical power and from an accumulator battery for at least 15 minutes or from a similar supply source.

Such battery may also be used for other services such as automation systems, where foreseen.

3.18 Power supply to the speed control systems of generator sets

3.18.1 Each electrically operated control and/or speed control system of generator sets is to be provided with a separate supply from a main source of electric power and from an accumulator battery for at least 15 minutes or from a similar supply source.

3.18.2 The wiring supplying a main source of electrical power is to be from the main switchboard or from independent section boards.

Being the main busbars divided into two sections, the governors are, as far as practicable, to be supplied from the sections to which the relevant generators are connected.

3.19 Harmonic distortion for ship electrical distribution system including harmonics filters

3.19.1 Where harmonic filters are installed on main busbars of electrical distribution system, other than those installed for single application frequency drives such as pump motors, the ships are to be fitted with facilities to continuously monitor the levels of harmonic distortion experienced on the main busbar. The crew is to be alerted when the level of harmonic distortion exceed the acceptable limits.

3.19.2 Where the electrical distribution system on board a ship includes harmonic filters the system integrator of the distribution system is to show, by calculation, the effect of a failure of a harmonic filter on the level of harmonic distortion experienced.

3.19.3 The system integrator of the distribution system is to provide the Society, for information, with guidance documenting permitted modes of operation of the electrical distribution system while maintaining harmonic distortion levels within acceptable limits during normal operation as well as following the failure of any combination of harmonic filters.

3.19.4 Arrangements are to be provided to alert the crew in the event of activation of the protection of a harmonic filter circuit.

3.19.5 A harmonic filter is to be arranged as a three phase unit with individual protection of each phase. The activation of the protection arrangement in a single phase is to result in automatic disconnection of the complete filter.

3.19.6 A current unbalance detection system, independent of the overcurrent protection, is to be provided in order to alert the crew in case of current unbalance.

3.19.7 Additional protection for the individual capacitor element as e.g. relief valve or overpressure disconnector in order to protect against damage from rupturing may be considered, depending on the type of capacitors used.

4 Degrees of protection of the enclosures

4.1 General

4.1.1 The minimum required degree of protection for electrical equipment, in relation to the place of installation, is generally that specified in Tab 2.

The degree of protection of control panels intended for specific equipment and of consoles is to be at least IP 20 and evaluated case by case by the Society with the agreement of the Naval Authority.

4.1.2 In addition to the requirements of this paragraph, equipment installed in spaces with an explosion hazard is also subject to the provisions of Ch 2, Sec 2, [6].

4.1.3 The enclosures of electrical equipment for the monitoring and control of watertight doors which are situated below the bulkhead deck are to provide suitable protection against the ingress of water.

In particular, the minimum required degree of protection is to be:

- IPX7 for electric motors, associated circuits and control components
- IPX8 for door position indicators and associated circuit components
- IPX6 for door movement warning signals.

Note 1: The water pressure testing of the enclosures protected to IPX8 is to be based on the pressure that may occur at the location of the component during flooding for a period of 18 hours.

4.1.4 Equipment supplied at nominal voltages in excess of 500 V and accessible to non-authorized personnel (e.g. equipment not located in machinery spaces or in locked compartments under the responsibility of the ship's officers) is to have a degree of protection against touching live parts of at least IP 4X.

Table 2 : Minimum required degrees of protection

Condition in location	Example of location	Switchboard, control gear, motor starters	Generators	Motors	Transformers	Luminaires	Heating appliances	Cooking appliances	Socket outlets	Accessories (e.g. switches, connection boxes)
Danger of touching live parts only	Dry accommodation spaces, dry control rooms	IP 20	X**(1)**	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20	IP 20
Danger of dripping liquid and/or moderate mechanical damage	Control rooms, wheel-house, radio room	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22
	Engine and boiler rooms above floor	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Steering gear rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Emergency machinery rooms	IP 22	IP 22	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	General storerooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 22	IP 44
	Pantries	IP 22	X	IP 22	IP 22	IP 22	IP 22	IP 22	IP 44	IP 44
	Provision rooms	IP 22	X	IP 22	IP 22	IP 22	IP 22	X	IP 44	IP 44
	Ventilation ducts	X	X	IP 22	X	X	X	X	X	X
Increased danger of liquid and/or mechanical damage	Bathrooms and/or showers	X	X	X	X	IP 34	IP 44	X	IP 55	IP 55
	Engine and boiler rooms below floor	X	X	IP 44	X	IP 34	IP 44	X	X	IP 55
	Closed fuel oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
	Closed lubricating oil separator rooms	IP 44	X	IP 44	IP 44	IP 34	IP 44	X	X	IP 55
Increased danger of liquid and mechanical damage	Ballast pump rooms	IP 44	X	IP 44 **(2)**	IP 44**(2)**	IP 34	IP 44	X	IP 55	IP 55
	Refrigerated rooms	X	X	IP 44	X	IP 34	IP 44	X	IP 55	IP 55
	Galleys and laundries	IP 44	X	IP 44	IP 44	IP 34	IP 44	IP 44	IP 44	IP 44
	Public bathrooms and shower	X	X	IP 44	IP 44	IP 34	IP 44	X	IP 44	IP 44
Danger of liquid spraying, presence of cargo dust, serious mechanical damage, aggressive fumes	Shaft or pipe tunnels in double bottom	IP 55	X	IP 55	IP 55	IP 55	IP 55	X	IP 56	IP 56
	Holds for general cargo	X	X	IP 55	X	IP 55	IP 55	X	IP 56	IP 56
	Ventilation trunks	X	X	IP 55	X	X	X	X	X	X
Danger of liquid in massive quantities	Open decks	IP 56	X	IP 56	X	IP 55	IP 56	X	IP 56	IP 56

(1) The symbol "X" denotes equipment which it is not advised to install.
(2) Electric motors and starting transformers for lateral thrust propellers located in spaces similar to ballast pump rooms may have degree of protection IP 22.

4.2 Installation of electrical and electronic equipment in engine rooms protected by fixed water-based local application fire-fighting systems (FWBLAFFS)

4.2.1 Unless it is essential for safety or operational purposes, electrical and electronic equipment is not to be located within areas protected by FWBLAFFS and in adjacent areas where water may extend.

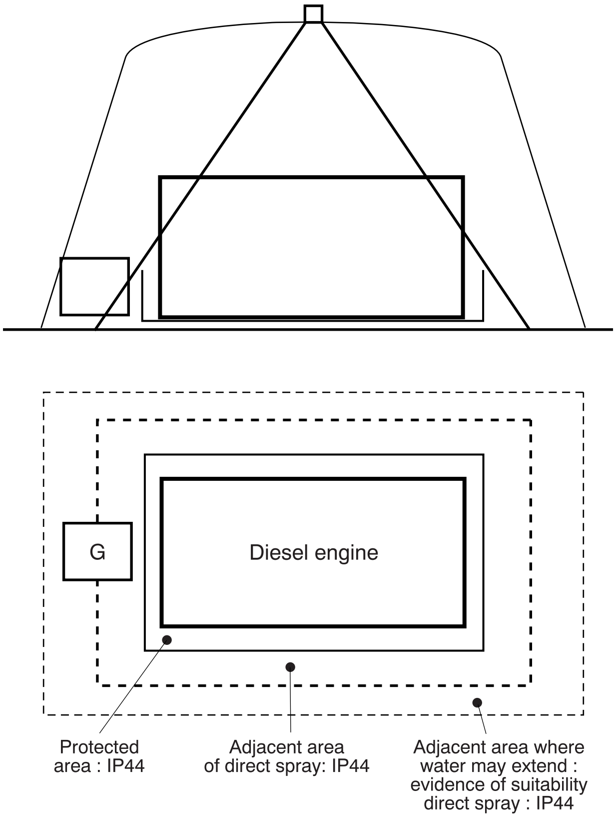
The electrical and electronic equipment located within areas protected by FWBLAFFS and those within adjacent exposed to direct spray are to have a degree of protection not less than IP44.

Electrical and electronic equipment within adjacent areas not exposed to direct spray may have a lower degree of protection provided evidence of suitability for use in these areas is submitted taking into account the design and equipment layout, e.g. position of inlet ventilation openings, filters, baffles, etc. to prevent or restrict the ingress mist/spray into the equipment. The cooling airflow for the equipment is to be assured.

Note 1: Definitions (see Fig 1):

- protected space: machinery space where a FWBLAFFS is installed
- protected areas: areas within a protected space which is required to be protected by FWBLAFFS
- adjacent areas:
  - areas other those protected areas, exposed
  - areas other those defined above, where water may extend.

Figure 1 : Definitions of areas



Note 2: Additional precautions may be required to be taken in respect of:

- tracking as the result of water entering the equipment
- potential damage as the result of residual salts from sea water systems
- high voltage installations
- personnel protection against electric shock.

Equipment may require maintenance after being subjected to water mist/spray.

5 Diversity (demand) factors

5.1 General

5.1.1 The cables and protective devices of final sub-circuits are to be rated in accordance with their connected load.

5.1.2 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justifiable, to the application of a diversity (demand) factor.

5.1.3 A diversity (demand) factor may be applied provided that the known or anticipated operating conditions in a particular part of an installation are suitable for the application of diversity.

6 Environmental categories of the equipment

6.1 Environmental categories

6.1.1 The environmental categories of the electrical equipment, in relation to the place of installation, are generally to be those specified in Tab 3.

Table 3 : Required environmental categories

Main areas on board	Location within main area			
	General	Inside cubicles, desks, etc.	On machinery such as internal combustion engines, compressors	Masts
Machinery spaces	EC21	EC31	EC23	X **(1)**
Steering gear	EC23	EC33	X	X
Control room, Accommodation, bridge	EC21 EC11C	EC31	X	X
Pump room, holds, rooms with no heating	EC41	X	X	X
Exposed Decks	EC41S	X	X	EC42S
(1) The symbol "X" denotes locations which are generally not applicable.				

7 Electrical protection

7.1 General requirements for overcurrent protection

7.1.1 Electrical installations are to be protected against accidental overcurrents including short-circuit.

The choice, arrangement and performance of the various protective devices are to provide complete and coordinated automatic protection in order to ensure as far as possible:

- continuity of service in the event of a fault, through coordinated and discriminative action of the protective devices, up to the second level of the main switchboard
- elimination of the effects of faults to reduce damage to the system and the hazard of fire as far as possible.

Note 1: An overcurrent is a current exceeding the nominal current.

Note 2: A short-circuit is the accidental connection by a relatively low resistance or impedance of two or more points in a circuit which are normally at different voltages.

7.1.2 Devices provided for overcurrent protection are to be chosen according to the requirements, especially with regard to overload and shortcircuit.

Note 1: Overload is an operating condition in an electrically undamaged circuit which causes an overcurrent.

7.1.3 Systems are to be such as to withstand the thermal and electrodynamic stresses caused by the possible overcurrent, including short-circuit, for the admissible duration.

7.2 Short-circuit currents

7.2.1 In calculating the maximum prospective short-circuit current, the source of current is to include the maximum number of generators which can be simultaneously connected (as far as permitted by any interlocking arrangements), and the maximum number of motors which are normally simultaneously connected in the system.

The maximum number of generators or transformers is to be evaluated without taking into consideration short-term parallel operation (e.g. for load transfer) provided that suitable interlock is foreseen.

7.2.2 Short-circuit current calculations are to be performed in accordance with a method recognized by the Society, such as that given in IEC Publication 60363.

7.2.3 In the absence of precise data concerning the characteristics of generators, accumulator batteries and motors, the maximum short-circuit currents on the main bus-bars may be calculated as follows:

- for alternating current systems:

  $I_{ac} = 10\ I_{TG} + 3{,}5\ I_{TM}$

  $I_{pk} = 2{,}4\ I_{ac}$

- for direct current systems supplied by batteries:

  $I_p = K\,C_{10} + 6\,I_{TM}$

where:

I_p : Maximum short-circuit current

I_{ac} : r.m.s. value of the symmetrical component (at the instant T/2)

I_{pk} : Maximum peak value

I_{TG} : Rated current of all generators which can be connected simultaneously

C_{10} : Battery capacity in Ah for a discharge duration of 10 hours

K : Ratio of the short-circuit current of the batteries to C_{10} (see Note 1)

I_{TM} : Rated current of all motors which are normally simultaneously connected in the system.

Note 1: For stationary batteries the following values may be assumed for guidance:

- vented lead-acid batteries: K = 8
- vented alkaline type batteries intended for discharge at low rates corresponding to a battery duration exceeding three hours: K = 15
- sealed lead-acid batteries having a capacity of 100 Ah or more or alkaline type batteries intended for discharge at high rates corresponding to a battery duration not exceeding three hours: K = 30.

7.3 Selection of equipment

7.3.1 Circuit-breakers of withdrawable type are required where they are not suitable for isolation and on main and emergency switchboards.

7.3.2 Equipment is to be chosen on the basis of its rated current and its making/breaking capacity.

7.3.3 In the selection of circuit-breakers with intentional short-time delay for short-circuit release, those of utilization category B are to be used and they are to be selected also taking into account their rated short-time withstand current capacity (I_{cw}).

For circuit-breakers without intentional short-time delay for short-circuit release, circuit breakers of utilization category A may be used and they are to be selected according to their rated service short-circuit breaking capacity (I_{cs}).

Note 1: For the purpose of these Rules, utilization categories A and B are defined as follows:

- Utilization category A: circuit-breakers not specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. without an intentional short-time delay provided for selectivity under short-circuit conditions
- Utilization category B: circuit-breakers specifically intended for selectivity under short-circuit conditions with respect to other short-circuit protective devices in series on the load side, i.e. with an intentional short-time delay (which may be adjustable) provided for selectivity under short-circuit conditions.

7.3.4 For non-essential services and duplicated essential services, circuit-breakers may be selected according to their ultimate short-circuit breaking capacity (I_{cu}).

7.3.5 For switches, the making/breaking capacity is to be in accordance with utilization category AC-22 A or DC-22 A (in compliance with IEC Publication 60947-3).

7.3.6 For fuse-switch disconnectors or switch-disconnector fuse units, the making/breaking capacity is to be in accordance with utilization categories AC-23 A or DC-23 A (in compliance with IEC Publication 60947-3).

7.4 Protection against short-circuit

7.4.1 Protection against short-circuit currents is to be provided by circuit- breakers or fuses.

7.4.2 The rated short-circuit breaking capacity of every protective device is to be not less than the maximum prospective value of the short-circuit current at the point of installation at the instant of contact separation.

7.4.3 The rated short-circuit making capacity of every mechanical switching device intended to be capable of being closed on short-circuit is to be not less than the maximum value of the short-circuit current at the point of installation.

On alternating current this maximum value corresponds to the peak value allowing for maximum asymmetry.

7.4.4 Every protective device or contactor not intended for short-circuit interruption is to be adequate for the maximum short-circuit current liable to occur at the point of installation having regard to the time required for the short-circuit to be removed.

7.4.5 The use of a protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point where it is installed is not permitted in general.

Nevertheless, this solution may be accepted upon agreement of the Naval Authority, and provided that the following are complied with:

- the protective device not having a short-circuit breaking or making capacity at least equal to the maximum prospective short-circuit current at the point is backed up on the generator side by a fuse or by a circuit-breaker having at least the necessary short-circuit rating and not being the generator circuit-breaker
- the same fuse or circuit-breaker is not to back up more than one circuit-breaker, except for circuits relevant to non essential services
- the short-circuit performance of the back-up arrangement is to be equal to the requirements of IEC Publication 60947-2 for a single circuit-breaker having the same short-circuit performance category as the backed-up circuit-breaker and rated for the maximum prospective short-circuit level at the supply terminals of the arrangement.

7.4.6 Circuit-breakers with fuses connected to the load side may be used, provided the back-up fuses and the circuit-breakers are of coordinated design, in order to ensure that the operation of the fuses takes place in due time so as to prevent arcing between poles or against metal parts of the circuit-breakers when they are submitted to overcurrents involving the operation of the fuse.

7.4.7 When determining the performance requirements for the above-mentioned back-up protection arrangement, it is permissible to take into account the impedance of the various circuit elements of the arrangement, such as the impedance of a cable connection when the backed-up circuit-breaker is located away from the back-up breaker or fuse.

7.5 Continuity of supply and continuity of service

7.5.1 Selectivity is to be ensured as far as practicable.

7.5.2 The protection is to be so arranged that the circuit under failure is the only one isolated from the network and a fault in one service does not cause the loss of any other essential services.

7.5.3 Selectivity is not strictly required for groups of consumers when the failure of one of them jeopardizes the operation of the whole system to which it belongs.

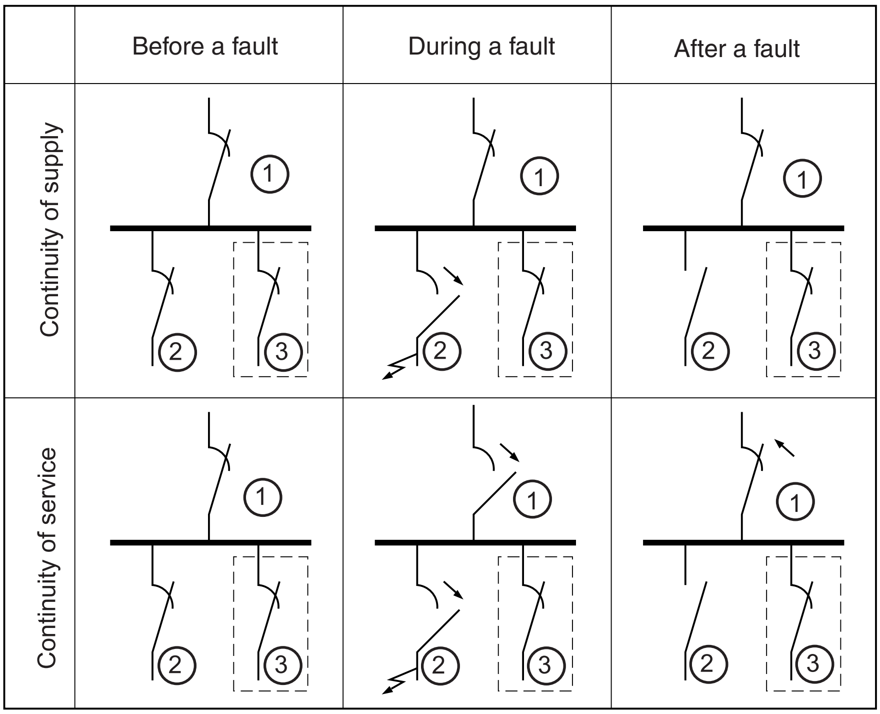
7.5.4 The protection of the emergency circuit is to be such that a failure in one circuit does not cause a loss of other emergency services.

7.6 Protection against overload

7.6.1 Devices provided for overload protection are to have a tripping characteristic (overcurrent-trip time) adequate for the overload ability of the elements of the system to be protected and for any discrimination requirements.

7.6.2 The use of fuses up to 320 A for overload protection is permitted.

Figure 2 :



7.7 Localization of over-current protection

7.7.1 Short-circuit protection is to be provided for every non-earthed conductor.

7.7.2 Overload protection is to be provided for every non-earthed conductor; nevertheless, in insulated single-phase circuits or insulated three-phase circuits having substantially balanced loads, the overload protection may be omitted on one conductor.

7.7.3 Short-circuit and overload protective devices are not to interrupt earthed conductors, except in the case of multiple disconnection devices which simultaneously interrupt all the conductors, whether earthed or not.

7.7.4 Electrical protection is to be located as close as possible to the origin of the protected circuit.

7.8 Protection of generators

7.8.1 Generators are to be protected against short-circuits and overloads by multipole circuit-breakers.

7.8.2 Where a circuit-breaker is used:

a) the overload protection is to trip the generator circuit-breaker at an overload between 10% and 50%; for an overload of 50% of the rated current of the generator the time delay is not to exceed 2 minutes; however, the figure of 50% or the time delay of 2 minutes may be exceeded if the construction of the generator permits this

b) the setting of the short-circuit protection is to instantaneously trip the generator circuit-breaker at an overcurrent less than the steady short-circuit current of the generator. Short time delays (e.g. from 0,5 s to 1 s) may be introduced for discrimination requirements in "instantaneous" tripping devices.

7.8.3 For emergency generators the overload protection may, instead of disconnecting the generator automatically, give a visual and audible alarm in a permanently attended space.

7.8.4 After disconnection of a generator due to overload, the circuit-breaker is to be ready for immediate reclosure.

7.8.5 Generator circuit-breakers are to be provided with a reclosing inhibitor which prevents their automatic reclosure after tripping due to a short-circuit.

7.8.6 Generators having a capacity of 1500 kVA or above are to be equipped with a suitable protective device or system which, in the event of a short-circuit in the generator or in the supply cable between the generator and its circuit-breaker, will de-excite the generator and open the circuit-breaker (e.g. by means of differential protection).

7.8.7 Where the main source of electrical power is necessary for the propulsion of the ship, load shedding or other equivalent arrangements are to be provided to protect the generators against sustained overload.

7.8.8 Arrangements are to be made to disconnect or reduce automatically the excess load when the generators are overloaded in such a way as to prevent a sustained loss of speed and/or voltage (see Ch 3, Sec 2, Tab 6). The operation of such device is to activate a visual and audible alarm. A time delay of 5-20 s is considered acceptable.

7.8.9 When an overload is detected the load shedding system is to disconnect automatically, after an appropriate time delay, the circuits supplying the non-essential services and, if necessary, services for maintaining normal habitable conditions.

7.8.10 Alternating current generators arranged to operate in parallel are to be provided with reverse-power protection.

The protection is to be selected in accordance with the characteristics of the prime mover.

The following values are recommended:

- 2-6% of the rated power for turbogenerators
- 8-15% of the rated power for diesel generators.

The reverse-power protection may be replaced by other devices ensuring adequate protection of the prime movers.

7.8.11 Generators are to be provided with an undervoltage protection which trips the breaker if the voltage falls to 70% - 35% of the rated voltage.

For generators arranged for parallel operation, measures are to be taken to prevent the generator breaker from closing if the generator is not generating and to prevent the generator remaining connected to the busbars if voltage collapses.

The operation of the undervoltage release is to be instantaneous when preventing closure of the breaker, but it is to be delayed for selectivity purposes when tripping the breaker.

7.9 Protection of circuits

7.9.1 Each separate circuit shall be protected against short-circuit and against overload, unless otherwise specified in these Rules or where the Society may exceptionally otherwise permit.

7.9.2 Each circuit is to be protected by a multipole circuit-breaker or switch and fuses against overloads and short-circuits.

7.9.3 Circuits for lighting are to be disconnected on both non-earthed conductors; single-pole disconnection of final sub-circuits with both poles insulated is permitted only in accommodation spaces.

7.9.4 The protective devices of the circuits supplying motors are to allow excess current to pass during transient starting of motors.

7.9.5 Final sub-circuits which supply one consumer with its own overload protection (for example motors), may be provided with short-circuit protection only.

7.9.6 Steering gear control circuits are to be provided with short-circuit protection only (see Ch 1, Sec 12).

7.10 Protection of motors

7.10.1 Motors of rating exceeding 1 kW and all motors for essential services are to be protected individually against overload and short-circuit. The short-circuit protection may be provided by the same protective device for the motor and its supply cable (see [7.9.5]).

7.10.2 For motors intended for essential services, the overload protection may be replaced by an overload alarm (for steering gear motors see Ch 1, Sec 12).

7.10.3 The protective devices are to be designed so as to allow excess current to pass during the normal accelerating period of motors according to the conditions corresponding to normal use.

If the current/time characteristic of the overload protection device does not correspond to the starting conditions of a motor (e.g. for motors with extra-long starting period), provision may be made to suppress operation of the device during the acceleration period on condition that the short-circuit protection remains operational and the suppression of overload protection is only temporary.

7.10.4 For continuous duty motors the protective gear is to have a time delay characteristic which ensures reliable thermal protection against overload.

7.10.5 The protective devices are to be adjusted so as to limit the maximum continuous current to a value within the range 105% - 120% of the motor's rated full load current.

7.10.6 For intermittent duty motors the current setting and the delay (as a function of time) of the protective devices are to be chosen in relation to the actual service conditions of the motor.

7.10.7 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor against unacceptable overload in the case of single phasing.

7.10.8 Motors rated above 1 kW are to be provided with:

- undervoltage protection, activated by the reduction or failure of voltage, to cause and maintain the interruption of power in the circuit until the motor is deliberately restarted or
- undervoltage release, activated by the reduction or failure of voltage, so arranged that the motor restarts automatically when power is restored after a power failure.

7.10.9 The automatic restart of a motor is not to produce a starting current such as to cause excessive voltage drop.

In the case of several motors required to restart automatically, the total starting current is not to cause an excessive voltage drop or sudden surge current; to this end, it may be necessary to achieve a sequence start.

7.10.10 The undervoltage protective devices are to allow the motor to be started when the voltage exceeds 85% of the rated voltage and are to intervene without fail when the voltage drops to less than approximately 20% of the rated voltage, at the rated frequency and with a time delay as necessary.

7.11 Protection of storage batteries

7.11.1 Batteries are to be protected against overload and short-circuit by means of fuses or multipole circuit-breakers at a position adjacent to the battery compartment.

Overcurrent protection may be omitted for the circuit to the starter motors when the current drawn is so large that is impracticable to obtain short-circuit protection.

7.11.2 Emergency batteries supplying essential services are to have short-circuit protection only.

7.12 Protection of shore power connection

7.12.1 Permanently fixed cables connecting the shore connection box to the main switchboard are to be protected by fuses or circuit-breakers (see [3.6]).

7.13 Protection of measuring instruments, pilot lamps and control circuits

7.13.1 Measuring circuits and devices (voltage transformers, voltmeters, voltage coils of measuring instruments, insulation monitoring devices etc.) and pilot lamps are to be protected against short-circuit by means of multipole circuit-breakers or fuses.

The protective devices are to be placed as near as possible to the tapping from the supply.

The secondary side of current transformers is not to be protected.

7.13.2 Control circuits and control transformers are to be protected against overload and short-circuit by means of multipole circuit-breakers or fuses on each pole not connected to earth.

Overload protection may be omitted for transformers with a rated current of less than 2 A on the secondary side.

The short-circuit protection on the secondary side may be omitted if the transformer is designed to sustain permanent short-circuit current.

7.13.3 Where a fault in a pilot lamp would impair the operation of essential services, such lamps are to be protected separately from other circuits such as control circuits.

Note 1: Pilot lamps connected via short-circuit-proof transformers may be protected in common with control circuits.

7.13.4 Circuits whose failure could endanger operation, such as steering gear control feeder circuits, are to be protected only against short-circuit.

7.13.5 The protection is to be adequate for the minimum cross-section of the protected circuits.

7.14 Protection of transformers

7.14.1 The primary winding side of power transformers is to be protected against short-circuit and overload by means of multipole circuit -breakers or switches and fuses.

7.14.2 The protection against short-circuit is to be such as to ensure the selectivity between the circuits supplied by the secondary side of the transformer and the feeder circuit of the transformer.

7.14.3 When transformers are arranged to operate in parallel, means are to be provided so as to trip the switch on the secondary winding side when the corresponding switch on the primary side is open.

8 System components

8.1 General

8.1.1 The components of the electrical system are to be dimensioned such as to withstand the currents that can pass through them during normal service without their rating being exceeded.

8.1.2 The components of the electrical system are to be designed and constructed so as to withstand for the admissible duration the thermal and electro-dynamic stresses caused by possible overcurrents, including short-circuit.

9 Electrical cables

9.1 General

9.1.1 All electrical cables and wiring external to equipment shall be at least of a flame-retardant type, in accordance with IEC Publication 60332-1 and they have to comply with Ch 2, Sec 9.

9.1.2 In addition to the provisions of [9.1.1], when cables are laid in bundles, cable types are to be chosen in compliance with IEC Publication 60332-3 Category A, or other means (See Ch 3, Sec 12) are to be provided such as not to impair their original flame-retarding properties.

9.1.3 Where necessary for specific applications such as radio frequency or digital communication systems, which require the use of particular types of cables, the Society, with the agreement of the Naval Authority; may permit the use of cables which do not comply with the provisions in [9.1.1] and [9.1.2].

9.1.4 Cables which are required to have fire-resisting characteristics are to comply with the requirements stipulated in IEC Publication 60331.

9.1.5 Cables used onboard are to be of the halogen free type and tested according to IEC 60754-1, IEC 60754-2, 61034-1 and 61034-2.

Halogen cables may be accepted if they do not exceed 10% of the total cables passing in the room.

Table 4 : Maximum rated conductor temperature

Type of insulating compound	Abbreviated designation	Maximum rated conductor temperature, in °C	
		Normal operation	Short-circuit
a) Thermoplastic: - based upon polyvinyl chloride or copolymer of vinyl chloride and vinyl acetate	PVC/A	60	150
b) Elastomeric or thermosetting:			
- based upon ethylene-propylene rubber or similar (EPM or EPDM)	EPR	85	250
- based upon high modulus or hardgrade ethylene propylene rubber	HEPR	85	250
- based upon cross-linked polyethylene	XLPE	85	250
- based upon rubber silicon	S 95	95	350
- based upon ethylene-propylene rubber or similar (EPM or EPDM) halogen free	HF EPR	85	250
- based upon high modulus or hardgrade halogen free ethylene propylene rubber	HF HEPR	85	250
- based upon cross-linked polyethylene halogen free	HF XLPE	85	250
- based upon rubber silicon halogen free	HF S 95	95	350
- based upon cross-linked polyolefin material for halogen free cable **(1)**	HF 85	85	250

(1) Used on sheathed cable only

9.2 Choice of insulation

9.2.1 The maximum rated operating temperature of the insulating material is to be at least 10°C higher than the maximum ambient temperature liable to occur or to be produced in the space where the cable is installed.

9.2.2 The maximum rated conductor temperature for normal and short-circuit operation, for the type of insulating compounds normally used for shipboard cables, is not to exceed the values stated in Tab 4. Special consideration will be given to other insulating materials.

9.2.3 PVC insulated cables are not to be used either in refrigerated spaces, or on decks exposed to the weather of ships classed for unrestricted service.

9.3 Choice of protective covering

9.3.1 The conductor insulating materials are to be enclosed in an impervious sheath of material appropriate to the expected ambient conditions where cables are installed in the following locations:

- on decks exposed to the weather
- in damp or wet spaces (e.g. in bathrooms)
- in refrigerated spaces
- in machinery spaces and, in general
- where condensation water or harmful vapour may be present.

9.3.2 Where cables are provided with armour or metallic braid (e.g. for cables installed in hazardous areas), an overall impervious sheath or other means to protect the metallic elements against corrosion is to be provided.

9.3.3 An impervious sheath is not required for single-core cables installed in tubes or ducts inside accommodation spaces, in circuits with maximum system voltage 250V.

9.3.4 In choosing different types of protective coverings, due consideration is to be given to the mechanical action to which each cable may be subjected during installation and in service.

If the mechanical strength of the protective covering is considered insufficient, the cables are to be mechanically protected (e.g. by an armour or by installation inside pipes or conduits).

9.3.5 Single-core cables for a.c. circuits with rated current exceeding 20 A are to be either non-armoured or armoured with non-magnetic material.

9.4 Cables in refrigerated spaces

9.4.1 Cables installed in refrigerated spaces are to have a watertight or impervious sheath and are to be protected against mechanical damage. If an armour is applied on the sheath, the armour is to be protected against corrosion by a further moisture-resisting covering.

9.5 Cables in areas with a risk of explosion

9.5.1 For cables in areas with a risk of explosion, see Article [10].

9.6 Cables in circuits required to be operable under fire condition

9.6.1 Electrical services required to be operable under fire conditions are as follows:

- control and power systems to power-operated fire doors and status indication for all fire doors
- control and power systems to power-operated watertight doors and their status indication
- emergency fire pump
- emergency lighting
- fire and general alarms
- fire detection systems
- fire-extinguishing systems and fire-extinguishing media release alarms
- low location lighting
- public address systems
- remote emergency stop/shutdown arrangements for systems which may support the propagation of fire and/or explosion.

9.6.2 Where cables for services specified in [9.6.1] including their power supplies pass through high fire risk areas, and through main vertical zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the service in any other area or zone. This may be achieved by either of the following measures:

a) Cables of a fire resistant type complying with Ch 2, Sec 9, [1.1.7] are installed and run continuous to keep the fire integrity within the high fire risk area (see Fig 3)

Note 1: The application of this requirement for public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 or more will be considered on the case-by-case basis.

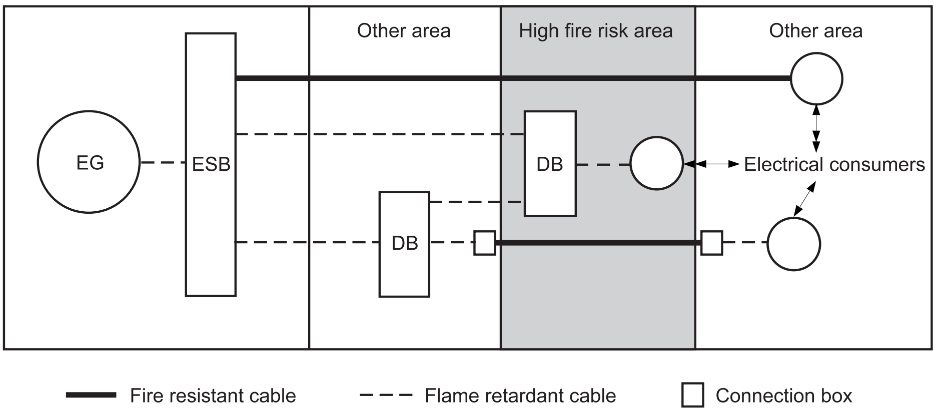
b) At least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Systems that are self monitoring, fail safe or duplicated with cable runs as widely separated as is practicable may be exempted.

9.6.3 Cables for services required to be operable under fire conditions, including their power supplies, are to be run as directly as is practicable.

9.6.4 Cables connecting fire pumps to the emergency switchboard shall be of a fire-resistant type where they pass through high fire risk areas.

Figure 3 : Routing of cables in high fire risk area



9.7 Cables for submerged bilge pumps

9.7.1 Cables and their connections to such pumps are to be capable of operating under a head of water equal to their distance below the bulkhead deck. The cable is to be impervious-sheathed and armoured, is to be installed in continuous lengths from above the bulkhead to the motor terminals and is to enter the air bell from the bottom.

9.8 Internal wiring of switchboards and other enclosures for equipment

9.8.1 For installation in switchboards and other enclosures for equipment, single-core cables may be used without further protection (sheath).

Other types of flame-retardant switchboard wiring may be accepted at the discretion of the Society.

9.9 Current carrying capacity of cables

9.9.1 The current carrying capacity for continuous service of cables given in Tab 5 to Tab 9 is based on the maximum permissible service temperature of the conductor also indicated therein and on an ambient temperature of 45°C.

9.9.2 The current carrying capacity cited in [9.9.1] is applicable, with rough approximation, to all types of protective covering (e.g. both armoured and non-armoured cables).

9.9.3 Values other than those shown in Tab 5 to Tab 9 may be accepted provided they are determined on the basis of calculation methods or experimental values approved by the Society.

9.9.4 When the actual ambient temperature obviously differs from 45°C, the correction factors shown in Tab 10 may be applied to the current carrying capacity in Tab 5 to Tab 9.

9.9.5 Where more than six cables are bunched together in such a way that there is an absence of free air circulating around them, and the cables can be expected to be under full load simultaneously, a correction factor of 0,85 is to be applied.

9.9.6 Where a cable is intended to supply a short-time load for 1/2-hour or 1-hour service (e.g. mooring winches or bow thruster propellers), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the corresponding correction factors given in Tab 11.

In no case a period shorter than 1/2-hour is to be used, whatever the effective period of operation.

9.9.7 For supply cables to single services for intermittent loads (e.g. cargo winches or machinery space cranes), the current carrying capacity obtained from Tab 5 to Tab 9 may be increased by applying the correction factors given in Tab 12.

The correction factors are calculated with rough approximation for periods of 10 minutes, of which 4 minutes with a constant load and 6 minutes without load.

9.9.8 The current carrying capacity of cables connected in parallel is the sum of the current ratings of all parallel conductors but the cables must have equal impedance, equal cross-section, equal maximum permissible conductor temperatures and follow substantially identical routing or be installed in close proximity. Connections in parallel are only permitted for cross-sections of 10 mm² or above. When equal impedance can not be assumed, a correction factor of 0,9 is to be applied to the current carrying capacity.

Table 5 : Current carrying capacity, in A in continuous service for cables based on maximum conductor operating temperature of 60°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	10	9	7
2,5	17	14	12
4	23	20	16
6	29	25	20
10	40	34	28
16	54	46	38
25	71	60	50
35	88	75	62
50	110	94	77
70	135	115	95
95	164	139	115
120	189	161	132
150	218	185	153
185	248	211	174
240	292	248	204
300	336	286	235
400	dc: 390 ac: 380	dc: 332 ac: 323	dc: 273 ac: 266
500	dc: 450 ac: 430	dc: 383 ac: 366	dc: 315 ac: 301
630	dc: 520 ac: 470	dc: 442 ac: 400	dc: 364 ac: 329

Table 6 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 85°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	21	18	15
2,5	28	24	20
4	38	32	27
6	49	42	34
10	67	57	47
16	91	77	64
25	120	102	84
35	148	126	104
50	184	156	129
70	228	194	160
95	276	235	193
120	319	271	223
150	367	312	257
185	418	355	293
240	492	418	344
300	565	480	396
400	dc: 650 ac: 630	dc: 553 ac: 536	dc: 455 ac: 441
500	dc: 740 ac: 680	dc: 629 ac: 578	dc: 518 ac: 476
630	dc: 840 ac: 740	dc: 714 ac: 629	dc: 588 ac: 518

Table 7 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 70°C (ambient temperature 45°C)

Nominal section, in mm²	Number of conductors		
	1	2	3 or 4
1,5	15	13	11
2,5	21	18	15
4	29	25	20
6	37	31	26
10	51	43	36
16	68	58	48
25	90	77	63
35	111	94	78
50	138	117	97
70	171	145	120
95	207	176	145
120	239	203	167
150	275	234	193
185	313	266	219
240	369	314	258
300	424	360	297
400	dc: 500 ac: 490	dc: 425 ac: 417	dc: 350 ac: 343
500	dc: 580 ac: 550	dc: 493 ac: 468	dc: 406 ac: 385
630	dc: 670 ac: 610	dc: 570 ac: 519	dc: 469 ac: 427

Table 8 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 90°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	23	20	16
2,5	30	26	21
4	40	34	28
6	52	44	36
10	72	61	50
16	96	82	67
25	127	108	89
35	157	133	110
50	196	167	137
70	242	206	169
95	293	249	205
120	339	288	237
150	389	331	272
185	444	377	311
240	522	444	365
300	601	511	421
400	dc: 690 ac: 670	dc: 587 ac: 570	dc: 483 ac: 469
500	dc: 780 ac: 720	dc: 663 ac: 612	dc: 546 ac: 504
630	dc: 890 ac: 780	dc: 757 ac: 663	dc: 623 ac: 546

Table 9 : Current carrying capacity, in A, in continuous service for cables based on maximum conductor operating temperature of 95°C (ambient temperature 45°C)

Nominal section (mm^2)	Number of conductors		
	1	2	3 or 4
1,5	26	22	18
2,5	32	27	22
4	43	37	30
6	55	47	39
10	76	65	53
16	102	87	71
25	135	115	95
35	166	141	116
50	208	177	146
70	256	218	179
95	310	264	217
120	359	305	251
150	412	350	288
185	470	400	329
240	553	470	387
300	636	541	445
400	dc: 760 ac: 725	dc: 646 ac: 616	dc: 532 ac: 508
500	dc: 875 ac: 810	dc: 744 ac: 689	dc: 612 ac: 567
630	dc: 1010 ac: 900	dc: 859 ac: 765	dc: 707 ac: 630

Table 10 : Correction factors for various ambient air temperatures

Maximum conductor temperature, in °C	Correction factors for ambient air temperature of:										
	35°C	40°C	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C	85°C
60	1,29	1,15	1,00	0,82	–	–	–	–	–	–	–
65	1,22	1,12	1,00	0,87	0,71	–	–	–	–	–	–
70	1,18	1,10	1,00	0,89	0,77	0,63	–	–	–	–	–
75	1,15	1,08	1,00	0,91	0,82	0,71	0,58	–	–	–	–
80	1,13	1,07	1,00	0,93	0,85	0,76	0,65	0,53	–	–	–
85	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	–	–
90	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	–
95	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 11 : Correction factors for short-time loads

½-hour service		1-hour service		Correction factor
Sum of nominal cross-sectional areas of all conductors in the cable, in mm²		Sum of nominal cross-sectional areas of all conductors in the cable, in mm²		
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
up to 20	up to 75	up to 80	up to 230	1,06
21-41	76-125	81-170	231-400	1,10
41-65	126-180	171-250	401-600	1,15
66-95	181-250	251-430	601-800	1,20
96-135	251-320	431-600	–	1,25
136-180	321-400	601-800	–	1,30
181-235	401-500	–	–	1,35
236-285	501-600	–	–	1,40
286-350	–	–	–	1,45

Table 12 : Correction factors for intermittent service

Sum of nominal cross sectional areas of all conductors in the cable, in mm²		Correction factor
Cables with metallic sheath and armoured cables	Cables with non-metallic sheath and non-armoured cables	
	S ≤ 5	1,10
	5 < S ≤ 8	1,15
	8 < S ≤ 16	1,20
S ≤ 4	16 < S ≤ 825	1,25
4 < S ≤ 7	25 < S ≤ 42	1,30
7 < S ≤ 17	42 < S ≤ 72	1,35
17 < S ≤ 42	72 < S ≤ 140	1,40
42 < S ≤ 110	140 < S	1,45
110 < S	–	1,50

Table 13 : Minimum nominal cross-sectional areas

Service	Nominal cross-sectional area	
	external wiring, in mm^2	internal wiring, in mm^2
Power, heating and lighting systems	1,0	1,0
Control circuits for power plant	1,0	1,0
Control circuits other than those for power plant	0,75	0,5
Control circuits for telecommunications, measurement, alarms	0,5	0,2
Telephone and bell equipment, not required for the safety of the ship or crew calls	0,2	0,1
Bus and data cables	0,2	0,1

9.10 Minimum nominal cross-sectional area of conductors

9.10.1 In general the minimum allowable conductor cross-sectional areas are those given in Tab 13.

9.10.2 The nominal cross-sectional area of the neutral conductor in three-phase distribution systems is to be equal to at least 50% of the cross-sectional area of the phases, unless the latter is less than or equal to 16 mm^2. In such case the cross-sectional area of the neutral conductor is to be equal to that of the phase.

9.10.3 For the nominal cross-sectional area of:

- earthing conductors, see Ch 2, Sec 12, [2.3]
- earthing connections for distribution systems, see Ch 2, Sec 12, [2.5]
- neutral connections for three-phase systems, see Ch 2, Sec 12, [2.4].

9.11 Choice of cables

9.11.1 The rated voltage of any cable is to be not lower than the nominal voltage of the circuit for which it is used.

9.11.2 The nominal cross-sectional area of each cable is to be sufficient to satisfy the following conditions with reference to the maximum anticipated ambient temperature:

- the current carrying capacity is to be not less than the highest continuous load carried by the cable
- the voltage drop in the circuit, by full load on this circuit, is not to exceed the specified limits
- the cross-sectional area calculated on the basis of the above is to be such that the temperature increases which may be caused by overcurrents or starting transients do not damage the insulation.

9.11.3 The highest continuous load carried by a cable is to be calculated on the basis of the power requirements and of the diversity factor of the loads and machines supplied through that cable.

9.11.4 When the conductors are carrying the maximum nominal service current, the voltage drop from the main or emergency switchboard busbars to any point in the installation is not to exceed 6% of the nominal voltage.

For battery circuits with supply voltage less than 55 V, this value may be increased to 10%.

For the circuits of navigation lights, the voltage drop is not to exceed 5% of the rated voltage under normal conditions.

10 Electrical installations in hazardous areas

10.1 Electrical equipment

10.1.1 No electrical equipment is to be installed in hazardous areas unless the Society is satisfied that such equipment is:

- essential for operational purposes
- of a type which will not ignite the mixture concerned
- appropriate to the space concerned, and
- appropriately certified for safe usage in the dusts, vapours or gases likely to be encountered.

10.1.2 Where electrical equipment of a safe type is permitted in hazardous areas it is to be selected with due consideration to the following:

a) risk of explosive dust concentration; see Ch 2, Sec 2, [6.2]:
   - degree of protection of the enclosure
   - maximum surface temperature

b) risk of explosive gas atmosphere; see Ch 2, Sec 2, [6.1]:
   - explosion group
   - temperature class.

10.1.3 Where electrical equipment is permitted in hazardous areas, all switches and protective devices are to interrupt all poles or phases and, where practicable, to be located in a non-hazardous area unless specifically permitted otherwise.

Such switches and equipment located in hazardous areas are to be suitably labelled for identification purposes.

10.1.4 For electrical equipment installed in Zone 0 hazardous areas, only the following types are permitted:
- certified intrinsically-safe apparatus Ex(ia)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ia” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules
- equipment specifically designed and certified by the appropriate authority for use in Zone 0.

10.1.5 For electrical equipment installed in Zone 1 hazardous areas, only the following types are permitted:
- any type that may be considered for Zone 0
- certified intrinsically-safe apparatus Ex(ib)
- simple electrical apparatus and components (e.g. thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ib” not capable of storing or generating electrical power or energy in excess of limits stated in the relevant rules)
- certified flameproof Ex(d)
- certified pressurized Ex(p)
- certified increased safety Ex(e)
- certified encapsulated Ex(m)
- certified sand filled Ex(q)
- certified specially Ex(s)
- through runs of cable.

10.1.6 For electrical equipment installed in Zone 2 hazardous areas, only the following types are permitted:
- any type that may be considered for Zone 1
- tested specially for Zone 2 (e.g. type “n” protection)
- pressurized, and accepted by the Society in agreement with the Naval Authority
- encapsulated, and accepted by the Society in agreement with the Naval Authority
- the type which ensures the absence of sparks and arcs and of “hot spots” during its normal operation (minimum class of protection IP55).

10.1.7 When apparatus incorporates a number of types of protection, it is to be ensured that all are suitable for use in the zone in which it is located.

10.2 Electrical cables

10.2.1 Electrical cables are not to be installed in hazardous areas except as specifically permitted or when associated with intrinsically safe circuits.

10.2.2 All cables installed in Zone 0, Zone 1 or weather exposed areas are to be sheathed with at least one of the following:

a) a non-metallic impervious sheath in combination with braiding or other metallic covering

b) a copper or stainless steel sheath (for mineral insulated cables only).

10.2.3 All cables installed in non-weather exposed Zone 2 areas are to be provided with at least a non-metallic external impervious sheath.

10.2.4 Cables of intrinsically safe circuits are to have a metallic shielding with at least a non-metallic external impervious sheath.

10.2.5 The circuits of a category “ib” intrinsically safe system are not to be contained in a cable associated with a category “ia” intrinsically safe system required for a hazardous area in which only category “ia” systems are permitted.

10.3 Electrical installations in battery rooms

10.3.1 Only intrinsically safe equipment and lighting fittings may be installed in compartments assigned solely to large vented storage batteries; see Ch 2, Sec 11, [6.2].

The associated switches are to be installed outside such spaces.

Electric ventilator motors are to be outside ventilation ducts and, if within 3 m of the exhaust end of the duct, they are to be of an explosion-proof safe type. The impeller of the fan is to be of the non-sparking type.

Overcurrent protective devices are to be installed as close as possible to, but outside of, battery rooms.

Electrical cables other than those pertaining to the equipment arranged in battery rooms are not permitted.

10.3.2 Electrical equipment for use in battery rooms is to have minimum explosion group IIC and temperature class T1.

10.3.3 Standard marine electrical equipment may be installed in compartments assigned solely to valve-regulated sealed storage batteries.

10.4 Electrical installations in paint stores

10.4.1 General

Electrical equipment is to be installed in paint stores and in ventilation ducts serving such spaces only when it is essential for operational services.

Certified safe type equipment of the following type is acceptable:

- certified intrinsically-safe apparatus Ex(i)
- certified flameproof Ex(d)
- certified pressurised Ex(p)
- certified increased safety Ex(e)
- certified specially Ex(s).

In general, cables (through runs or termination cables) of armoured type or installed in metallic conduits are to be used. However, through runs of cables complying with [10.2] are allowed in paint stores.

10.4.2 In the areas on open deck within 1 m of inlet and exhaust ventilation openings of paint stores or within 3 m of exhaust mechanical ventilation outlets of such spaces, the following electrical equipment may be installed:

- electrical equipment with the type of protection as permitted in paint stores
- equipment of protection class Ex(n)
- appliances which do not generate arcs in service and whose surface does not reach unacceptably high temperature
- appliances with simplified pressurised enclosures or vapour-proof enclosures (minimum class of protection IP55) whose surface does not reach unacceptably high temperature or
- cables as specified in [10.4.1].

10.4.3 Minimum requirements

The minimum requirements for the certified safe type equipment are as follows:

- explosion group II B
- temperature class T3.

10.4.4 Switches, protective devices and motor control gear of electrical equipment installed in a paint store are to interrupt all poles or phases and are preferably to be located in a non-hazardous space.

10.4.5 Hazardous area classification

a) The paint stores and supply and exhaust ventilation ducts serving such spaces are to be classified as Zone 1, as defined in Ch 2, Sec 1, [3.25].

b) Areas on open deck within 1 m of inlet and exhaust ventilation openings of paint stores or within 3 m of exhaust mechanical ventilation outlets of such spaces are to be classified as Zone 2, as defined in Ch 2, Sec 1, [3.25].

c) Enclosed spaces giving access to paint stores may be considered as non-hazardous, provided that:
   - the door to the paint store is a gastight door with self-closing devices without holding back arrangements. A watertight door may be considered as being gastight.
   - the paint store is provided with an acceptable, independent, natural ventilation system ventilated from a safe area, and
   - warning notices are fitted adjacent to the paint store entrance stating that the store contains flammable liquids.

10.5 Electrical installations in stores for welding gas (acetylene) bottles

10.5.1 The following equipment may be installed in stores for welding gas bottles provided that it is of a safe type appropriate for Zone 1 area installation:

- lighting fittings
- ventilator motors where provided.

10.5.2 Electrical cables other than those pertaining to the equipment arranged in stores for welding gas bottles are not permitted.

10.5.3 Electrical equipment for use in stores for welding gas bottles is to have minimum explosion group IIC and temperature class T2.

10.6 Ammunition spaces

10.6.1 The following spaces may be considered as hazardous areas according to the specification of the Naval Authorithy:

- ammunition storage spaces
- ammunition transit/preparation room
- ammunition elevators.

In such a case, the electrical equipment in these spaces are to be certified of a safety type accordingly.

Section 4 Rotating Machines

1 Constructional requirements for generators and motors

1.1 Mechanical construction

1.1.1 Insulating materials, insulated windings and construction of electrical machines are to conform to the relevant requirements of Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.1.2 Shafts are to be made of material complying with the provisions of NR216 Materials and Welding, Chapter 5, Sec 3 or, where rolled products are allowed in place of forgings, with those of NR216 Materials and Welding, Chapter 3, Sec 8.

1.1.3 Where welded parts are foreseen on shafts and rotors, the provisions of NR216 Materials and Welding, Chapter 12 are to apply.

1.1.4 Sleeve bearings are to be efficiently and automatically lubricated at all running speeds.

Provision is to be made for preventing the lubricant from gaining access to windings or other insulated or bare current carrying parts.

1.1.5 Means are to be provided to prevent bearings from being damaged by the flow of currents circulating between them and the shaft. According to the Manufacturer's requirements, electrical insulation of at least one bearing is to be considered.

1.1.6 For surface-cooled machines with an external fan installed on the open deck, adequate protection of the fan against icing is to be provided.

1.1.7 When liquid cooling is used, the coolers are to be so arranged as to avoid entry of water into the machine, whether by leakage or condensation in the heat exchanger, and provision is to be made for the detection of leakage.

1.1.8 Rotating machines whose ventilation or lubrication system efficiency depends on the direction of rotation are to be provided with a warning plate.

1.1.9 Generator and their excitation system which may be required to sustain overloads (for limited and specified periods of time) are to be designed so as to maintain network electrical characteristics within the prescribed limits.

1.2 Sliprings, commutators and brushes

1.2.1 Sliprings and commutators with their brushgear are to be so constructed that undue arcing is avoided under all normal load conditions.

1.2.2 The working position of brushgear is to be clearly and permanently marked.

1.2.3 Sliprings, commutators and brushgear are to be readily accessible for inspection, repairs and maintenance.

1.3 Terminal connectors

1.3.1 Suitable, fixed terminal connectors are to be provided in an accessible position for connection of the external cables.

1.3.2 All terminal connectors are to be clearly identified with reference to a diagram.

1.4 Electrical insulation

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2, [4.2] and Ch 2, Sec 2, [4.3].

2 Special requirements for generators

2.1 Prime movers, speed governors and overspeed protection

2.1.1 Prime movers for generators are to comply with the relevant requirements of Ch 1, Sec 2, [2.10].

2.1.2 When a.c. generators are to operate in parallel, the characteristics of speed governors are to comply with the provisions of [2.2].

2.2 A.c. generators

2.2.1 Alternators are to be so constructed that, when started up, they take up the voltage without the aid of an external electrical power source.

Where these provisions are not complied with, the external electrical power source is to be constituted by a battery installation in accordance with the requirements for electrical starting systems of auxiliary machinery (see Ch 1, Sec 2).

2.2.2 The voltage wave form is to be approximately sinusoidal, with a maximum deviation from the sinusoidal fundamental curve of 5% of the peak value.

2.2.3 Each alternator is to be provided with automatic means of voltage regulation.

2.2.4 For a.c. generating sets operating in parallel, the governing characteristics of the prime movers are to be such that, within the limits of 20% and 100% total load, the load on any generating set will not normally differ from its proportionate share of the total load by more than 15% of the rated power in kW of the largest machine or 25% of the rated power in kW of the individual machine in question, whichever is the lesser.

2.2.5 For a.c. generating sets intended to operate in parallel, means are to be provided to regulate the governor so as to permit an adjustment of load not exceeding 5% of the rated load at normal frequency.

2.2.6 When a.c. generators are operated in parallel, the reactive loads of the individual generating sets are not to differ from their proportionate share of the total reactive load by more than 10% of the rated reactive power of the largest machine, or 25% of that of the smallest machine, whichever is the lesser.

2.3 Approval of generating gensets

2.3.1 A generating set is considered as a whole system including:

- a prime mover engine and its auxiliaries (for fuel oil, turbo compressor, lubricating oil, cooling circuits...)
- an alternator, and its auxiliaries, if any (lubricating and cooling system...)
- engine control system, speed governor and associated sensors
- an automatic voltage regulator
- a coupling system
- cabling.

2.3.2 Components are to be type approved. Case-by-case approvals may be admitted at the discretion of the Society.

2.3.3 Documentation for system assembly is to be provided:

- list of components
- general electrical diagram
- coupling system
- Torsional Vibration Calculation, when required in Ch 1, Sec 9, [1.1].

3 Testing of rotating machines

3.1 General

3.1.1 All machines are to be tested by the Manufacturer

3.1.2 Manufacturer's test records are to be provided for machines for essential services, for other machines they are to be available upon request.

3.1.3 All tests are to be carried out according to IEC Publication 60092-301.

3.1.4 All machines of 50 kW and over, intended for essential services are to be surveyed by the Society during testing and, if appropriate, during manufacturing.

3.2 Shaft material

3.2.1 Shaft material for electric propulsion motors and for main engine driven generators where the shaft is part of the propulsion shafting is to be certified by the Society.

3.2.2 Shaft material for other machines is to be in accordance with recognized international or national standards (see [1.1.2]).

3.3 Tests

3.3.1 Type tests are to be carried out on a prototype machine or on the first of a batch of machines, and routine tests carried out on subsequent machines in accordance with Tab 1.

Table 1 : Tests to be carried out on electrical rotating machines

No.	Tests	a.c. generators		Motors	
		Type test**(1)**	Routine test**(2)**	Type test**(1)**	Routine test**(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection	X	X	X	X
2	Insulation resistance measurement	X	X	X	X
3	Winding resistance measurement	X	X	X	X
4	Verification of the voltage regulation system	X	X**(3)**		
5	Rated load test and temperature rise measurement	X		X	
6	Overload/overcurrent test	X	X	X	X**(4)**
7	Verification of steady short-circuit conditions**(5)**	X			
8	Overspeed test	X	X	X**(6)**	X**(6)**
9	Dielectric strength test	X	X	X	X
10	No load test	X	X	X	X
11	Verification of degree of protection	X		X	
12	Verification of bearings	X	X	X	X

(1) Type tests on prototype machine or tests on at least the first of a batch of machines.
(2) The report on routinely tested machines is to contain the Manufacturer's serial number of the machine which has been type tested and the test result.
(3) Only functional test of voltage regulator system.
(4) Only applicable for machine of essential services rated above 50 kW/kVA.
(5) Verification of steady short circuit condition applies to synchronous generators only.
(6) Not applicable for squirrel cage motors.

4 Description of the test

4.1 Examination of the technical documentation, as appropriate, and visual inspection

4.1.1 Examination of the technical documentation

Technical documentation of machines rated at 50 kW (kVA) and over is to be available for examination by the Surveyor.

4.1.2 Visual inspection

A visual examination of the machine is to be made to ensure, as far as is practicable, that it complies with the technical documentation.

4.2 Insulation resistance measurement

4.2.1 Immediately after the high voltage tests the insulation resistances are to be measured using a direct current insulation tester between:

a) all current carrying parts connected together and earth,

b) all current carrying parts of different polarity or phase, where both ends of each polarity or phase are individually accessible.

The minimum values of test voltages and corresponding insulation resistances are given in Tab 2. The insulation resistance is to be measured close to the operating temperature, or an appropriate method of calculation is to be used.

4.3 Winding resistance measurement

4.3.1 The resistances of the machine windings are to be measured and recorded using an appropriate bridge method or voltage and current method.

Table 2 : Minimum insulation resistance

Rated voltage U_n, in V	Minimum test voltage, in V	Minimum insulation resistance, in MΩ
$U_n = 250$	$2\ U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$U_n / 1000 + 1$
$7200 < U_n \leq 15000$	5000	$U_n / 1000 + 1$

4.4 Verification of the voltage regulation system

4.4.1 The alternating current generator, together with its voltage regulation system, is to be verified in such a way that, at all loads from no load running to full load, the rated voltage at the rated power factor is maintained under steady conditions within ± 2.5%. These limits may be increased to ± 3.5% for emergency sets.

4.4.2 When the generator is driven at rated speed, giving its rated voltage, and is subjected to a sudden change of symmetrical load within the limits of specified current and power factor, the voltage is not to fall below 85% nor exceed 120% of the rated voltage

4.4.3 The voltage of the generator is then to be restored to within plus or minus 3% of the rated voltage for the main generator sets in not more than 1.5 s. For emergency sets, these values may be increased to plus or minus 4% in not more than 5 s.

4.4.4 In the absence of precise information concerning the maximum values of the sudden loads, the following conditions may be assumed: 60% of the rated current with a power factor of between 0.4 lagging and zero to be suddenly switched on with the generator running at no load, and then switched off after steady - state conditions have been reached.

4.5 Rated load test and temperature rise measurements

4.5.1 The temperature rises are to be measured at the rated output, voltage and frequency and for the duty for which the machine is rated and marked in accordance with the testing methods specified in IEC Publication 60034-1, or by means of a combination of other tests.

The limits of temperature rise are those specified in Table 6 of IEC Publication 60034-1 adjusted as necessary for the ambient reference temperatures specified in Ch 2, Sec 2.

4.6 Overload/overcurrent tests

4.6.1 Overload test is to be carried out as a type test for generators as proof of overload capability of generators and the excitation system, for motors as proof of momentary excess torque as required in IEC Publication 60034-1. The overload test can be replaced at a routine test by an overcurrent test. The overcurrent test is to be proof of the current capability of the windings, wires, connections etc. of each machine. The overcurrent test can be performed at reduced speed (motors) or at short-circuit (generators).

4.6.2 In the case of machines for special uses (e.g. for windlasses), overload values other than the above may be considered.

4.7 Verification of steady short-circuit conditions

4.7.1 It is to be verified that under steady state short-circuit conditions, the generator with its voltage regulating system is capable of maintaining, without sustaining any damage, a current of at least three times the rated current for a duration of at least 2 s or, where precise data is available, for a duration of any time delay which may be fitted in a tripping device for discrimination purposes.

4.8 Overspeed test

4.8.1 Machines are to withstand the overspeed test as specified in IEC Publication 60034-1. This test is not applicable for squirrel cage motors.

4.9 Dielectric strength test

4.9.1 New and completed rotating machines are to withstand a dielectric test as specified in IEC Publication 60034-1.

4.9.2 For high voltage machines an impulse test is to be carried out on the coils according to Ch 2, Sec 13.

4.9.3 When it is necessary to perform an additional high voltage test, this is to be carried out after any further drying, with a test voltage of 80% of that specified in IEC Publication 60034-1.

4.9.4 Completely rewound windings of used machines are to be tested with the full test voltage applied in the case of new machines.

4.9.5 Partially rewound windings are to be tested at 75% of the test voltage required for new machines. Prior to the test, the old part of the winding is to be carefully cleaned and dried.

4.9.6 Following cleaning and drying, overhauled machines are to be subjected to a test at a voltage equal to 1,5 times the rated voltage, with a minimum of 500 V if the rated voltage is less than 100 V, and with a minimum of 1000 V if the rated voltage is equal to or greater than 100 V.

4.9.7 A repetition of the high voltage test for groups of machines and apparatus is to be avoided if possible, but if a test on an assembled group of several pieces of new apparatus, each of which has previously passed its high voltage test, is performed, the test voltage to be applied to such assembled group is 80% of the lowest test voltage appropriate for any part of the group.

Note 1: For windings of one or more machines connected together electrically, the voltage to be considered is the maximum voltage that occurs in relation to earth.

4.10 No load test

4.10.1 Machines are to be operated at no load and rated speed whilst being supplied at rated voltage and frequency as a motor while generators are to be driven by a suitable means and excited to give rated terminal voltage.

During the running test, the vibration of the machine and operation of the bearing lubrication system, if appropriate, are to be checked.

4.11 Verification of degree of protection

4.11.1 As specified in IEC Publication 60034-5.

4.12 Verification of bearings

4.12.1 Upon completion of the above tests, machines which have sleeve bearings are to be opened upon request for examination by the Surveyor, to establish that the shaft is correctly seated in the bearing shells.

Section 5 Transformers

1 Constructional requirements

1.1 Construction

1.1.1 Transformers, except those for motor starting, are to be double wound (two or more separate windings).

1.1.2 Transformers are normally to be of the dry, air-cooled type.

1.1.3 When a forced air cooling system is used, an alarm is to be activated in the event of its failure.

1.1.4 Liquid-cooled transformers may be used provided that:

- the liquid is non-toxic and of a type which does not readily support combustion
- the construction is such that the liquid is not spilled in inclined position
- temperature and pressure relief devices with an alarm are installed
- drip trays or other suitable arrangements for collecting the liquid from leakages are provided
- a liquid gauge indicating the normal liquid level range is fitted.

1.1.5 Transformers are to have enclosures with a degree of protection in accordance with Ch 2, Sec 3, Tab 3.

1.2 Terminals

1.2.1 Suitable fixed terminal connections are to be provided in an accessible position with sufficient space for convenient connection of the external cables.

1.2.2 Terminals are to be clearly identified.

1.3 Voltage variation, short-circuit conditions and parallel operation

1.3.1 Under resistive load (cos φ = 1), the voltage drop from no load to full load is not to exceed 2,5%.

For transformers with a power lower than 5 kVA per phase, this voltage drop is not to exceed 5%.

An exception is made for special transformers, such as starting and instrument transformers, for which a different voltage variation may be considered.

1.3.2 In determining the voltage ratio and the impedance voltage of transformers, account is to be taken of the total permitted voltage drop from the main switchboard's busbars to the consumers (see Ch 2, Sec 3, [9.11.4]).

1.3.3 Transformers are to be constructed to withstand, without damage, the thermal and mechanical effects of a secondary terminal short-circuit for 2 s, with rated primary voltage and frequency.

For transformers of 1 MVA and over, this is to be justified with appropriate tests or documentation.

1.3.4 When transformers are so arranged that their secondary windings may be connected in parallel, they are to be identical and in particular they are to be of the same rated power, their winding connections are to be compatible, their rated voltage ratios are to be equal (with tolerances allowed) and their short-circuit impedance values, expressed as a percentage, are to have a ratio within 0,9 to 1,1.

1.4 Electrical insulation and temperature rise

1.4.1 Insulating materials for windings and other current carrying parts are to comply with the requirements of Ch 2, Sec 2.

1.4.2 All windings of air-cooled transformers are to be suitably treated to resist moisture, air salt mist and oil vapours.

1.4.3 The permissible limits of temperature rise with an ambient air temperature of 45°C for (natural or forced) air-cooled transformers are given in Tab 1. The temperature rises shown for windings refer to measurement by the resistance method while those for the core refer to the thermometer method.

1.4.4 For dry-type transformers cooled with an external liquid cooling system, the permissible limits of temperature rise with a sea water temperature of 32°C are 13°C higher than those specified in Tab 1.

Table 1 : Temperature rise limits for transformers

No.	Part of machine	Temperature rise by class of insulation °C				
		A	E	B	F	H
1	Windings	55	70	75	95	120
2	Cores and other parts: a) in contact with the windings b) not in contact with the windings	a) the same values as for the windings b) in no case is the temperature to reach values such as to damage either the core itself or other adjacent parts or materials				

1.4.5 For liquid-cooled transformers, the following temperature rises measured by the resistance method apply:

- 55°C where the fluid is cooled by air
- 68°C where the fluid is cooled by water.

2 Testing

2.1 General

2.1.1 On new transformers intended for essential services the tests specified in [2.2] are to be carried out.

2.1.2 The manufacturer is to issue a test report giving, inter alia, information concerning the construction, type, serial number, insulation class and all other technical data relevant to the transformer, as well as the results of the tests required.

Such test reports are to be made available to the Society.

2.1.3 In the case of transformers which are completely identical in rating and in all other constructional details, it will be acceptable for the temperature rise test to be performed on only one transformer.

The results of this test and the serial number of the tested transformer are to be inserted in the test reports for the other transformers.

2.1.4 Where the test procedure is not specified, the requirements of IEC 60076 and 60726 apply.

2.1.5 The tests and, if appropriate, manufacture of transformers of 50 kVA and over (30 kVA when single phase) intended for essential services are to be attended by a Surveyor of the Society.

Transformers of 5 kVA up to the limit specified above are approved on a case by case basis, at the discretion of the Society, subject to the submission of adequate documentation and routine tests.

2.2 Tests on transformers

2.2.1 Tests to be carried out on transformers are specified in Tab 2.

Table 2 : Tests to be carried out on transformers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)**	X	X
2	Insulation resistance measurement	X	X
3	Voltage drop	X	X
4	High voltage test	X	X
5	Temperature rise measurement	X	
6	Induced voltage test	X	X
7	Voltage ratio	X	X

(1) Type test on prototype transformer or test on at least the first batch of transformers.
(2) The certificates of transformers routine tested are to contain the manufacturer's serial number of the transformer which has been type tested and the test result.
(3) A visual examination is to be made of the transformer to ensure, as far as practicable, that it complies with technical documentation.

2.3 Insulation tests

2.3.1 Transformers are to be subjected to a high voltage test in accordance with the procedure defined in Ch 2, Sec 4.

2.3.2 The test voltage is to be applied between each winding under test and the other windings not under test, core and enclosure all connected together.

Single-phase transformers for use in a polyphase group are to be tested in accordance with the requirements applicable to that group.

2.3.3 The r.m.s. value of the test voltage is to be equal to 2 U + 1000 V, with a minimum of 2500 V, where U is the rated voltage of the winding. The full voltage is to be maintained for 1 minute.

2.3.4 Partially rewound windings are to be tested at 75% of the test voltage required for new machines.

2.3.5 The insulation resistance of a new, clean and dry transformer, measured after the temperature rise test has been carried out (at or near operating temperature) at a voltage equal to 500 V d.c., is to be not less than 5 MΩ.

2.3.6 Transformers are to be subjected to an induced voltage insulation test by applying to the terminals of the winding under test a voltage equal to twice the rated voltage. The duration of the test is to be 60 s for any test frequency fp up to and including twice the rated frequency fn.

If the test frequency exceeds twice the rated frequency, the test time in seconds will be 120 f_n/f_p with a minimum of 15 s.

Section 6 Semiconductor Converters

1 Constructional and operational requirements

1.1 Construction

1.1.1 Semiconductor convertors are generally to comply with the requirements for switchgear assemblies (see Ch 2, Sec 8).

1.1.2 The design of semi-conductor converters is to comply with the requirements of IEC Publication 60146-1-1 with applicable requirements modified to suit marine installations like e.g. environmental requirements stated in Ch 2, Sec 2.

1.1.3 The design of semi-conductor converters for power supply is to comply with the requirements of IEC 62040 serie (see Article [2]).

1.1.4 The design of semi-conductor converters for motor drives is to comply with the requirements of IEC 61800 serie.

1.1.5 The monitoring and control circuits are generally to comply with the requirements of Part C, Chapter 3.

1.1.6 For liquid-cooled convertors the following provisions are to be satisfied:

- liquid is to be non-toxic and of low flammability
- drip trays or other suitable means are to be provided to contain any liquid leakages
- the resistivity of the cooling fluid in direct contact with semiconductor or other current carrying parts is to be monitored and an alarm initiated if the resistivity is outside the specified limits.

1.1.7 For semiconductor convertors over 1 KVA where forced cooling is used, the temperature of the heated cooling medium is to be monitored.

If the temperature exceeds a preset value an alarm is to be given and the shutdown of the convertor is to be activated.

1.1.8 For semiconductor convertors over 1 KVA where forced (air or liquid) cooling is provided, it is to be so arranged that the convertor cannot be or remain loaded unless effective cooling is maintained.

Alternatively, other effective means of protection against overtemperature may be provided.

1.1.9 Stacks of semiconductor elements, and other equipment such as fuses, or control and firing circuit boards etc., are to be so arranged that they can be removed from equipment without dismantling the complete unit.

1.1.10 Semiconductor convertors are to be rated for the required duty having regard to the peak loads, system transient and overvoltage and to be dimensioned so as to withstand the maximum short-circuit currents foreseen at the point of installation for the time necessary to trip the protection of the circuits they supply.

1.1.11 Harmonic distortion are to be kept within the limit specified in Ch 2, Sec 2, [2.4].

1.2 Protection

1.2.1 Semiconductor elements are to be protected against short-circuit by means of devices suitable for the point of installation in the network.

1.2.2 Overcurrent or overvoltage protection is to be installed to protect the convertor. When the semiconductor convertor is designed to work as an inverter supplying the network in transient periods, precautions necessary to limit the current are to be taken.

1.2.3 Semiconductor convertors are not to cause distortion in the voltage wave form of the power supply at levels exceeding the voltage wave form tolerances at the other user input terminals (see Ch 2, Sec 2, [2.4]).

1.2.4 An alarm is to be provided for tripping of protective devices against overvoltages and overcurrents in electric propulsion convertors and for convertors for the emergency source of power.

1.3 Parallel operation with other power sources

1.3.1 For convertors arranged to operate in parallel with other power sources, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable.

1.4 Temperature rise

1.4.1 The permissible limit of temperature rise of the enclosure of the semiconductors is to be assessed on the basis of an ambient air temperature of 45°C or sea water temperature of 32°C for water-cooled elements, taking into account its specified maximum permissible temperature value.

1.4.2 The value of the maximum permissible temperature of the elements at the point where this can be measured (point of reference) is to be stated by the manufacturer.

1.4.3 The value of the mean rated current of the semiconductor element is to be stated by the manufacturer.

1.5 Creepage and clearance distances

1.5.1 Creepage and clearance distances are to comply with the requirements specified in IEC 61800-5-1. An interpolation of the specified values is permitted for high voltage semi-conductor converters.

2 Requirements for uninterruptible power system (UPS) units as alternative and/or transitional power

2.1 Definitions

2.1.1 Uninterruptible power system (UPS)

Combination of converters, switches and energy storage means, for example batteries, constituting a power system for maintaining continuity of load power in case of input power failure (see IEC Publication 62040-3).

2.1.2 Off line UPS unit

A UPS unit where under normal operation the output load is powered from the bypass line (raw mains) and only transferred to the inverter if the bypass supply fails or goes outside preset limits. This transition will invariably result in a brief (typically 2 to 10 ms) break in the load supply.

2.1.3 Line interactive UPS unit

An off-line UPS unit where the bypass line switch to stored energy power when the input power goes outside the preset voltage and frequency limits.

2.1.4 On line UPS unit

A UPS unit where under normal operation the output load is powered from the inverter, and will therefore continue to operate without break in the event of the supply input failing or going outside preset limits.

2.2 Design and construction

2.2.1 UPS units are to be constructed in accordance with IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

2.2.2 The operation of the UPS is not to depend upon external services.

2.2.3 The type of UPS unit employed, whether off-line, line interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

2.2.4 An external bypass is to be provided.

2.2.5 The UPS unit is to be monitored and audible and visual alarm is to be given in a normally attended location for:

- power supply failure (voltage and frequency) to the connected load
- earth fault
- operation of battery protective device
- when the battery is being discharged
- when the bypass is in operation for on-line UPS units.

2.3 Location

2.3.1 The UPS unit is to be suitably located for use in an emergency.

2.3.2 UPS units utilising valve regulated sealed batteries may be located in compartments with normal electrical equipment, provided the ventilation arrangements are in accordance with the requirements of IEC 62040-1, IEC 62040-2, IEC 62040-3, IEC 62040-4 and/or IEC 62040-5-3, as applicable, or an acceptable and relevant national or international standard.

2.4 Performance

2.4.1 The output power is to be maintained for the duration required for the connected equipment as stated in Ch 2, Sec 3, [3.5.3], Pt D, Ch 2, Sec 4, [3.2.3], Pt D, Ch 4, Sec 5, [3.1.1] or Pt D, Ch 5, Sec 5, [2.2.3] as applicable.

2.4.2 No additional circuits are to be connected to the UPS unit without verification that the UPS unit has adequate capacity.

2.4.3 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified in the regulations.

2.4.4 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

3 Testing

3.1 General

3.1.1 Convertors intended for essential services are to be subjected to the tests stated in [3.2].

3.1.2 The manufacturer is to issue a test report giving information on the construction, type, serial number and all technical data relevant to the convertor, as well as the results of the tests required.

3.1.3 In the case of convertors which are completely identical in rating and in all other constructional details, it will be acceptable for the rated current test and temperature rise measurement stipulated in [3.2] not to be repeated.

3.1.4 The tests and, if appropriate, manufacture of converters of 5 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

3.2 Tests on convertors

3.2.1 Convertors are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype convertor or the first of a batch of convertors, and routine tests are the tests to be carried out on subsequent convertors of a particular type.

3.2.2 The electronic components of the convertors are to be constructed to withstand the tests required in Ch 3, Sec 6.

3.2.3 Final approval of convertors is to include complete function tests after installation on board, performed with all ship's systems in operation and in all characteristic load conditions.

Table 1 : Tests to be carried out on static convertors

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Light load function test to verify all basic and auxiliary functions	X	X
3	Rated current test	X	
4	Temperature rise measurement	X	
5	Insulation test (high voltage test and insulation resistance measurement)	X	X
6	Protection of the convertors in case of failure of forced cooling system	X	X

(1) Type test on prototype convertor or test on at least the first batch of convertors.
(2) The certificates of convertors routine tested are to contain the manufacturer's serial number of the convertor which has been type tested and the test result.
(3) A visual examination is to be made of the convertor to ensure, as far as practicable, that it complies with technical documentation.

3.3 Additional testing and survey for uninterruptible power system (UPS) units as alternative and/ or transitional power

3.3.1 UPS units of 50 kVA and over are to be surveyed by the Society during manufacturing and testing.

3.3.2 Appropriate testing is to be carried out to demonstrate that the UPS unit is suitable for its intended environment. This is expected to include as a minimum the following tests:

- functionality, including operation of alarms
- ventilation rate
- battery capacity.

3.3.3 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical test.

3.4 Insulation test

3.4.1 The test procedure is that specified in IEC Publication 60146.

3.4.2 The effective value of the test voltage for the insulation test is to be as shown in Tab 2.

Table 2 : Test voltages for high voltage test on static convertors

$\frac{U_m}{\sqrt{2}} = U$ in V **(1)**	Test voltage in V
$U \leq 60$	600
$60 < U \leq 90$	900
$90 < U$	2 U + 1000 (at least 2000)
(1) U_m : Highest crest value to be expected between any pair of terminals.	

Section 7 Storage Batteries and Chargers

1 Constructional requirements for batteries

1.1 General

1.1.1 The requirements of this Section apply to permanently installed storage batteries (not to portable batteries).

1.1.2 Storage batteries may be of the lead-acid or nickel-alkaline type, due consideration being given to the suitability for any specific application.

Other types of storage batteries of satisfactorily proven design (e.g. silver/zinc) may be accepted provided they are suitable for shipboard use to the satisfaction of the Society.

1.1.3 Cells are to be assembled in suitable crates or trays equipped with handles for convenient lifting.

1.2 Vented batteries

1.2.1 Vented batteries are those in which the electrolyte can be replaced and freely releases gas during periods of charge and overcharge.

1.2.2 Vented batteries are to be constructed to withstand the movement of the ship and the atmosphere (salt mist, oil etc.) to which they may be exposed.

1.2.3 Battery cells are to be so constructed as to prevent spilling of electrolyte at any inclination of the battery up to 40° from the vertical.

1.2.4 It is to be possible to check the electrolyte level and the pH.

1.3 Valve-regulated sealed batteries

1.3.1 Valve-regulated sealed batteries are batteries whose cells are closed under normal conditions but which have an arrangement which allows the escape of gas if the internal pressure exceeds a predetermined value. The cells cannot normally receive addition to the electrolyte.

Note 1: The cells of batteries which are marketed as “sealed” or “maintenance free” are fitted with a pressure relief valve as a safety precaution to enable uncombined gas to be vented to the atmosphere; they should more properly be referred to as valve-regulated sealed batteries. In some circumstances the quantity of gas vented can be up to 25% of the equivalent vented design. The design is to take into consideration provision for proper ventilation.

1.3.2 Cell design is to minimize risks of release of gas under normal and abnormal conditions.

1.4 Tests on batteries

1.4.1 The battery autonomy is to be verified on board in accordance with the operating conditions.

2 Constructional requirements for chargers

2.1 Characteristics

2.1.1 Chargers are to be adequate for the batteries for which they are intended and provided with a voltage regulator.

2.1.2 In the absence of indications regarding its operation, the battery charger is to be such that the completely discharged battery can be recharged to 80% capacity within a period of 10 hours without exceeding the maximum permissible charging current. A charging rate other than the above (e.g. fully charged within 6 hours for batteries for starting of motors) may be required in relation to the use of the battery.

2.1.3 For floating service or for any other condition where the load is connected to the battery while it is on charge, the maximum battery voltage is not to exceed the safe value of any connected apparatus.

Note 1: Consideration is to be given to the temperature variation of the batteries.

2.1.4 The battery charger is to be designed so that the charging current is set within the maximum current allowed by the manufacturer when the battery is discharged and the floating current to keep the battery fully charged.

2.1.5 Trickle charging to neutralize internal losses is to be provided. An indication is to be provided to indicate a charging voltage being present at the charging unit.

2.1.6 Protection against reversal of the charging current is to be provided.

2.1.7 Battery chargers are to be constructed to simplify maintenance operation. Indications are to be provided to visualize the proper operation of the charger and for troubleshooting.

2.2 Tests on chargers

2.2.1 Battery chargers are to be subjected to tests in accordance with Tab 1.

Type tests are the tests to be carried out on a prototype charger or the first of a batch of chargers, and routine tests are the tests to be carried out on subsequent chargers of a particular type.

2.2.2 The electronic components of the battery chargers are to be constructed to withstand the tests required in Ch 3, Sec 6.

2.2.3 The tests of battery chargers of 10 kVA and over intended for essential services are to be attended by a Surveyor of the Society.

Table 1 : Tests to be carried out on battery chargers

No.	Tests	Type test **(1)**	Routine test **(2)**
1	Examination of the technical documentation, as appropriate, and visual inspection **(3)** including check of earth continuity	X	X
2	Functional tests (current and voltage regulation, quick, slow, floating charge, alarms)	X	X
3	Temperature rise measurement	X	
4	Insulation test (high voltage test and insulation resistance measurement)	X	X

(1) Type test on prototype battery charger or test on at least the first batch of battery chargers.
(2) The certificates of battery chargers routine tested are to contain the manufacturer's serial number of the battery charger which has been type tested and the test result.
(3) A visual examination is to be made of the battery charger to ensure, as far as practicable, that it complies with technical documentation.

Section 8 Switchgear and Controlgear Assemblies

1 Constructional requirements for main and emergency switchboards

1.1 Construction

1.1.1 Construction is to be in accordance with IEC 60092-302.

1.1.2 Where the framework, panels and doors of the enclosure are of steel, suitable measures are to be taken to prevent overheating due to the possible circulation of eddy currents.

1.1.3 Insulating material for panels and other elements of the switchboard is at least to be moisture-resistant and flame-retardant.

1.1.4 Switchboards are to be of dead front type, with enclosure protection according to Ch 2, Sec 3, Tab 3.

1.1.5 Switchboards are to be provided with insulated handrails or handles fitted in an appropriate position at the front of the switchboard. Where access to the rear is necessary for operational or maintenance purposes, an insulated handrail or insulated handles are to be fitted.

1.1.6 Where the aggregate capacity of generators connected to the main busbars exceeds 100 kVA, a separate cubicle for each generator is to be arranged with flame-retardant partitions between the different cubicles. Similar partitions are to be provided between the generator cubicles and outgoing circuits.

1.1.7 Instruments, handles or push-buttons for switchgear operation are to be placed on the front of the switchboard. All other parts which require operation are to be accessible and so placed that the risk of accidental touching of live parts, or accidental making of short-circuits and earthings, is reduced as far as practicable.

1.1.8 Where it is necessary to make provision for the opening of the doors of the switchboard, this is to be in accordance with one of the following requirements:

a) opening is to necessitate the use of a key or tool (e.g. when it is necessary to replace a lamp or a fuse-link)
b) all live parts which can be accidentally touched after the door has been opened are to be disconnected before the door can be opened
c) the switchboard is to include an internal barrier or shutter with a degree of protection not less than IP2X shielding all live parts such that they cannot accidentally be touched when the door is open. It is not to be possible to remove this barrier or shutter except by the use of a key or tool.

1.1.9 All parts of the switchboard are to be readily accessible for maintenance, repair or replacement. In particular, fuses are to be able to be safely inserted and withdrawn from their fuse-bases.

1.1.10 Hinged doors which are to be opened for operation of equipment on the door or inside are to be provided with fixing devices for keeping them in open position.

1.1.11 Means of isolation of the circuit-breakers of generators and other important parts of the installation are to be provided so as to permit safe maintenance while the main busbars are alive.

1.1.12 Where components with voltage exceeding the safety voltage are mounted on hinged doors, the latter are to be electrically connected to the switchboard by means of a separate, flexible protective conductor.

1.1.13 All measuring instruments and all monitoring and control devices are to be clearly identified with indelible labels of durable, flame-retardant material.

1.1.14 The rating of each circuit, together with the rating of the fuse or the appropriate setting of the overload protective device (circuit-breaker, thermal relay etc.) for each circuit is to be permanently indicated at the location of the fuse or protective device.

1.1.15 When the switchboard location and arrangement is so that fumes from an internal fire can be harmful for persons on board, mica coins are recommended to be provided in the front part of all switchgear assemblies for possible internal fire extinction.

1.2 Busbars and bare conductors

1.2.1 Busbars are to be of copper or of copper-surrounded aluminium alloy if suitable for use in the marine environment and if precautions are taken to avoid galvanic corrosion.

1.2.2 All connections are to be so made as to inhibit corrosion.

1.2.3 Busbars are to be dimensioned in accordance with IEC 60092-302.

The mean temperature rise of busbars is not to exceed 45°C under rated current condition with an ambient air temperature of 45°C and is not to have any harmful effect on adjacent components. Higher values of temperature rise may be accepted to the satisfaction of the Society.

1.2.4 The cross-section of neutral connection on an a.c. three-phase, four-wire system is to be at least 50% of the cross-section for the corresponding phases.

1.2.5 Bare main busbars, excluding the conductors between the main busbars and the supply side of outgoing units, are to have the minimum clearances and creepage distances given in Tab 1. The values shown apply to clearances and creepage distances between live parts as well as between live parts and exposed conductive parts.

Note 1: Clearance is the distance between two conductive parts along a string stretched the shortest way between such parts. Creepage distance is the shortest distance along the surface of an insulating material between two conductive parts.

Table 1 : Clearance and creepage distances

Rated insulation voltage a.c. r.m.s. or d.c. in V	Minimum clearance, in mm	Minimum creepage distance, in mm
≤ 250	15	20
> 250 to ≤ 690	20	25
> 690	25	35

1.2.6 Reduced values as specified in IEC 60092-302 may be accepted for type tested and partially type tested assemblies.

The reference values for the evaluation of the minimum clearances and creepage distances for these assemblies are based on the following:

- pollution degree 3 (conductive pollution occurs, or dry non-conductive pollution occurs which becomes conductive due to condensation which is expected)
- overvoltage category III (distribution circuit level)
- unhomogenous field conditions (case A)
- rated operational voltage 1000 V a.c., 1500 V d.c.
- group of insulating material IIIa.

Special consideration is to be given to equipment located in spaces where a pollution degree higher than 3 is applicable, e.g. in diesel engine rooms.

1.2.7 Busbars and other bare conductors with their supports are to be mechanically dimensioned and fixed such that they can withstand the stresses caused by short-circuits.

Where maximum symmetrical short-circuit currents are expected to exceed 50 KA, calculation is to be submitted to the Society.

1.2.8 Busbars and bare conductors are to be protected, where necessary, against falling objects (e.g. tools, fuses or other objects).

1.3 Internal wiring

1.3.1 Insulated conductors for internal wiring of auxiliary circuits of switchboards are to be constructed in accordance with Ch 2, Sec 9, [1.1.5].

1.3.2 All insulated conductors provided for in [1.3.1] are to be of flexible construction and of the stranded type.

1.3.3 Connections from busbars to protective devices are to be as short as possible. They are to be laid and secured in such a way to minimize the risk of a short-circuit.

1.3.4 All conductors are to be secured to prevent vibration and are to be kept away from sharp edges.

1.3.5 Connections leading to indicating and control instruments or apparatus mounted in doors are to be installed such that they cannot be mechanically damaged due to movement of the doors.

1.3.6 Non-metallic trays for internal wiring of switchboards are to be of flame-retardant material.

1.3.7 Control circuits are to be installed and protected such that they cannot be damaged by arcs from the protective devices.

1.3.8 Where foreseen, fixed terminal connectors for connection of the external cables are to be arranged in readily accessible positions.

1.3.9 Colour of insulated conductors for internal wiring are preferably to be chosen as follows:

- 440 volts: red
- 115 volts: white
- 24 volts: black
- Intrinsically safe circuits: blue
- Optical fibre: orange

1.4 Switchgear and controlgear

1.4.1 Switchgear and controlgear are to comply with IEC 60947 series and to be chosen from among that type approved by the Society.

1.4.2 The characteristics of switchgear, controlgear and protective devices for the various consumers are to be in compliance with Ch 2, Sec 3, [7].

1.5 Auxiliary circuits

1.5.1 Auxiliary circuits are to be designed in such a manner that, as far as practicable, faults in such circuits do not impair the safety of the system. In particular, control circuits are to be designed so as to limit the dangers resulting from a fault between the control circuit and earth (e.g. inadvertent operation or malfunction of a component in the installation), also taking account of the earthing system of their supply.

1.5.2 Auxiliary circuits of essential systems are to be independent of other auxiliary circuits.

1.5.3 Common auxiliary circuits for groups of consumers are permitted only when the failure of one consumer jeopardizes the operation of the entire system to which it belongs.

1.5.4 Auxiliary circuits are to be branched off from the main circuit in which the relevant switchgear is used.

1.5.5 The supply of auxiliary circuits by specifically arranged control distribution systems will be specially considered by the Society.

1.5.6 Means are to be provided for isolating the auxiliary circuits as well when the main circuit is isolated (e.g. for maintenance purposes).

1.5.7 For the protection of auxiliary circuits see Ch 2, Sec 3, [7.13].

1.6 Instruments

1.6.1 The upper limit of the scale of every voltmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.2 The upper limit of the scale of every ammeter is to be not less than 130% of the normal rating of the circuit in which it is installed.

1.6.3 The upper limit of the scale of every wattmeter is to be not less than 120% of the rated voltage of the circuit in which it is installed.

1.6.4 Wattmeters for use with a.c. generators which may be operated in parallel are to be capable of indicating 15% reverse power.

1.6.5 For wattmeters using one current circuit only, the measurement of the current of all generators is to be made in the same phase.

1.6.6 The rated value of the measure read, at full load, is to be clearly indicated on the scales of instruments.

1.6.7 Frequency meters are to have a scale at least ± 5% of the nominal frequency.

1.6.8 The secondary windings of instrument transformers are to be earthed.

1.6.9 Each a.c. generator not operated in parallel is to be provided with:

- 1 voltmeter
- 1 frequency meter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read
- 1 three-phase wattmeter in the case of generators rated more than 50 kVA.

1.6.10 Each a.c. generator operated in parallel is to be provided with:

- 1 three-phase wattmeter
- 1 ammeter in each phase or 1 ammeter with a selector switch to enable the current in each phase to be read.

1.6.11 For paralleling purposes the following are to be provided:

- 2 voltmeters
- 2 frequency meters
- 1 synchroscope and synchronising indicating lamps or equivalent means.

A switch is to be provided to enable one voltmeter and one frequency meter to be connected to each generator before the latter is connected to the busbars.

The other voltmeter and frequency meter are to be permanently connected to the busbars.

1.6.12 Each secondary distribution system is to be provided with one voltmeter.

1.6.13 Switchboards are to be fitted with means for monitoring the insulation level of insulated distribution systems as stipulated in Ch 2, Sec 3, [3.2.1].

1.6.14 The main switchboard is to be fitted with a voltmeter or signal lamp indicating that the cable between the shore-connection box and the main switchboard is energized (see Ch 2, Sec 3, [3.6.7]).

1.6.15 For each d.c. power source (e.g. convertors, rectifiers and batteries), one voltmeter and one ammeter are to be provided, except for d.c. power sources for starting devices (e.g. starting motor for emergency generator).

2 Constructional requirements for section boards and distribution boards

2.1 Construction

2.1.1 Section boards and distribution boards are to be constructed, insofar as applicable, as specified for main and emergency switchboards.

2.1.2 All parts which require operation in normal use are to be placed on the front.

2.1.3 Distribution switchboards which are provided with two or more supply circuits arranged for automatic standby connection are to be provided with positive indication of which of the circuits is feeding the switchboard.

2.1.4 Where switchboard supplying essential services is provided with a forced air cooling system, the air temperature is to be monitored. An alarm is to be activated when temperature exceeds a preset value.

3 Testing

3.1 General

3.1.1 Switchboards are to be subjected to the tests specified from [3.2] to [3.4].

3.1.2 The manufacturer is to issue the relative test reports providing information concerning the construction, serial number and technical data relevant to the switchboard, as well as the results of the tests required.

3.1.3 The tests are to be carried out prior to installation on board.

3.1.4 The test procedures are as specified in IEC 60092-302.

3.2 Inspection of equipment, check of wiring and electrical operation test

3.2.1 It is to be verified that the switchboard:

- complies with the approved drawings
- maintains the prescribed degree of protection
- is constructed in accordance with the relevant constructional requirements, in particular as regards creepage and clearance distances.

3.2.2 The connections, especially screwed or bolted connections, are to be checked for adequate contact, possibly by random tests.

3.2.3 Depending on the complexity of the switchboard it may be necessary to carry out an electrical functioning test. The test procedure and the number of tests depend on whether or not the switchboard includes complicated interlocks, sequence control facilities, etc. In some cases it may be necessary to conduct or repeat this test following installation on board.

3.3 High voltage test

3.3.1 The test is to be performed with alternating voltage at a frequency between 25 and 100 Hz of approximately sinusoidal form.

3.3.2 The test voltage is to be applied:

- between all live parts connected together and earth
- between each polarity and all the other polarities connected to earth for the test.

During the high voltage test, measuring instruments, ancillary apparatus and electronic devices may be disconnected and tested separately in accordance with the appropriate requirements.

3.3.3 The test voltage at the moment of application is not to exceed half of the prescribed value. It is then to be increased steadily within a few seconds to its full value. The prescribed test voltage is to be maintained for 1 minute.

3.3.4 The value of the test voltage for main and auxiliary circuits is given in Tab 2 and Tab 3.

Table 2 : Test voltages for main circuits

Rated insulation voltage U_i in V	Test voltage c.a (r.m.s.), in V
$U_i \leq 60$	1000
$60 < U_i \leq 300$	2000
$300 < U_i \leq 660$	2500
$660 < U_i \leq 800$	3000
$800 < U_i \leq 1000$	3500

Table 3 : Test voltage for auxiliary circuits

Rated insulation voltage U_i in V	Test voltage c.a (r.m.s.), in V
$U_i \leq 12$	250
$12 < U_i \leq 60$	500
$U_i > 60$	$2 U_i + 1000$ (at least 1500)

3.4 Measurement of insulation resistance

3.4.1 Immediately after the high voltage test, the insulation resistance is to be measured using a device with a direct current voltage of at least 500 V.

3.4.2 The insulation resistance between all current carrying parts and earth (and between each polarity and the other polarities) is to be at least equal to 1 MΩ.

Section 9 Cables

1 Constructional requirements

1.1 Construction

1.1.1 Cables and insulated wiring are generally to be constructed in accordance with the relevant recommendations of IEC Publications 60092-350, 60092-352, 60092-353, 60092-354, 60092-360, 60092-370, and 60092-376, as well with the provisions of this Chapter.

1.1.2 Regarding smoke emission and halogen acid gas content, subject to Ch 2, Sec 3, [9.1.5], cables are to be in compliance with IEC 60754-1, 60754-2, 61034-1, 61034-2.

1.1.3 Optical fibre cables are to be constructed in accordance with IEC 60794.

1.1.4 Flexible cables constructed according to national standards will be specially considered by the Society.

1.1.5 Cables and insulated wires manufactured and tested in accordance with standards other than those specified in [1.1.1] will be accepted provided they are in accordance with an acceptable and relevant international or national standard and are of an equivalent or higher safety level than those listed in [1.1.1]. However, cables such as flexible cable, fibre-optic cable, etc. used for special purposes may be accepted provided they are manufactured and tested in accordance with the relevant standards accepted by the Society.

1.1.6 Insulated wiring for auxiliary circuits of switchboards and control gears may be constituted by cables with a single conductor of the stranded type for all sections, in accordance with the Publications cited in [1.1.1] and without further protection.

The insulated wiring is to be at least of the flame-retardant type according to IEC 60332-1 and in accordance with IEC 60754-1, 60754-2, 61034-1 and 61034-2. Equivalent types of flame-retardant switchboard wires will be specially considered by the Society.

1.1.7 Fire resistant cables are to be designed and tested in accordance with the relevant IEC Publication 60092-series standards.

They are to comply with the requirements of:

- IEC Standard 60331-1 for cables with an overall diameter exceeding 20 mm, or
- IEC Standard 60331-2 for cables with an overall diameter not exceeding 20 mm,
- otherwise IEC 60331-21.

The minimum flame application time is to be at least 90 minutes.

Fire resistant type cables are to be easily distinguishable.

Note 1: For special cables, requirements in the following standards may be used:

- IEC 60331-23: Procedures and requirements - Electric data cables
- IEC 60331-25: Procedures and requirements - Optical fibre cables.

1.2 Conductors

1.2.1 Conductors are to be of annealed electrolytic copper with a resistivity not exceeding 17,241 Ω mm^2/km at 20°C according to IEC 60228.

1.2.2 Individual conductor wires of rubber-insulated cables and cables having cross sectional area less than 10 mm are to be tinned or coated with a suitable alloy.

1.2.3 All conductors are to be stranded, except for cables of nominal cross-sectional area 2,5 mm^2 and less (provided that adequate flexibility of the finished cable is assured).

1.2.4 For the minimum nominal cross-sectional areas permitted, see Ch 2, Sec 3, [9.10].

1.3 Insulating materials

1.3.1 The materials used for insulation are to comply with IEC 60092-360 and to have the thicknesses specified for each type of cable in the relevant standard. The maximum permissible rated temperature is specified for the various materials.

1.3.2 Materials and thicknesses other than those in [1.3.1] will be specially considered by the Society.

1.4 Inner covering, fillers and binders

1.4.1 The cores of a multicore cable are to be laid up. The spaces between the cores are to be filled so as to obtain an assembly having an essentially circular cross-section. The filling may be omitted in multicore cables having a conductor cross-sectional area not exceeding 4 mm^2.

When a non-metallic sheath is applied directly over the inner covering or the fillers, it may substitute partially for the inner covering or fillers.

1.4.2 The materials used, the binders and the thicknesses of the inner coverings are generally to be in accordance with IEC Publications of the series 60092-3.., in relation to the type of cable.

1.5 Protective coverings (armour and sheath)

1.5.1 Metallic armour, if not otherwise protected against corrosion, is to be protected by means of a coating of protective paint (see Ch 2, Sec 3, [9.3]).

1.5.2 The paint is to be non-flammable and of adequate viscosity. When dry, it is not to flake off.

1.5.3 The materials and construction used for (metal) armour are to be in accordance with IEC 60092-350 and their dimensions are to be those specified for each type of cable in the relevant standard.

1.5.4 The materials used for sheaths are to be in accordance with IEC 60092-360 and are to have the thicknesses specified for each type of cable in the relevant standard.

The quality of the materials is to be adequate to the service temperature of the cable.

1.5.5 Materials other than those in [1.5.3] and [1.5.4] will be specially considered by the Society.

1.6 Identification

1.6.1 Each cable is to have clear means of identification so that the manufacturer can be determined.

1.6.2 Fire non propagating cables are to be clearly labelled with indication of the standard according to which this characteristic has been verified and, if applicable, of the category to which they correspond.

1.6.3 An identification tag is to be fitted at both end of the cable.

2 Testing

2.1 Type tests

2.1.1 Type tests are to be in accordance with the relevant IEC 60092-3.. Series Publications and IEC 60332-1, IEC 60332-3 Category A, IEC 60754-1, IEC 60754-2, IEC 61034-1, IEC 61034-2, and IEC 60331 where applicable or with standard recognized by the Society.

2.2 Routine tests

2.2.1 Every length of finished cable is to be subjected to the tests specified in [2.2.2].

2.2.2 The following routine tests are to be carried out:

a) visual inspection

b) check of conductor cross-sectional area by measuring electrical resistance

c) high voltage test

d) insulation resistance measurement

e) dimensional checks (as necessary).

2.2.3 The manufacturer is to issue a statement providing information on the type and characteristics of the cable, as well as the results of the tests required and the Type Approval Certificates.

2.2.4 The test procedure is as specified in IEC 60092-350.

2.2.5 Where an alternative scheme, e.g. a certified quality assurance system, is recognized by the Society, attendance of the Surveyor may not be required.

Section 10 Miscellaneous Equipment

1 Switchgear and controlgear, protective devices

1.1 General

1.1.1 Switchgear and controlgear are to comply with IEC Publication 60947.

1.1.2 For materials and construction see Ch 2, Sec 2, [4] and Ch 2, Sec 2, [5].

1.2 Circuit-breakers

1.2.1 Power-driven circuit-breakers are to be equipped with an additional separate drive operated by hand.

1.2.2 Power circuit-breakers with a making capacity exceeding 10 kA are to be equipped with a drive which performs the make operation independently of the actuating force and speed.

1.2.3 Where the conditions for closing the circuit-breaker are not satisfied (e.g. if the undervoltage trip is not energized), the closing mechanism is not to cause the closing of the contacts.

1.2.4 All circuit-breakers rated more than 16 A are to be of the trip-free type, i.e. the breaking action initiated by overcurrent or undervoltage releases is to be fulfilled independently of the position of the manual handle or other closing devices.

1.3 Protection devices

1.3.1 Short-circuit releases are generally to be independent of energy supplied from circuits other than that to be protected. Tripping due to short-circuit is to be reliable even in the event of a total loss of voltage in the protected circuit.

1.3.2 Short-circuit releases for generators are to be equipped with reclosing inhibitors and are to be delayed for selective tripping.

1.3.3 Overload releases or relays are to operate reliably at any voltage variation of the supply voltage in the protected circuit.

1.3.4 Undervoltage relays or releases are to cause the circuit-breaker to open if the voltage drops to 70%-35% of the rated voltage.

1.3.5 Shunt releases are to ensure the disconnection of the circuit-breaker even when the supply voltage of the release drops to 85% of the rated supply voltage.

1.3.6 The reverse power protection device is to respond to the active power regardless of the power factor, and is to operate only in the event of reverse power.

1.3.7 Single-phase failure devices in three-phase circuits are to operate without a time lag.

1.3.8 Insulation monitoring devices are to continuously monitor the insulation resistance to earth and trigger an alarm should the insulation resistance fall below a predetermined value.

The measuring current of such devices is not to exceed 30 mA in the event of a total short to earth.

2 Lighting fittings

2.1 Applicable requirements

2.1.1 Lighting fittings are to comply with IEC Publications 60598 and 60092-306.

Lighting fittings complying with other standards will be specially considered by the Society.

2.2 Construction

2.2.1 The temperature of terminals for connection of supplying cables is not to exceed the maximum conductor temperature permitted for the cable (see Ch 2, Sec 3, [9.9]).

Where necessary, luminaires are to be fitted with terminal boxes which are thermally insulated from the light source.

2.2.2 Wires used for internal connections are to be of a temperature class which corresponds to the maximum temperature within the luminaire.

2.2.3 The temperature rise of parts of luminaires which are in contact with the support is not to exceed 50°C. The rise is not to exceed 40°C for parts in contact with flammable materials.

2.2.4 The temperature rise of surface parts which can easily be touched in service is not to exceed 15°C.

2.2.5 High-power lights with higher surface temperatures than those in [2.2.2] and [2.2.3] are to be adequately protected against accidental contact.

3 Accessories

3.1 Applicable requirements

3.1.1 Accessories are to be constructed in accordance with the relevant IEC Publications, and in particular with Publication 60092-306.

3.2 Construction

3.2.1 Enclosures of accessories are to be of metal having characteristics suitable for the intended use on board, or of flame-retardant insulating material.

3.2.2 Terminals are to be suitable for the connection of stranded conductors, except in the case of rigid conductors for mineral-insulated cables.

4 Plug-and-socket connections

4.1 Applicable requirements

4.1.1 Plug-and-socket connections are to comply with IEC Publication 60092-306 and with the following additional standards in relation to their use:

- in accommodation spaces, day rooms and service rooms (up to 16 A, 250 V a.c.): IEC Publication 60083 or 60320, as applicable
- for power circuits (up to 250 A, 690 V a.c.): IEC Publication 60309
- for electronic switchgear: IEC Publications, e.g. 60130 and 60603
- for refrigerated containers: ISO 1496-2.

5 Heating and cooking appliances

5.1 Applicable requirements

5.1.1 Heating and cooking appliances are to comply with the relevant IEC Publications (e.g. those of series 60335), with particular attention to IEC 60092-307.

5.2 General

5.2.1 Heating elements are to be enclosed and protected with metal or refractory material.

5.2.2 The terminals of the power supply cable are not to be subjected to a higher temperature than that permitted for the conductor of the connection cable.

5.2.3 The temperature of parts which are to be handled in service (switch knobs, operating handles and the like) is not to exceed the following values:

- 55°C for metal parts
- 65°C for vitreous or moulded material.

5.3 Space heaters

5.3.1 The casing or enclosure of heaters is to be so designed that clothing or other flammable material cannot be placed on them.

5.3.2 The temperature of the external surface of space heaters is not to exceed 60°C.

5.3.3 Space heaters are to be provided with a temperature limiting device without automatic reconnection which automatically trips all poles or phases not connected to earth when the temperature exceeds the maximum permissible value.

5.4 Cooking appliances

5.4.1 Live parts of cooking appliances are to be protected such that any foods or liquids which boil over or spill do not cause short-circuits or loss of insulation.

5.4.2 An emergency stop for deep fryers to be installed outside the room where they are located.

5.5 Fuel oil and lube oil heaters

5.5.1 In continuous-flow fuel oil and lube oil heaters, the maximum temperature of the heating elements is to be below the boiling point of the oil.

5.5.2 Each oil heater is to be provided with a thermostat maintaining the oil temperature at the correct level.

5.5.3 In addition to the thermostat in [5.5.2], each oil heater is to be provided with a temperature limiting device without automatic reconnection, and with the sensing device installed as close as possible to the heating elements and permanently submerged in the liquid.

5.6 Water heaters

5.6.1 Water heaters are to be provided with a thermostat and safety temperature limiter.

Section 11 Location

1 General

1.1 Location

1.1.1 The degree of protection of the enclosures and the environmental categories of the equipment are to be appropriate to the spaces or areas in which they are located; see Ch 2, Sec 3, Tab 3 and Ch 2, Sec 2, [5.2.2].

1.2 Areas with a risk of explosion

1.2.1 Except where the installation of equipment for explosive gas atmosphere is provided for by the Rules, electrical equipment is not to be installed where flammable gases or vapours are liable to accumulate; see Ch 2, Sec 3, [10].

2 Main electrical system

2.1 Location in relation to the emergency system

2.1.1 The arrangement of the emergency electrical system is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard will not render inoperative the main electric lighting system and the other primary essential services.

2.2 Main switchboard

2.2.1 Main switchboards, lighting distribution boards, transformers and converting equipment are to be so placed relative to their associated generator(s) so that, as far as practicable, the integrity of the main system of supply is affected only by a fire or other casualty in one space. Switchboards are to be located, as close as practicable to their associated generators.

2.2.2 An environmental enclosure for a main switchboard, such as may be provided by a machinery control room situated within the main boundaries of the space, is not to be considered as separating switchboards from generators.

3 Emergency electrical system

3.1 Spaces for the emergency source

3.1.1 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard shall be located inside the V-lines.

They shall not be located forward of the collision bulkhead.

3.1.2 The spaces containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard are not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switch-board.

Where this is not practicable, the contiguous boundaries are to be Class A60.

3.2 Location in relation to the main electrical system

3.2.1 The location of the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency power, the emergency switch-board and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard shall be such as to ensure to the satisfaction of the Society that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard or in any machinery space of Category A will not interfere with the supply, control and distribution of emergency electrical power.

3.2.2 The arrangement of the main electrical system is to be such that a fire or other casualty in spaces containing the main source of electrical power, associated converting equipment, if any, the main switchboard and the main lighting switchboard will not render inoperative the emergency electric lighting system and the other emergency services other than those located within the spaces where the fire or casualty has occurred.

3.3 Emergency switchboard

3.3.1 The emergency switchboard shall be installed as near as is practicable to the emergency source of electrical power.

3.3.2 Where the emergency source of electrical power is a generator, the emergency switchboard shall be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.4 Emergency battery

3.4.1 No accumulator battery fitted in accordance with the provisions of Ch 2, Sec 3, [2.3] shall be installed in the same space as the emergency switchboard.

4 Distribution boards

4.1 Distribution boards for cargo spaces and similar spaces

4.1.1 Distribution boards containing multipole switches for the control of power and lighting circuits in bunkers and cargo spaces are to be situated outside such spaces.

4.2 Distribution board for navigation lights

4.2.1 The distribution board for navigation lights is to be placed in an accessible position on the bridge.

5 Cable runs

5.1 General

5.1.1 Cable runs are to be selected so as to be as far as practicable accessible, with the exception of single cables, situated behind walls or ceilings constructed of incombustible materials, supplying lighting fittings and socket-outlets in accommodation spaces, or cables enclosed in pipes or conduits for installation purposes.

5.1.2 Cable runs are to be selected so as to avoid action from condensed moisture and from dripping of liquids.

5.1.3 Connection and draw boxes are to be accessible.

5.1.4 Cables are generally not to be installed across expansion joints. Where this is unavoidable, however, a loop of cable of length proportional to the expansion of the joint is to be provided (see Sec 12 [7.2.2]).

5.2 Location of cables in relation to the risk of fire and overheating

5.2.1 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are, so far as is practicable, to be routed clear of galleys, laundries, machinery spaces of Category A and their casings and other high fire risk areas, except for supplying equipment in those spaces.

5.2.2 When it is essential that a circuit functions for some time during a fire and it is unavoidable to carry the cable for such a circuit through a high fire risk area (e.g. cables connecting fire pumps to the emergency switchboard), the cable is to be of a fire-resistant type or adequately protected against direct exposure to fire.

5.2.3 The electrical cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source(s) of power and prime mover(s).

They are to be of a fire resistant type, in accordance with Ch 2, Sec 9, [1.1.7], where they pass through other high fire risk areas.

5.2.4 Main cable runs (see Note 1) and cables for the supply and control of essential services are, as far as is practicable, to be kept away from machinery parts having an increased fire risk (see Note 2) unless:

- the cables have to be connected to the subject equipment,
- the cables are protected by a steel bulkhead or deck, or
- the cables in that area are of the fire-resisting type.

Note 1: Main cable runs are for example:

- cable runs from generators and propulsion motors to main and emergency switchboards
- cable runs directly above or below main and emergency switchboards, centralised motor starter panels, section boards and centralised control panels for propulsion and essential auxiliaries.

Note 2: Machinery, machinery parts or equipment handling combustibles are considered to present an increased fire risk.

5.2.5 Cables and wiring serving essential or emergency power, lighting, internal communications or signals are to be arranged, as far as practicable, in such a manner as to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

5.2.6 Cables are to be arranged as remote as possible from sources of heat such as hot pipes, resistors, etc. Where installation of cables near heat sources cannot be avoided, and where there is consequently a risk of damage to the cables by heat, suitable shields are to be installed, or other precautions to avoid overheating are to be taken, for example use of ventilation, heat insulation materials or special heat-resisting cables.

5.3 Location of cables in relation to electromagnetic interference

5.3.1 For the installation of cables in the vicinity of radio equipment or of cables belonging to electronic control and monitoring systems, steps are to be taken in order to limit the effects of unwanted electromagnetic interference (see Ch 3, Sec 5).

5.4 Services with a duplicate feeder

5.4.1 Duplicated supplies and associated control cables for essential services (e.g. steering gear circuits) are to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

5.5 Emergency circuits

5.5.1 Cables supplying emergency circuits are not to run through spaces containing the main source of electrical power, associated transforming equipment, if any, the main switchboard and the main lighting switchboard, except for cables supplying emergency equipment located within such spaces (see [3.2.2]).

6 Storage batteries

6.1 General

6.1.1 Batteries are to be located where they are not exposed to excessive heat, extreme cold, spray, steam or other conditions which would impair performance or accelerate deterioration. They are to be installed in such a way that no damage may be caused to surrounding appliances by the vapours generated.

6.1.2 Storage batteries are to be suitably housed, and compartments (rooms, lockers or boxes) used primarily for their accommodation are to be properly constructed and efficiently ventilated so as to prevent accumulation of flammable gas.

6.1.3 Starter batteries are to be located as close as practicable to the engine or engines served.

6.1.4 Accumulator batteries shall not be located in sleeping quarters except where hermetically sealed to the satisfaction of the Society.

6.1.5 Lead-acid batteries and alkaline batteries are not to be installed in the same compartment (room, locker, box), unless of valve-regulated sealed type.

6.2 Large vented batteries

6.2.1 Batteries connected to a charging device of power exceeding 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery (hereafter referred to as "large batteries") are to be installed in a room assigned to batteries only.

Where this is not possible, they may be arranged in a suitable locker on deck.

6.2.2 Rooms assigned to large batteries are to be provided with mechanical exhaust ventilation.

Natural ventilation may be employed for boxes located on open deck.

6.2.3 The provisions of [6.2.1] and [6.2.2] also apply to several batteries connected to charging devices of total power exceeding 2 kW calculated for each one as stated in [6.2.1].

6.3 Moderate vented batteries

6.3.1 Batteries connected to a charging device of power between 0,2 kW and 2 kW calculated as stated in [6.2.1] (hereafter referred to as “moderate batteries”) are to be arranged in the same manner as large batteries or placed in a box or locker in suitable locations such as machinery spaces, storerooms or similar spaces. In machinery spaces and similar well-ventilated compartments, these batteries may be installed without a box or locker provided they are protected from falling objects, dripping water and condensation where necessary.

6.3.2 Rooms, lockers or boxes assigned to moderate batteries are to be provided with natural ventilation or mechanical exhaust ventilation, except for batteries installed without a box or locker (located open) in well-ventilated spaces.

6.3.3 The provisions of [6.3.1] and [6.3.2] also apply to several batteries connected to charging devices of total power between 0,2 kW and 2 kW calculated for each one as stated in [6.2.1].

6.4 Small vented batteries

6.4.1 Batteries connected to a charging device of power less than 0,2 kW calculated as stated in [6.2.1] (hereafter referred to as "small batteries") are to be arranged in the same manner as moderate or large batteries, or without a box or locker, provided they are protected from falling objects, or in a box in a ventilated area.

6.4.2 Boxes for small batteries may be ventilated only by means of openings near the top to permit escape of gas.

6.5 Ventilation

6.5.1 The ventilation of battery compartments is to be independent of ventilation systems for other spaces.

6.5.2 The quantity of air expelled (by natural or forced ventilation) for compartments containing vented type batteries is to be at least equal to:

$Q = 110 \cdot I \cdot n$

where:

Q	:	Quantity of air expelled, in litres per hour
I	:	Maximum current delivered by the charging equipment during gas formation, but not less than one quarter of the maximum obtainable charging current in amperes
n	:	Number of cells in series.

6.5.3 The quantity of air expelled (by natural or forced ventilation) for compartments containing valve-regulated sealed batteries is to be at least 25% of that given in [6.5.2].

6.5.4 Ducts are to be made of a corrosion-resisting material or their interior surfaces are to be painted with corrosion-resistant paint.

6.5.5 Adequate air inlets (whether connected to ducts or not) are to be provided near the floor of battery rooms or the bottom of lockers or boxes (except for that of small batteries).

Air inlet may be from the open air or from another space (for example from machinery spaces).

6.5.6 Exhaust ducts of natural ventilation systems:

a) are to be run directly from the top of the compartment to the open air above (they may terminate in the open or in well-ventilated spaces)

b) are to terminate not less than 90 cm above the top of the battery compartment

c) are to have no part more than 45° from the vertical

d) are not to contain appliances (for example for barring flames) which may impede the free passage of air or gas mixtures.

Where natural ventilation is impracticable or insufficient, mechanical exhaust ventilation is to be provided.

6.5.7 In mechanical exhaust ventilation systems:

a) electric motors are to be outside the exhaust ducts and battery compartment and are to be of safe type if installed within 3 m from the exhaust of the ventilation duct

b) fans are to be so constructed and of a material such as to render sparking impossible in the event of the impeller touching the fan casing

c) steel or aluminium impellers are not to be used

d) the system is to be interlocked with the charging device so that the battery cannot be charged without ventilation (trickle charge may be maintained)

e) a temperature sensor is to be located in the battery compartment to monitor the correct behaviour of the battery in cases where the battery element is sensitive to temperature.

6.5.8 For natural ventilation systems for deck boxes:

a) holes for air inlet are to be provided on at least two opposite sides of the box

b) the exhaust duct is to be of ample dimensions

c) the duct is to terminate at least 1,25 m above the box in a goose-neck or mushroom-head or the equivalent

d) the degree of protection is to be in accordance with Ch 2, Sec 3, Tab 3.

Section 12 Installation

1 General

1.1 Protection against injury or damage caused by electrical equipment

1.1.1 All electrical equipment is to be so installed as not to cause injury when handled or touched in the normal manner.

1.1.2 All electrical equipment is to be installed in such a way that live parts cannot be inadvertently touched, unless supplied at a safety voltage.

1.1.3 For protective earthing as a precaution against indirect contact, see Article [2].

1.1.4 Equipment is to be installed so as not to cause malfunctions due to electromagnetic interference.

1.2 Protection against damage to electrical equipment

1.2.1 Electrical equipment is to be so placed that as far as practicable it is not exposed to risk of damage from water, steam, oil or oil vapours.

1.2.2 The air supply for internal ventilation of electrical equipment is to be as clean and dry as practicable; cooling air for internal ventilation is not to be drawn from below the floor plates in engine and/or boiler rooms.

1.2.3 Equipment is to be so mounted that its enclosing arrangements and the functioning of the built-in equipment will not be affected by distortions, vibrations and movements of the ship's structure or by other damage liable to occur.

1.2.4 If electrical fittings, not of aluminium, are attached to aluminium, suitable provision is to be made to prevent galvanic corrosion.

1.3 Accessibility

1.3.1 Equipment is to be so installed that sufficient space is available for inspection and maintenance as required for all its parts (see [6.1.3]).

1.4 Environmentally controlled spaces

1.4.1 Where electrical equipment is installed in environmentally controlled spaces the ambient temperature for which the equipment is to be suitable may be reduced from 45°C to a value not less than 35°C provided:

a) the equipment is not for use for emergency services

b) temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is capable of satisfactorily maintaining the design temperature

c) the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45°C ambient temperature

d) audible and visual alarms are provided, at a continuously manned control station, to indicate any malfunction of the cooling units.

1.4.2 In accepting a lesser ambient temperature than 45°C, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

2 Earthing of non-current carrying parts

2.1 Parts which are to be earthed

2.1.1 Exposed metal parts of both fixed and portable electrical machines or equipment which are not intended to be live but which are liable under fault conditions to become live and similar metal parts inside non-metallic enclosures are to be earthed unless the machines or equipment are:

a) supplied at a voltage not exceeding 50 V direct current or 50 V, root mean square between conductors, achieved without the use of auto-transformers (safety voltage); or

b) constructed in accordance with the principle of double insulation.

2.1.2 To minimize shock from high frequency voltage induced by the radio transmitter, handles, handrails and other metal elements on the bridge or open decks are to be in electrical connection with the hull or superstructures.

2.2 Methods of earthing

2.2.1 Metal frames or enclosures of apparatus and electrical machinery may be fixed to, and in metallic contact with, the ship's structure, provided that the surfaces in contact are clean and free from rust, scale or paint when installed and are firmly bolted together.

2.2.2 For metal frames or enclosures which are not earthed as specified in [2.2.1], earthing connections complying with [2.3] and [2.4] are to be used.

2.2.3 For requirements regarding the earthing of coverings of cables and the mechanical protection of cables, see [7.11] and [7.12].

Table 1 : Cross-sectional area of earth-continuity conductors and earthing connections

<table>
<tr><th colspan="2">Type of earthing connection</th><th>Cross-sectional area of associated current carrying conductor</th><th colspan="2">Minimum cross-sectional area of copper earthing connection</th></tr>
<tr><td>1</td><td>Earth-continuity conductor in flexible cable or flexible cord</td><td>Any</td><td colspan="2">Same as current carrying conductor up to and including 16 mm^2 and one half above 16 mm^2 but at least 16 mm^2</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Earth-continuity conductor incorporated in fixed cable</td><td rowspan="3">Any</td><td colspan="2">a) for cables having an insulated earth-continuity conductor:
• a cross-section equal to the main conductors up to and including 16 mm^2, but minimum 1,5 mm^2
• a cross-section not less than 50% of the cross-section of the main conductor when the latter is more than 16 mm^2, but at least 16 mm^2
b) for cables with a bare earth wire in direct contact with the lead sheath</td></tr>
<tr><td>Cross-section of main conductor (mm^2)</td><td>Earthing connection (mm^2)</td></tr>
<tr><td>1 ÷ 2,5
4 ÷ 6</td><td>1
1,5</td></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Separate fixed earthing conductor</td><td>≤ 2,5 mm^2</td><td colspan="2">Same as current carrying conductor subject to minimum of 1,5 mm^2 for stranded earthing connection or 2,5 mm^2 for unstranded earthing connection</td></tr>
<tr><td>> 2,5 mm^2
but ≤ 120 mm^2</td><td colspan="2">One half the cross-sectional area of the current carrying conductor, subjected to a minimum of 4 mm^2</td></tr>
<tr><td>> 120 mm^2</td><td colspan="2">70 mm^2</td></tr>
</table>

2.3 Earthing connections

2.3.1 Every earthing connection is to be of copper or other corrosion-resistant material and is to be securely installed and protected, where necessary, against damage and electrolytic corrosion.

2.3.2 The nominal cross-sectional area of each copper earthing connection is to be not less than that required in Tab 1.

Earthing connections of other metals are to have conductance at least equal to that specified for a copper earthing connection.

2.3.3 Metal parts of portable appliances are to be earthed, where required (see [2.1.1]), by means of an earth-continuity conductor in the flexible supply cable or cord, which has the cross-sectional area specified in Tab 1 and which is earthed, for example, through the associated plug and socket.

2.3.4 The lead sheathing or armour of cables is never to be relied upon as the sole means of earthing.

2.3.5 The resistance of earth connection is to be less than 0,1 Ohms.

2.4 Connection to the ship's structure

2.4.1 Every connection of an earth-continuity conductor or earthing lead to the ship's structure is to be secured by means of a screw of brass or other corrosion-resistant material of diameter not less than 6 mm.

2.4.2 Such earthing connection is not to be used for other purposes.

2.4.3 The connection described in [2.4.1] is to be located in an accessible position where it may readily be checked.

2.5 Earthed distribution systems

2.5.1 The system earthing of earthed distribution systems is to be effected by means independent of any earthing arrangements of non-current carrying parts and is to be connected to the hull at one point only

2.5.2 In an earthed distribution system in which the earthing connection does not normally carry current, this connection is to conform with the requirements of [2.3], except that the lower limit of 70 mm^2 (see Tab 1) does not apply.

2.5.3 The earthing connection is to be in an accessible position where it may readily be inspected and disconnected for insulation testing.

2.6 Aluminium superstructures

2.6.1 When aluminium superstructures are insulated from the steel hull to prevent electrolytic corrosion, they are to be secured to the hull by means of a separate bonding connection.

2.6.2 The connections are to be adequately close together and are to have a resistance less than 0,1 Ω.

2.6.3 The connections are to be located where they may readily be inspected.

3 Rotating machines

3.1 General

3.1.1 Every rotating machine is preferably to be installed with the shaft in the fore-and-aft direction. Where a rotating machine of 100 kW and over is installed athwartship, or vertically, it is to be ensured that the design of the bearings and the arrangements for lubrication are satisfactory to withstand the rolling specified in Ch 2, Sec 2, Tab 4.

4 Semiconductor convertors

4.1 Semiconductor power convertors

4.1.1 Naturally air-cooled semiconductor convertors are to be installed such that the circulation of air to and from the stacks or enclosures is not impeded and that the temperature of the cooling inlet air to convertor stacks does not exceed the ambient temperature for which the stacks are specified.

5 Vented type storage batteries

5.1 General

5.1.1 Batteries are to be arranged so that each cell or crate of cells is accessible from the top and at least one side to permit replacement and periodical maintenance.

5.1.2 Cells or crates are to be carried on insulating supports of material non-absorbent to the electrolyte (e.g. treated wood).

5.1.3 Cells are to be securely chocked by means of insulating material non-absorbent to the electrolyte, e.g. strips of treated wood. Special mechanical precautions are to be taken to prevent the emergency battery from being damaged by the shock.

5.1.4 Provision is to be made for the free circulation of air.

5.1.5 The direct current cables laid between the batteries and the protective device are to be as short as possible, and each cable is to be protected with a isolating conduit or rigidly supported on isolating supports so as to constitute a short circuit proof installation

5.2 Protection against corrosion

5.2.1 The interior of battery compartments (rooms, lockers, boxes) including all metal parts subject to the electrolyte is to be protected against the deteriorating effect of the latter by electrolyte-resistant coating or other equivalent means, unless corrosion-resistant materials are used.

5.2.2 Interior surfaces of metal shelves for battery cells, whether or not grouped in crates or trays, are to be protected by a lining of electrolyte-resistant material, watertight and carried up to at least 75 mm on all sides. In particular, linings are to have a minimum thickness of 1,5 mm, if of lead sheet for lead-acid batteries, and of 0,8 mm, if of steel for alkaline batteries.

Alternatively, the floor of the room or locker is to be lined as specified above to a height of at least 150 mm.

5.2.3 Battery boxes are to be lined in accordance with [5.2.2] to a height of at least 75 mm.

6 Switchgear and controlgear assemblies

6.1 Main switchboard

6.1.1 A main switchboard is to be so arranged as to give easy access as may be needed to apparatus and equipment, without danger to personnel.

6.1.2 An unobstructed space is to be left in front of the switchboard wide enough to allow access for operation; such width is generally about 1 metre.

When withdrawable equipment is contained in the switchboard, the width of the space is to be not less than 0,5 m when the equipment is fully withdrawn.

Reduced widths may be considered for small ships.

6.1.3 Where necessary, an unobstructed space is to be provided at the rear of the switchboard ample to permit maintenance; in general, the width of this passage is to be not less than 0,6 m, except that this may be reduced to 0,5 m in way of stiffeners and frames, and the height sufficient for the operation foreseen.

6.1.4 If necessary, the clear height above the switchboard specified by the manufacturer is to be maintained for pressure relief in the event of a short-circuit.

6.1.5 When the voltage exceeds the safety voltage, non-conducting mats or gratings are to be provided at the front and rear of the switchboard as necessary,

6.1.6 Piping and conduits are not to be installed in the same space of main switchboards.

Where this is unavoidable, pipes and conduits are to have welded joints only or to be provided with protection against spray from steam or pressurised liquids or dripping.

Alternatively the degree of protection of the switchboard is to be adequately increased.

6.2 Emergency switchboard

6.2.1 For the installation of the emergency switchboard, the same requirements apply as given in [6.1] for the installation of the main switchboard.

6.3 Section boards and distribution boards

6.3.1 For the installation of section and distribution boards, the same requirements apply, as far as applicable, as given in [6.1] for the installation of the main switchboard.

6.3.2 Piping and conduits are not to be installed directly above boards, electrical panels and consoles or in their vicinity.

7 Cables

7.1 General

7.1.1 Cables having insulating materials with different maximum permissible conductor temperatures are not to be bunched together.

Where this is not practicable, the cables are to be so installed that no cable reaches a temperature higher than its rating.

7.1.2 Cables having a protective covering which may damage the covering of more vulnerable cables are not to be bunched with the latter.

7.1.3 Cables having a bare metallic sheath (e.g. of copper) or braid or armour are to be installed in such a way that galvanic corrosion by contact with other metals is prevented.

7.1.4 All cables and wiring external to equipment are to be so installed as not to impair their original flame-retarding properties.

To this end, the following methods may be used:

a) the use of cables which have been tested in accordance with IEC Publication 60332-3 Category A or an equivalent test procedure for cables installed in bunches, or

b) the use of fire stops having at least B0 penetrations fitted as follows (see Fig 1, Fig 2, Fig 3 and Fig 4):
   - cable entries at the main and emergency switchboard
   - where cables enter engine control rooms
   - cable entries at centralised control panels for propulsion machinery and essential auxiliaries
   - at each end of totally enclosed cable trunks
   - at every second deck or approximately 6 metres for verticals runs and every 14 metres for horizontal runs in enclosed and semi-enclosed spaces

c) the use of fire protection coating applied to at least 1 metre in every 14 metres on horizontal cable runs and over the entire length of vertical cable runs for cables installed in enclosed and semi-enclosed spaces.

The cable penetrations are to be installed in steel plates of at least 3 mm thickness extending all around to twice the largest dimension of the cable run for vertical runs and once for horizontal runs, but need not extend through ceilings, decks, bulkheads or solid sides of trunks.

These precautions apply in particular to bunches of 5 or more cables in areas with a high fire risk (such as Category A machinery spaces, galleys etc.) and to bunches of more than 10 cables in other areas.

7.1.5 The cable of different voltage are to be segregated, according to their mutual influence. There shall be at least a segregation between following type of cable:

- Control and measurement cable (sensitive cable)
- Power cable
- High emissivity cable.

Figure 1 : Totally enclosed trunks

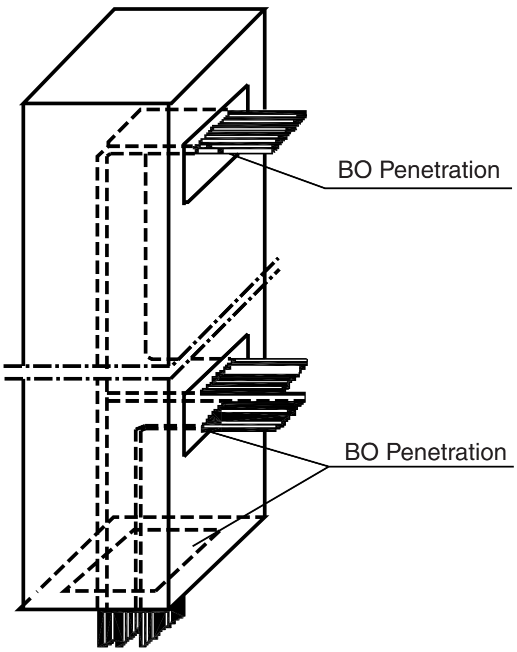


Figure 2 : Non-totally enclosed trunks, vertical

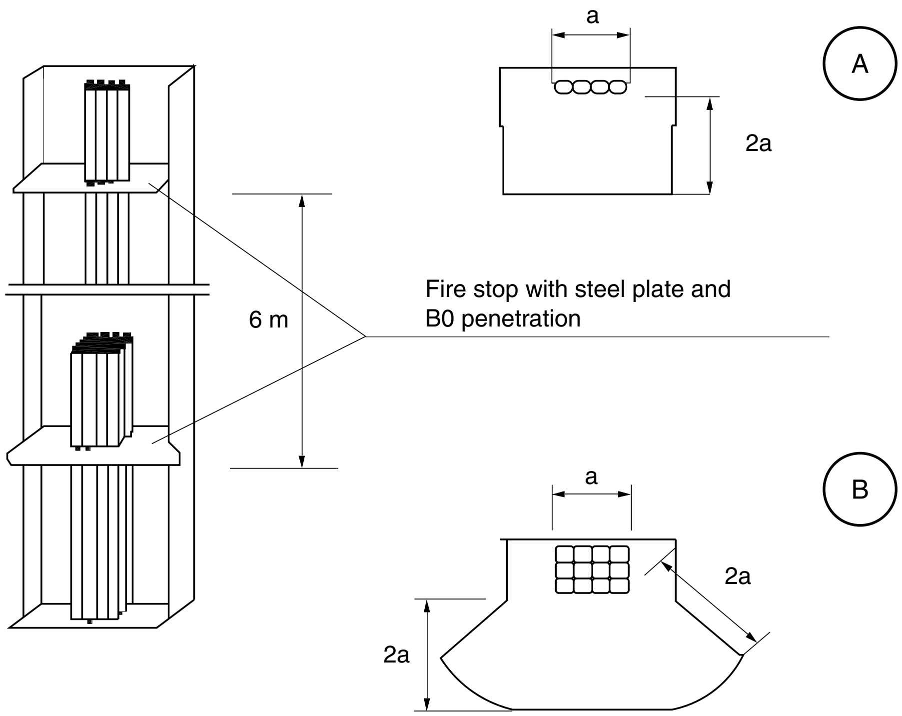


Figure 3 : Non-totally enclosed trunks, horizontal

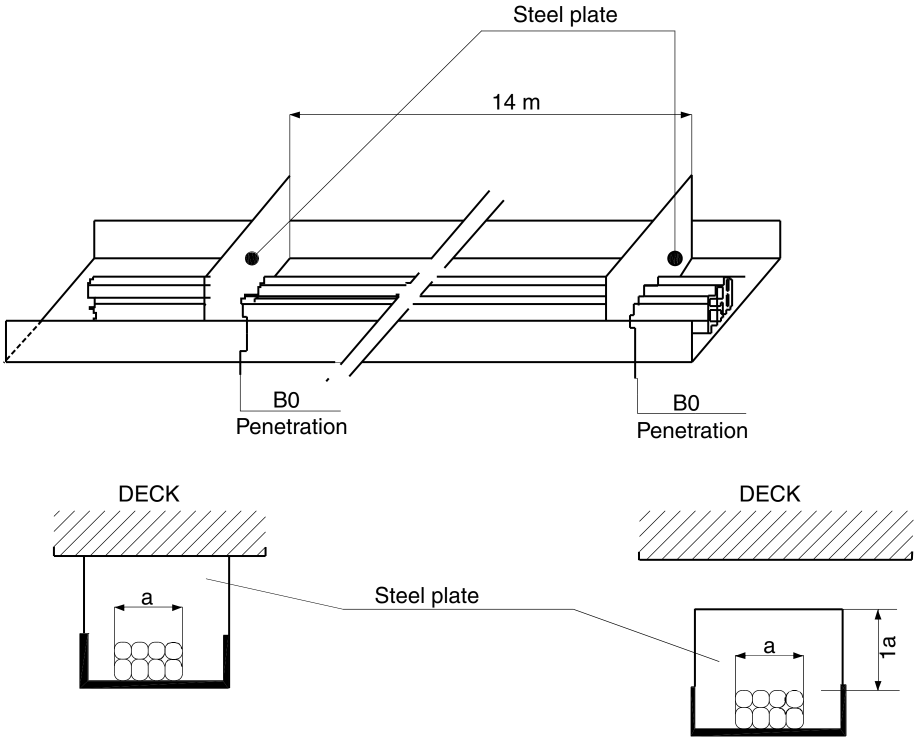
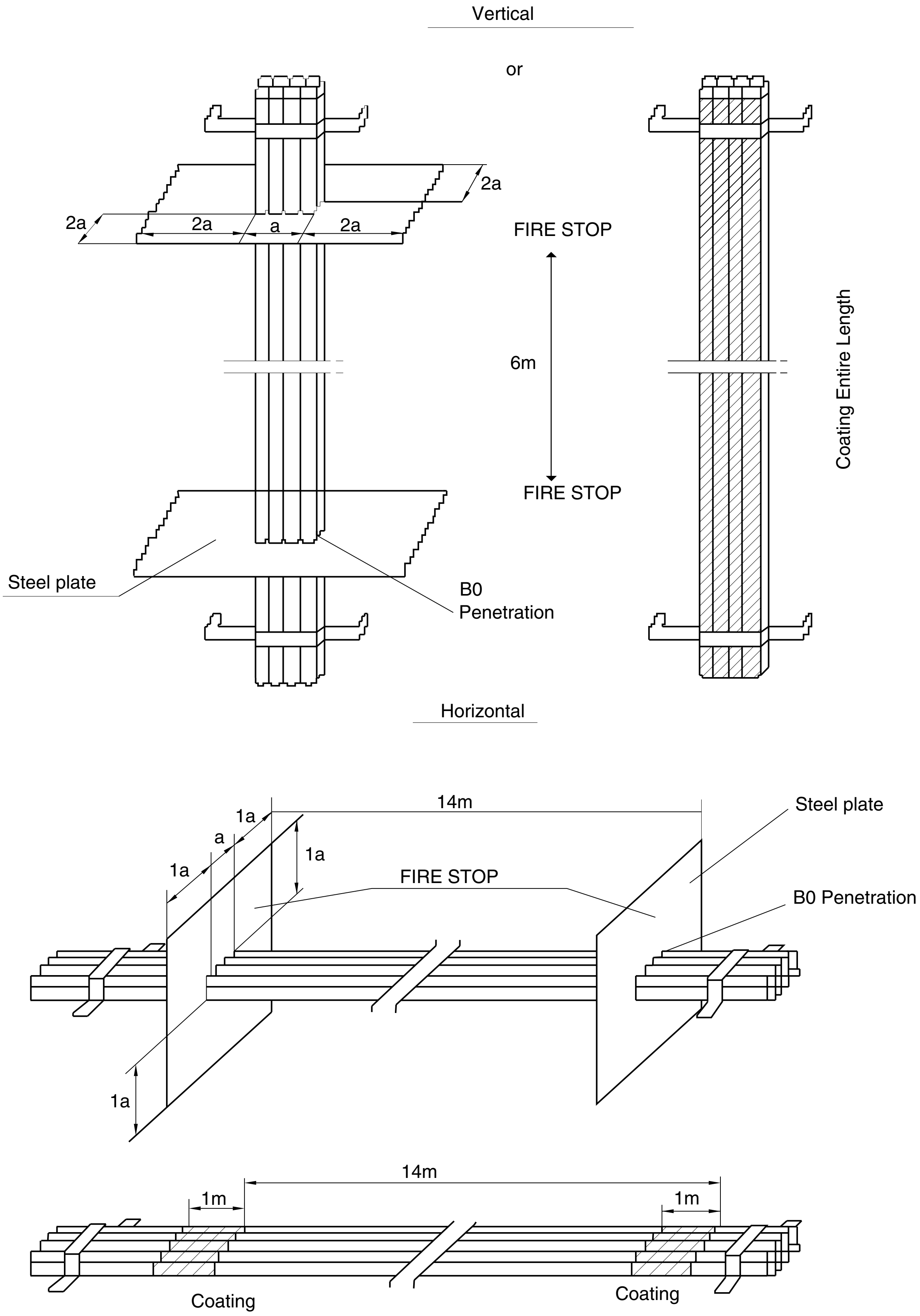


Figure 4 : Open cables runs



7.2 Radius of bend

7.2.1 The internal radius of bend for the installation of cables is to be chosen according to the type of cable as recommended by the manufacturer.

Its value is generally to be not less than the figure given in Tab 2.

7.2.2 Where the installation of cables across expansion joints is unavoidable, the minimum internal radius of the loop at the end of the travel of the expansion joint is to be not less than 12 times the external diameter of the cable.

7.3 Fixing of cables

7.3.1 Cables shall be installed and supported in such a manner as to avoid chafing or other damage.

7.3.2 The supports (tray plates, separate support brackets or hanger ladders) and the corresponding accessories are to be of robust construction and of corrosion-resistant material or suitably treated before erection to resist corrosion.

When cables are installed directly on aluminium structures, fixing devices of aluminium or suitably treated steel are to be used.

7.3.3 With the exception of cables installed in pipes, conduits, trunkings or special casings, cables are to be fixed by means of clips, saddles or straps of suitable material, in order to tighten the cables without their coverings being damaged.

7.3.4 Cable clips or straps made from a material other than metal are to be manufactured of a flame-retardant material.

Table 2 : Bending radii

Cable construction		Overall diameter of cable (D)	Minimum internal radius of bend
Insulation	Outer covering		
Thermoplastic or thermosetting with circular copper conductors	Unarmoured or unbraided	≤ 25 mm	4 D
		> 25 mm	6 D
	Metal braid screened or armoured	Any	6 D
	Metal wire armoured Metal tape armoured or metal-sheathed	Any	6 D
	Composite polyester/metal laminate tape screened units or collective tape screening	Any	8 D
Thermoplastic or thermosetting with shaped copper conductors	Any	Any	8 D

7.3.5 The distances between fastenings and between supports are to be suitably chosen according to the type and number of cables and the probability of vibration.

7.3.6 When cables are fixed by means of clips or straps made from a material other than metal and these cables are not laid on top of horizontal cable supports (e.g. in the case of vertical installation), suitable metal clips or saddles spaced not more than 1 metre apart are to be used in addition in order to prevent the release of cables during a fire.

7.3.7 Suspended cables of fire-resisting type are to be fixed by means of steel straps spaced not more than 500 mm apart.

7.4 Mechanical protection

7.4.1 Cables exposed to risk of mechanical damage are to be protected by metal casing, profiles or grids or enclosed in metal pipes or conduits, unless the cable covering (e.g. armour or sheath) provides adequate mechanical protection.

7.4.2 In situations where there would be an exceptional risk of mechanical damage, cables are to be protected by metal casing, trunkings or conduits, even when armoured, if the ship's structure or attached parts do not afford sufficient protection for the cables.

7.4.3 For the protection of cables passing through decks, see [7.5.3].

7.4.4 Metal casing used for mechanical protection of cables is to be effectively protected against corrosion.

7.5 Penetrations of bulkheads and decks

7.5.1 If cables have to pass without adequate support through non-watertight bulkheads and generally through holes drilled in sheets of structural steel, these holes are to be fitted with glands or bushings of suitable material.

7.5.2 If cables have to pass through a watertight bulkhead or deck, the penetration is to be effected in a watertight manner.

Either suitable individual watertight glands for single cables or boxes containing several cables and filled with a flame-retardant packing may be used for this purpose. Whichever type of penetration is used, the watertight integrity of the bulkheads or deck is to be maintained.

7.5.3 Cables passing through decks and continuing vertically are to be protected against mechanical damage to a suitable height above the deck.

7.5.4 Where cables pass through bulkheads or decks separating areas with a risk of explosion, arrangements are to be such that hazardous gas or dust cannot penetrate through openings for the passage of cables into other areas.

7.5.5 Where cables pass through a bulkhead or deck which is required to have some degree of fire integrity, penetration is to be so effected as to ensure that the required degree of fire integrity is not impaired.

7.5.6 If cables have to pass through deck or bulkhead specially designed for possible submersion of the room, the cable penetration is to reconstitute the tightness of the corresponding deck or bulkhead penetration, with an approved arrangement. test according to IEC 60529 is to be carried out.

7.6 Expansion joints

7.6.1 If there is reason to fear that a tray plate, pipe or conduit may break because of the motion of the ship, different load conditions and temperature variations, appropriate expansion joints are to be provided.

This may apply in particular in the case of cable runs on the weather deck.

7.7 Cables in closed pipes or conduits

7.7.1 Closed pipes or conduits are to have such internal dimensions and radius of bend as will permit the easy drawing in and out of the cables which they are to contain; the internal radius of bend is to be not less than that permitted for cables and, for pipes exceeding 63 mm external diameter, not less than twice the external diameter of the pipe where this value is greater.

7.7.2 Closed pipes and conduits are to be suitably smooth on the interior and are to have their ends shaped or bushed in such a way as not to damage the cable covering.

7.7.3 The space factor (ratio of the sum of the cross-sectional areas corresponding to the external diameters of the cables to the internal cross-sectional areas of the pipe or conduit) is to be not greater than 0,4.

7.7.4 If necessary, openings are to be provided at the highest and lowest points so as to permit air circulation and ensure that the heat from the cables can be dissipated, and to obviate the possibility of water accumulating at any part of the pipe or conduit.

7.7.5 Vertical trunking for electrical cables is to be so constructed as not to jeopardize the required passive fire protection between the spaces.

7.7.6 Metal pipes or conduits are to be protected against corrosion.

7.7.7 Non-metallic pipes or conduits are to be flame-retardant.

7.8 Cables in casings or trunking and conduits with removable covers

7.8.1 Covers are to be removable and when they are open, cables are to be accessible.

7.8.2 Materials used are to comply with [7.7.6] and [7.7.7].

7.8.3 If the fixing of covers is by means of screws, the latter are to be of non-rusting material and arranged so as not to damage the cables.

7.8.4 Means are to be provided to ensure that the heat from the cables can be dissipated and water accumulation is avoided (see [7.7.4]).

7.9 Cable ends

7.9.1 Terminations in all conductors are to be so made as to retain the original electrical, mechanical, flame-retarding properties of the cable.

7.9.2 Where mechanical clamps are not used, the ends of all conductors having a cross-sectional area greater than 4 mm^2 are to be fitted with soldering sockets or compression-type sockets of sufficient size to contain all the strands of the conductor.

7.10 Joints and tappings (branch circuit)

7.10.1 Cable are not to include joints. Where absolutely necessary, cable joints are to be carried out by a junction method approved by the Society, with rebuilding of the insulation and protective coverings.

7.10.2 Joints in all conductors are to be so made as to retain the original electrical (continuity and isolation), mechanical (strength and protection), flame-retarding and, where necessary, fire-resisting properties of the cable.

7.10.3 Tappings (branch circuits) are to be made via suitable connections or in suitable boxes of such design that the conductors remain adequately insulated and protected from atmospheric action and are fitted with terminals or busbars of dimensions appropriate to the current rating.

7.10.4 Cables for safety voltages are not to terminate in the same connection boxes as cable for higher voltages unless separated by suitable means.

7.11 Earthing and continuity of metal coverings of cables

7.11.1 All metal coverings of cables are to be electrically connected to the metal hull of the ship.

7.11.2 Metal coverings are generally to be earthed at both ends of the cable, except for [7.11.3] and [7.11.4].

7.11.3 Single-point earthing is admitted for final sub-circuits (at the supply end), except for those circuits located in areas with a risk of explosion.

7.11.4 Earthing is to be at one end only in those installations (intrinsically safe circuits, control circuits, etc.) where it is required for technical or safety reasons.

7.11.5 Metal coverings of single-core a.c. cables and special d.c. cables with high "ripple" content (e.g. for thyristor equipment) are to be earthed at one point only (e.g. at the mid-point).

7.11.6 The electrical continuity of all metal coverings of cables throughout the length of the latter, particularly at joints and tappings, is to be ensured.

7.11.7 The metal covering of cables may be earthed by means of glands intended for the purpose and so designed as to ensure an effective earth connection.

The glands are to be firmly attached to, and in effective electrical contact with, a metal structure earthed in accordance with these requirements.

7.11.8 The metal covering of cables may also be earthed by means of clamps or clips of corrosion-resistant material making effective contact with the covering and earthed metal.

7.12 Earthing and continuity of metal pipes, conduits and trunking or casings

7.12.1 Metal casings, pipes, conduits and trunking are to be effectively earthed.

7.12.2 Pipes or conduits may be earthed by being screwed into a metal enclosure, or by nuts on both sides of the wall of a metallic enclosure, provided the surfaces in contact are clean and free from rust, scale or paint and that the enclosure is in accordance with these requirements on earthing.

The connection is to be painted immediately after assembly in order to inhibit corrosion.

7.12.3 Pipes and conduits may be earthed by means of clamps or clips of corrosion-resistant metal making effective contact with the earthed metal.

7.12.4 Pipes, conduits or trunking together with connection boxes of metallic material are to be electrically continuous.

7.12.5 All joints in metal pipes and conduits used for earth continuity are to be soundly made and protected, where necessary, against corrosion.

7.13 Precautions for single-core cables for a.c.

7.13.1 For the earthing of metal coverings see [7.11.5].

7.13.2 Where it is necessary to use single-core cables for alternating current circuits rated in excess of 20 A, the requirements of [7.13.3] to [7.13.7] are to be complied with.

7.13.3 Conductors belonging to the same circuit are to be contained within the same pipe, conduit or trunking, unless this is of non-magnetic material.

7.13.4 Cable clips are to include cables of all phases of a circuit unless the clips are of non-magnetic material.

7.13.5 In the installation of two, three or four single-core cables forming respectively single-phase circuits, three-phase circuits, or three-phase and neutral circuits, the cables are to be in contact with one another, as far as possible. In any event, the distance between the external covering of two adjacent cables is to be not greater than one diameter.

7.13.6 When single-core cables having a current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.13.7 Magnetic material is not to be used between single-core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is to be no less than 75 mm, unless the cables belonging to the same circuit are installed in trefoil twisted formation.

7.14 Cables in refrigerated spaces

7.14.1 For the types of cables permitted in refrigerated spaces, see Ch 2, Sec 3, [9.4].

7.14.2 Power cables installed in refrigerated spaces are not to be covered by thermal insulation. Moreover, such cables are not to be placed directly on the face of the refrigerated space unless they have a thermoplastic or elastomeric extruded.

7.14.3 Power cables entering a refrigerated space are to pass through the walls and thermal insulation at right angles, in tubes sealed at each end and protected against oxidation.

7.15 Cables in areas with a risk of explosion

7.15.1 For the types of cables permitted in areas with a risk of explosion, see Ch 2, Sec 3, [10.2].

7.15.2 For penetration of bulkheads or decks separating areas with a risk of explosion, see [7.5.4].

7.15.3 Cables of intrinsically safe circuits are to be separated from the cables of all other circuits (minimum 50 mm).

7.15.4 Cables for fire pump are to chosen according to Ch 2, Sec 3, [9.6].

7.15.5 Where cables are to go through fuel tank, the cable is to be protected with a pipe which is to be defined according to Ch 1, Sec 10, Tab 3.

7.16 Cables in the vicinity of radio equipment

7.16.1 All cables between antennas and transmitters are to be routed separately of any other cable.

7.16.2 Where it is necessary to use single-core cables, the arrangement of conductors is to be such as to avoid complete or partial loops.

7.17 Cables for submerged bilge pumps

7.17.1 See Ch 2, Sec 3, [9.7].

8 Various appliances

8.1 Lighting fittings

8.1.1 Lighting fittings are to be so arranged as to prevent temperature rises which could damage the cables and wiring.

Note 1: Where the temperature of terminals of lighting fittings exceeds the maximum conductor temperature permitted for the supplied cable (see Ch 2, Sec 3, [9.9]), special installation arrangements, such as terminal boxes thermally insulated from the light source, are to be provided.

8.1.2 Lighting fittings are to be so arranged as to prevent surrounding material from becoming excessively hot.

8.1.3 Lighting fittings are to be secured in place such that they cannot be displaced by the motion of the vessel.

8.2 Heating appliances

8.2.1 Space heaters are to be so installed that clothing, bedding and other flammable material cannot come in con-tact with them in such a manner as to cause risk of fire.

Note 1: To this end, for example, hooks or other devices for hanging garments are not to be fitted above space heaters or, where appropriate, a perforated plate of incombustible material is to be mounted above each heater, slanted to prevent hanging anything on the heater itself.

8.2.2 Space heaters are to be so installed that there is no risk of excessive heating of the bulkheads or decks on which or next to which they are mounted.

8.2.3 Combustible materials in the vicinity of space heaters are to be protected by suitable incombustible and thermal-insulating materials.

8.3 Heating cables and tapes or other heating elements

8.3.1 Heating cables and tapes or other heating elements are not to be installed in contact with combustible materials. Where they are installed close to such materials, they are to be separated by means of a non-flammable material.

Section 13 High Voltage Installations

1 General

1.1 Field of application

1.1.1 The following requirements apply to a.c. three-phase systems with nominal voltage exceeding 1kV, the nominal voltage being the voltage between phases.

If not otherwise stated herein, construction and installation applicable to low voltage equipment generally apply to high voltage equipment.

1.2 Nominal system voltage

1.2.1 The nominal system voltage is not to exceed 15 kV. Nominal voltage below 11 KV are to be chosen according to Tab 1.

Note 1: Where necessary for special application, higher voltages may be accepted by the Society.

1.3 High-voltage, low-voltage segregation

1.3.1 Equipment with voltage above about 1 kV is not to be installed in the same enclosure as low voltage equipment, unless segregation or other suitable measures are taken to ensure that access to low voltage equipment is obtained without danger.

2 System design

2.1 Distribution

2.1.1 Network configuration for continuity of ship services

It is to be possible to split the main switchboard into at least two independent sections, by means of at least one circuit breaker or other suitable disconnecting devices, each supplied by at least one generator. If two separate switchboards are provided and interconnected with cables, a circuit breaker is to be provided at each end of the cable.

Services which are duplicated are to be divided between the sections.

2.1.2 Earthed neutral systems

In the event of an earth fault, the current is not to be greater than full load current of the largest generator on the switchboard or relevant switchboard section and not less than three times the minimum current required to operate any device against earth fault.

It is to be assured that at least one source neutral to ground connection is available whenever the system is in the energized mode. Electrical equipment in directly earthed neutral or other neutral earthed systems is to withstand the current due to a single phase fault against earth for the time necessary to trip the protection device.

2.1.3 Neutral disconnection

Means of disconnection are to be fitted in the neutral earthing connection of each generator so that the generator may be disconnected for maintenance and for insulation resistance measurement.

2.1.4 Hull connection of earthing impedance

All earthing impedances are to be connected to the hull. The connection to the hull is to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

2.1.5 Divided systems

In systems with neutral earthed, connection of the neutral to the hull is to be provided for each section.

2.1.6 Means of disconnection are to be fitted in the star point connected to earth of each alternator before the resistor so that the alternator may be disconnected for maintenance and insulation resistance measurement.

2.1.7 All earthing resistors are to be connected to the hull. In order to eliminate possible interference with radio, radar and communication systems, it is recommended that earthing resistors should be bonded together on the hull side of the resistors by means of bonding independent of that provided by the hull.

2.1.8 Alternators running in parallel may have a common neutral connection to earth provided they are suitably designed to avoid excessive circulating currents.

This is particularly important if the alternators are of different size and make. Alternators in which the third harmonic content does not exceed 5% may be considered adequate.

Note 1: This would mostly occur with a neutral bus with a single grounding resistor with the associated neutral switching. Where individual resistors are used, circulation of the third harmonic currents between paralleled alternators is minimised.

2.1.9 In systems with earthed neutral, resistors or other current-limiting devices for the connection of the neutrals to the hull are to be provided for each section in which the systems are split [2.1.2].

2.2 Degrees of protection

2.2.1 General

Each part of the electrical installation is to be provided with a degree of protection appropriate to the location, as a minimum the requirements of Ch 2, Sec 3, Tab 3.

2.2.2 Rotating machines

The degree of protection of enclosures of rotating electrical machines is to be at least the one required by IP 23 (see Ch 2, Sec 3).

The degree of protection of terminals is to be at least IP44.

For motors installed in spaces accessible to unqualified personnel, a degree of protection against approaching or contact with live or moving parts of at least IP4X is required.

2.2.3 Transformers

The degree of protection of enclosures of transformers is to be at least IP23.

For transformers installed in spaces accessible to unqualified personnel a degree of protection of at least IP4X is required.

For transformers not contained in enclosures, see [7.1].

2.2.4 Switchgear, controlgear assemblies and convertors

The degree of protection of metal enclosed switchgear, controlgear assemblies and static convertors is to be at least IP32. For switchgear, control gear assemblies and static convertors installed in spaces accessible to unqualified personnel, a degree of protection of at least IP4X is required.

2.3 Insulation

2.3.1 In general, for non Type Tested equipment phase-to-phase air clearances and phase-to- earth air clearances between non-insulated parts are to be not less than those specified in Tab 1.

Intermediate values may be accepted for nominal voltages provided that the next highest air clearance is observed.

In the case of smaller distances, an appropriate voltage impulse test is to be applied.

Table 1 : Minimum clearances

Rated voltage kV	Minimum clearance mm
3 - 3,3	55
6 - 6,6	90
10 - 11	120

2.3.2 Creepage distances between live parts and between live parts and earthed metal parts for standard components are to be in accordance with relevant IEC Publications for the nominal voltage of the system, the nature of the insulation material and the transient overvoltage developed by switch and fault conditions.

For non-standardized parts within the busbar section of a switchgear assembly, the minimum creepage distance is to be at least 25 mm/kV and behind current limiting devices, 16mm/kV.

2.4 Protection

2.4.1 Faults on the generator side of the circuit breaker

Protective devices are to be provided against phase-to-phase faults in the cables connecting the generators to the main switchboard and against interwinding faults within the generators. The protective devices are to trip the generator circuit breaker and to automatically de-excite the generator.

In distribution systems with a neutral earthed, phase to earth faults are also to be treated as above.

2.4.2 Any earth fault in the system is to be indicated by means of a visual and audible alarm.

In low impedance or direct earthed systems provision is to be made to automatically disconnect the faulty circuits. In high impedance earthed systems, where outgoing feeders will not be isolated in case of an earth fault, the insulation of the equipment is to be designed for the phase to phase voltage.

A system is defined effectively earthed (low impedance) when this factor is lower than 0.8. A system is defined non-effectively earthed (high impedance) when this factor is higher than 0,8.

Note 1: Earthing factor is defined as the ratio between the phase to earth voltage of the health phase and the phase to phase voltage. This factor may vary between $1/3^{1/2}$ and 1.

2.4.3 Power transformers

Power transformers are to be provided with overload and short circuit protection.

When transformers are connected in parallel, tripping of the protective devices on the primary side is to automatically trip the switch connected on the secondary side.

2.4.4 Voltage transformers for control and instrumentation

Voltage transformers are to be provided with overload and short circuit protection on the secondary side.

2.4.5 Fuses

Fuses are not to be used for overload protection.

2.4.6 Low voltage systems

Lower voltage systems supplied through transformers from high voltage systems are to be protected against overvoltages. This may be achieved by:

a) direct earthing of the lower voltage system

b) appropriate neutral voltage limiters

c) earthed screen between the primary and secondary windings of transformers.

3 Rotating machinery

3.1 Stator windings of generators

3.1.1 Generator stator windings are to have all phase ends brought out for the installation of the differential protection.

3.2 Temperature detectors

3.2.1 Rotating machinery is to be provided with temperature detectors in its stator windings to actuate a visual and audible alarm in a normally attended position whenever the temperature exceeds the permissible limit.

If embedded temperature detectors are used, means are to be provided to protect the circuit against overvoltage.

3.3 Tests

3.3.1 In addition to the tests normally required for rotating machinery, a high frequency high voltage test in accordance with IEC 60034-15 is to be carried out on the individual coils in order to demonstrate a satisfactory withstand level of the inter-turn insulation to steep fronted switching surges.

4 Power transformers

4.1 General

4.1.1 Transformers are to be of dry type according to IEC 60726.

5 Cables

5.1 General

5.1.1 Cables are to be constructed in accordance with IEC 60092-353 and 60092-354 or other equivalent Standard.

6 Switchgear and controlgear assemblies

6.1 General

6.1.1 Switchgear and controlgear assemblies are to be constructed according to IEC 60298 and the following additional requirements.

6.2 Construction

6.2.1 Mechanical construction

Switchgear is to be of metal - enclosed type in accordance with IEC 60298 or of the insulation - enclosed type in accordance with IEC 60466.

6.2.2 Locking facilities

Withdrawable circuit breakers and switches are to be provided with mechanical locking facilities in both service and disconnected positions. For maintenance purposes, key locking of withdrawable circuit breakers and switches and fixed disconnectors is to be possible.

Withdrawable circuit breakers are to be located in the service position so that there is no relative motion between fixed and moving portions.

6.2.3 Shutters

The fixed contacts of withdrawable circuit breakers and switches are to be so arranged that in the withdrawable position the live contacts are automatically covered.

6.2.4 Earthing and short-circuiting

For maintenance purposes an adequate number of earthing and short-circuiting devices is to be provided to enable circuits to be worked on in safety.

6.3 Auxiliary systems

6.3.1 Source of supply

If electrical energy and/or physical energy is required for the operation of circuit breakers and switches, a store supply of such energy is to be provided for at least two operations of all the components.

However, the tripping due to overload or short-circuit, and under-voltage is to be independent of any stored electrical energy sources. This does not preclude shunt tripping provided that alarms are activated upon lack of continuity in the release circuits and power supply failures.

6.3.2 Number of supply sources

At least two independent sources of supply for auxiliary circuits of each independent section of the system (see [2.1.1]) are to be provided. Where necessary one source of supply is to be from the emergency source of electrical power for the start up from dead ship condition.

6.4 High voltage test

6.4.1 A power-frequency voltage test is to be carried out on any switchgear and controlgear assemblies. The test procedure and voltages are to be according to IEC 60298.

7 Installation

7.1 Electrical equipment

7.1.1 Where equipment is not contained in an enclosure but a room forms the enclosure of the equipment, the access doors are to be so interlocked that they cannot be opened until the supply is isolated and the equipment earthed down.

At the entrance to spaces where high-voltage electrical equipment is installed, a suitable marking is to be placed indicating danger of high-voltage. As regards high-voltage electrical equipment installed outside the aforementioned spaces, similar marking is to be provided.

7.2 Cables

7.2.1 Runs of cables

In accommodation spaces, high voltage cables are to be run in enclosed cable transit systems.

7.2.2 Segregation

High voltage cables are to be segregated from cables operating at different voltage ratings; in particular, they are not to be run in the same cable bunch, in the same ducts or pipes, or in the same box.

Where high voltage cables of different voltage ratings are installed on the same cable tray, the air clearance between cables is not to be less than the minimum air clearance for the higher voltage side in [2.3.1]. However, high voltage cables are not to be installed on the same cable tray for cables operating at the nominal system voltage of 1 kV and less.

7.2.3 Installation arrangements

High voltage cables are generally to be installed on carrier plating when they are provided with a continuous metallic sheath or armour which is effectively bonded to earth; otherwise they are to be installed for their entire length in metallic castings effectively bonded to earth.

7.2.4 Terminations

Terminations in all conductors of high voltage cables are, as far as practicable, to be effectively covered with suitable insulating material. In terminal boxes, if conductors are not insulated, phases are to be separated from earth and from each other by substantial barriers of suitable insulating materials.

High voltage cables of the radial field type, i.e. having a conductive layer to control the electric field within the insulation, are to have terminations which provide electric stress control.

Terminations are to be of a type compatible with the insulation and jacket material of the cable and are to be provided with means to ground all metallic shielding components (i.e. tapes, wires etc).

7.2.5 Marking

High voltage cables are to be readily identifiable by suitable marking.

7.2.6 Test after installation

Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories.

The test is to be carried out after an insulation resistance test.

When a d.c. voltage withstand test is carried out, the voltage is to be not less than:

- 1,6 (2,5 Uo + 2 kV) for cables of rated voltage (Uo) up to and including 3,6 kV, or
- 4,2 Uo for higher rated voltages

where Uo is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.

The test voltage is to be maintained for a minimum of 15 minutes.

After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge.

An insulation resistance test is then repeated.

Alternatively, an a.c. voltage withstand test may be carried out on the advice of the high voltage cable manufacturer at a voltage not less than the normal operating voltage of the cable, to be maintained for a minimum of 24 hours.

Note 1: Tests specified in IEC 60502 will be considered adequate.

Section 14 Electric Propulsion Plant

1 General

1.1 Applicable requirements

1.1.1 The following requirements apply to ships for which the main propulsion plants are provided by at least one electric propulsion motor and its electrical supply. All electrical components of the propulsion plants are to comply with these requirements.

1.1.2 Prime movers are to comply with the requirements of Ch 1, Sec 2.

1.1.3 For the torsional vibration characteristics of the electric propulsion plant, the provisions of Ch 1, Sec 9 apply.

1.1.4 Cooling and lubricating oil systems are to comply with the requirements of Ch 1, Sec 10.

1.1.5 Monitoring and control systems are to comply with the requirements of Part C, Chapter 3.

1.1.6 Installations assigned an additional notation for automation are to comply with the requirements of Part E.

1.2 Operating conditions

1.2.1 The normal torque available on the electric propulsion motors for manoeuvring is to be such as to enable the vessel to be stopped or reversed when sailing at its maximum service speed.

1.2.2 Adequate torque margin is to be provided for three-phase synchronous motors to avoid the motor pulling out of synchronism during rough weather and when turning.

1.2.3 When an electric generating plant has a continuous rating greater than the electric propulsion motor rating, means are to be provided to limit the continuous input to the motor. This value is not to exceed the continuous full load torque for which motor and shafts are designed.

1.2.4 The plant as a whole is to have sufficient overload capacity to provide the torque, power and reactive power needed during starting and manoeuvring conditions.

Locked rotor torque which may be required in relation to the operation of the vessel (e.g. for navigation in ice) is to be considered.

1.2.5 The electric motors and shaftline are to be constructed and installed so that, at any speed reached in service, all the moving components are suitably balanced.

2 Design of the propulsion plant

2.1 General

2.1.1 The electrical power for the propulsion system may be supplied from generating sets, dedicated to the propulsion system, or from a central power generation plant, which supplies the ship's services and electric propulsion.

The minimum configuration of an electric propulsion plant consists of one prime mover, one generator and one electric motor. When the electrical production used for propulsion is independent of the shipboard production, the diesel engines driving the electric generators are to be considered as main engines.

2.1.2 For plants having only one propulsion motor controlled via a static convertors, a standby convertors which it is easy to switch over to is to be provided. Double stator windings with one convertor for each winding are considered as an alternative solution.

2.1.3 In electric propulsion plants having two or more constant voltage propulsion generating sets, the electrical power for the ship's auxiliary services may be derived from this source. Additional ship's generators for auxiliary services need not be fitted provided that effective propulsion and the services mentioned in Ch 2, Sec 3, [2.2.3] are maintained with any one generating set out of service.

Where transformers are used to supply the ship's auxiliary services, see Ch 2, Sec 5.

2.1.4 Plants having two or more propulsion generators, two or more static convertors or two or more motors on one propeller shaft are to be so arranged that any unit may be taken out of service and disconnected electrically, without affecting the operation of the others.

2.2 Power supply

2.2.1 Where the plant is intended exclusively for electric propulsion, voltage variations and maximum voltage are to be maintained within the limits required in Ch 2, Sec 2.

2.2.2 In special conditions (e.g. during crash-stop manoeuvres), frequency variations may exceed the limits stipulated in Ch 2, Sec 2 provided that other equipment operating on the same network is not unduly affected.

2.2.3 The electric plant is to be so designed as to prevent the harmful effects of electromagnetic interference generated by semiconductor convertors, in accordance with Ch 2, Sec 2.

2.3 Auxiliary machinery

2.3.1 Propeller/thruster auxiliary plants are to be supplied directly from the main switchboard or from the main distribution board or from a distribution board reserved for such circuits, at the auxiliary rated voltage.

2.3.2 When the installation has one or more lubrication systems, devices are to be provided to ensure the monitoring of the lubricating oil return temperature.

2.3.3 Propelling machinery installations with a forced lubrication system are to be provided with alarm devices which will operate in the event of oil pressure loss.

2.4 Electrical Protection

2.4.1 Automatic disconnections of electric propulsion plants which adversely affect the manoeuvrability of the ship are to be restricted to faults liable to cause severe damage to the equipment.

2.4.2 The following protection of convertors is to be provided:

- protection against overvoltage in the supply systems to which convertors are connected
- protection against overcurrents in semiconductor elements during normal operation
- short-circuit protection.

2.4.3 Overcurrent protective devices in the main circuits are to be set sufficiently high so that there is no possibility of activation due to the overcurrents caused in the course of normal operation, e.g. during manoeuvring or in heavy seas.

2.4.4 Overcurrent protection may be replaced by automatic control systems ensuring that overcurrents do not reach values which may endanger the plant, e.g. by selective tripping or rapid reduction of the magnetic fluxes of the generators and motors.

2.4.5 In the case of propulsion plants supplied by generators in parallel, suitable controls are to ensure that, if one or more generators are disconnected, those remaining are not overloaded by the propulsion motors.

2.4.6 In three-phase systems, phase-balance protective devices are to be provided for the motor circuit which de-excite the generators and motors or disconnect the circuit concerned.

2.5 Excitation of electric propulsion motor

2.5.1 Where applicable, each propulsion motor is to have its own exciter.

2.5.2 For plants where only one generator or only one motor is foreseen, each machine is to be provided with a standby exciter, which it is easy to switch over to.

2.5.3 In the case of multi-propeller propulsion ships, one standby exciter which it is easy to switch over to is to be provided.

2.5.4 For the protection of field windings and cables, means are to be provided for limiting the induced voltage when the field circuits are opened. Alternatively, the induced voltage when the field circuits are opened is to be maintained at the nominal design voltage.

2.5.5 In excitation circuits, there is to be no overload protection causing the opening of the circuit, except for excitation circuits with semiconductor convertors.

3 Construction of rotating machines and semiconductor convertors

3.1 Ventilation

3.1.1 Where electrical machines are fitted with an integrated fan and are to be operated at speeds below the rated speed with full load torque, full load current, full load excitation or the like, the design temperature rise is not to be exceeded.

3.1.2 Where electrical machines or convertors are force-ventilated, at least two fans, or other suitable arrangements, are to be provided so that limited operation is possible in the event of one fan failing.

3.2 Protection against moisture and condensate

3.2.1 Machines and equipment which may be subject to the accumulation of moisture and condensate are to be provided with effective means of heating. The latter is to be provided for motors above 500 kW, in order to maintain the temperature inside the machine at about 3°C above the ambient temperature.

3.2.2 Provision is to be made to prevent the accumulation of bilge water, which is likely to enter inside the machine.

3.3 Rotating machines

3.3.1 Electrical machines are to be able to withstand the excess speed which may occur during operation of the ship.

3.3.2 The design of rotating machines supplied by static convertors is to consider the effects of harmonics.

3.3.3 The winding insulation of electrical machines is to be capable of withstanding the overvoltage which may occur in manoeuvring conditions.

3.3.4 The design of a.c. machines is to be such that they can withstand without damage a sudden short-circuit at their terminals under rated operating conditions.

3.3.5 The obtainable current and voltage of exciters and their supply are to be suitable for the output required during manoeuvring and overcurrent conditions, including short-circuit in the transient period.

3.4 Semiconductor convertors

3.4.1 The following limiting repetitive peak voltages U_{RM} are to be used as a base for each semiconductor valve:

- when connected to a supply specifically for propeller drives:

  $U_{RM} = 1,5\ U_P$

- when connected to a common main supply:

  $U_{RM} = 1,8\ U_P$

  where:

  U_P : Peak value of the rated voltage at the input of the semiconductor convertors.

3.4.2 For semiconductor convertors elements connected in series, the values in [3.4.1] are to be increased by 10%. Equal voltage distribution is to be ensured.

3.4.3 For parallel-connected convertors elements, an equal current distribution is to be ensured.

3.4.4 Means are to be provided, where necessary, to limit the effects of the rate of harmonics to the system and to other semiconductor convertors. Suitable filters are to be installed to keep the current and voltage within the limits given in Ch 2, Sec 2.

4 Control and monitoring

4.1 General

4.1.1 The control and monitoring systems, including computer based systems, are to be type approved, according to Ch 3, Sec 6.

4.2 Power plant control systems

4.2.1 The power plant control systems are to ensure that adequate propulsion power is available, by means of automatic control systems and/or manual remote control systems.

4.2.2 The automatic control systems are to be such that, in the event of a fault, the propeller speed and direction of thrust do not undergo substantial variations.

4.2.3 Failure of the power plant control system is not to cause complete loss of generated power (i.e. blackout) or loss of propulsion.

4.2.4 The loss of power plant control systems is not to cause variations in the available power; i.e. starting or stopping of generating sets is not to occur as a result.

4.2.5 Where power-aided control (for example with electrical, pneumatic or hydraulic aid) is used for manual operation, failure of such aid is not to result in interruption of power to the propeller, any such device is to be capable of purely manual operation.

4.2.6 The control system is to include the following main functions:

- monitoring of the alarms: any event critical for the proper operation of an essential auxiliary or a main element of the installation requiring immediate action to avoid a breakdown is to activate an alarm
- speed or pitch control of the propeller
- shutdown or slow down when necessary.

4.2.7 Where the electric propulsion system is supplied by the main switchboard together with the ship's services, load shedding of the non-essential services and /or power limitation of the electric propulsion is to be provided. An alarm is to be triggered in the event of power limitation or load shedding.

4.2.8 The risk of blackout due to electric propulsion operation is to be eliminated. At the request of the Society, a failure mode and effects analysis is to be carried out to demonstrate the reliability of the system.

4.3 Indicating instruments

4.3.1 In addition to the provisions of Part C, Chapter 3 of the Rules, instruments indicating consumed power and power available for propulsion are to be provided at each propulsion remote control position.

4.3.2 The instruments specified in [4.3.3]and [4.3.4] in relation to the type of plant are to be provided on the power control board or in another appropriate position.

4.3.3 The following instruments are required for each propulsion alternator:

- an ammeter on each phase, or with a selector switch to all phases
- a voltmeter with a selector switch to all phases
- a wattmeter
- a tachometer or frequency meter
- a power factor meter or a var-meter or a field ammeter for each alternator operating in parallel
- a temperature indicator for direct reading of the temperature of the stator windings, for each alternator rated above 500 kW.

4.3.4 The following instruments are required for each a.c. propulsion motor:

- an ammeter on the main circuit
- an embedded sensor for direct reading of the temperature of the stator windings, for motors rated above 500 kW
- an ammeter on the excitation circuit for each synchronous motor
- a voltmeter for the measurement of the voltage between phases of each motor supplied through a semiconductor frequency convertors.

4.3.5 Where a speed measuring system is used for control and indication, the system is to be duplicated with separate sensor circuits and separate power supply.

4.3.6 An ammeter is to be provided on the supply circuit for each propulsion semiconductor bridge.

4.4 Alarm system

4.4.1 An alarm system is to be provided, in accordance with the requirements of Part C, Chapter 3. The system is to give an indication at the control positions when the parameters specified in [4.4] assume abnormal values or any event occurs which can affect the electric propulsion.

4.4.2 Where an alarm system is provided for other essential equipment or installations, the alarms in [4.4.1] may be connected to such system.

4.4.3 Critical alarms for propulsion are to be indicated to the bridge separately.

4.4.4 The following alarms are to be provided, where applicable:

- high temperature of the cooling air of machines and semiconductor convertors provided with forced ventilation (see Note 1)
- reduced flow of primary and secondary coolants of machines and semiconductor convertors having a closed cooling system with a heat exchanger
- leakage of coolant inside the enclosure of machines and semiconductor convertors with liquid-air heat exchangers
- high winding temperature of generators and propulsion motors, where required (see [4.3])
- low lubricating oil pressure of bearings for machines with forced oil lubrication
- tripping of protective devices against overvoltages in semiconductor convertors (critical alarm)
- tripping of protection on filter circuits to limit the disturbances due to semiconductor convertors
- tripping of protective devices against overcurrents up to and including short-circuit in semiconductor convertors (critical alarm)
- voltage unbalance of three-phase a.c. systems supplied by semiconductor frequency convertors

- earth fault for the main propulsion circuit (see Note 2)
- earth fault for excitation circuits of propulsion machines (see Note 3).

Note 1: As an alternative to the air temperature of convertors or to the airflow, the supply of electrical energy to the ventilator or the temperature of the semiconductors may be monitored.

Note 2: In the case of star connected a.c. generators and motors with neutral points earthed, this device may not detect an earth fault in the entire winding of the machine.

Note 3: This may be omitted in brushless excitation systems and in the excitation circuits of machines rated up to 500 kW. In such cases, lamps, voltmeters or other means are to be provided to detect the insulation status under operating conditions.

4.5 Reduction of power

4.5.1 Power is to be automatically reduced in the following cases:

- low lubricating oil pressure of bearings of propulsion generators and motors
- high winding temperature of propulsion generators and motors
- fan failure in machines and convertors provided with forced ventilation, or failure of cooling system
- lack of coolant in machines and semiconductor convertors
- load limitation of generators or inadequate available power.

4.5.2 When power is reduced automatically, this is to be indicated at the propulsion control position (critical alarm).

4.5.3 Switching-off of the semiconductors in the event of abnormal service operation is to be provided in accordance with the manufacturer's specification.

5 Installation

5.1 Ventilation of spaces

5.1.1 Loss of ventilation to spaces with forced air cooling is not to cause loss of propulsion. To this end, two sets of ventilation fans are to be provided, one acting as a standby unit for the other. Equivalent arrangements using several independently supplied fans may be considered.

5.2 Cable runs

5.2.1 Instrumentation and control cables are to comply with the requirements of Ch 3, Sec 5 of the Rules.

5.2.2 Where there is more than one propulsion motor, all cables for any one machine are to be run as far as is practicable away from the cables of other machines.

5.2.3 Cables which are connected to the sliprings of synchronous motors are to be suitably insulated for the voltage to which they are subjected during manoeuvring.

6 Tests

6.1 Test of rotating machines

6.1.1 The test requirements are to comply with Ch 2, Sec 4.

6.1.2 For rotating machines, such as synchronous generators and synchronous electric motors, of a power of more than 3 MW, a test program is to be submitted to the Society for approval.

6.1.3 In relation to the evaluation of the temperature rise, it is necessary to consider the supplementary thermal losses induced by harmonic currents in the stator winding. To this end, two methods may be used:

- direct test method, when the electric propulsion motor is being supplied by its own frequency convertors, and/or back to back arrangement according to the supplier's facility
- indirect test method, when a validation of the estimation of the temperature excess due to harmonics is to be documented. A justification based on a computer program calculation may be taken into consideration, provided that validation of such program is demonstrated by previous experience.

7 Specific requirements for PODs

7.1 General

7.1.1 The requirements for the structural part of a POD are specified in Pt B, Ch 9, Sec 1, [11].

7.1.2 When used as steering manoeuvring system, the POD is to comply with the requirements of Ch 1, Sec 12.

7.2 Rotating commutators

7.2.1 As far as the electrical installation is concerned, the electric motor is supplied by a rotating commutator which rotates with the POD. The fixed part of the power transmission is connected to the ship supply, which uses the same components as a conventional propulsion system. Sliding contacts with a suitable support are used between the fixed and rotating parts.

7.2.2 The rotating commutator is to be type approved. Type tests are to be carried out, unless the manufacturer can produce evidence based on previous experience indicating the satisfactory performance of such equipment on board ships.

7.2.3 A test program is to be submitted to the Society for approval. It is to be to demonstrated that the power transmission and transmission of low level signals are not affected by the environmental and operational conditions prevailing on board. To this end, the following checks and tests are to be considered:

- check of the protection index (I.P.), in accordance with the location of the rotating commutator
- check of the clearances and creepage distances
- check of insulation material (according to the test procedure described in IEC Publication 60112)
- endurance test:

  After the contact pressure and rated current are set, the commutator is subjected to a rotation test. The number of rotations is evaluated taking into consideration the ship operation and speed rotation control system. The possibility of turning the POD 180° to proceed astern and 360° to return to the original position is to be considered. The commutator may be submitted to cycles comprising full or partial rotation in relation to the use of the POD as steering gear. The voltage drops and current are to be recorded.

  An overload test is to be carried out in accordance with Ch 2, Sec 4 (minimum 150%, 15 seconds)
- check of the behaviour of the sliprings when subjected to the vibration defined in Ch 3, Sec 6
- check of the behaviour of the sliprings, after damp heat test, as defined in Part C, Chapter 3, and possible corrosion of the moving parts and contacts

  After the damp heat test, the following are to be carried out:
- Insulation measurement resistance test. The minimum resistance is to be in accordance with Ch 2, Sec 4, Tab 2.
- Dielectric strength test as defined in Ch 2, Sec 4.

7.3 Electric motors

7.3.1 The thermal losses are dissipated by the liquid cooling of the bulb and by the internal ventilation of the POD. The justification for the evaluation of the heating balance between the sea water and air cooling is to be submitted to the Society.

Note 1: The calculation method used for the evaluation of the cooling system (mainly based on computer programs) is to be documented. The calculation method is to be justified based on the experience of the designer of the system. The results of scale model tests or other methods may be taken into consideration.

7.3.2 Means to adjust the air cooler characteristics are to be provided on board, in order to obtain an acceptable temperature rise of the windings. Such means are to be set following the dock and sea trials.

7.4 Instrumentation and associated devices

7.4.1 Means are to be provided to transmit the low level signals connected to the sensors located in the POD.

7.5 Additional tests

7.5.1 Tests of electric propulsion motors are to be carried out in accordance with Ch 2, Sec 4, and other tests in accordance with Ch 2, Sec 15.

7.5.2 Tests are to be performed to check the validation of the temperature rise calculation.

Section 15 Testing

1 General

1.1 Rule application

1.1.1 Before a new installation, or any alteration or addition to an existing installation, is put into service, the electrical equipment is to be tested in accordance with Articles [3], [4] and [5] to the satisfaction of the Surveyor in charge.

1.2 Insulation-testing instruments

1.2.1 Insulation resistance may be measured with an instrument applying a voltage of at least 500 V. The measurement will be taken when the deviation of the measuring device is stabilized.

Note 1: Any electronic devices present in the installation are to be disconnected prior to the test in order to prevent damage.

1.2.2 For high voltage installation, the measurement is to be taken with an instrument applying a voltage adapted to the rated value and agreed with the Society

2 Type approved components

2.1

2.1.1 The following components are to be type approved or in accordance with [2.1.2]:

- electrical cables
- transformers
- electric motors
- electrical convertors for primary essential services
- switching devices (circuit-breakers, contactors, disconnectors, etc.) and overcurrent protective devices
- sensors, alarm panels, electronic protective devices, automatic and remote control equipment, actuators, safety devices for installations intended for essential services (steering, controllable pitch propellers, propulsion machinery, etc.), electronic speed regulators for main or auxiliary engines
- computers used for tasks essential to safety.

2.1.2 Case by case approval based on submission of adequate documentation and execution of tests may also be granted at the discretion of the Society.

3 Insulation resistance

3.1 Lighting and power circuits

3.1.1 The insulation resistance between all insulated poles (or phases) and earth and, where practicable, between poles (or phases), is to be at least 1 MΩ in ordinary conditions.

The installation may be subdivided to any desired extent and appliances may be disconnected if initial tests give results less than that indicated above.

3.2 Internal communication circuits

3.2.1 Circuits operating at a voltage of 50 V and above are to have an insulation resistance between conductors and between each conductor and earth of at least 1 MΩ.

3.2.2 Circuits operating at voltages below 50 V are to have an insulation resistance between conductors and between each conductor and earth of at least 0,33 MΩ.

3.2.3 If necessary, any or all appliances connected to the circuit may be disconnected while the test is being conducted.

3.3 Switchboards

3.3.1 The insulation resistance between each busbar and earth and between each insulated busbar and the busbar connected to the other poles (or phases) of each main switchboard, emergency switchboard, section board, etc. is to be not less than 1 MΩ.

3.3.2 The test is to be performed before the switchboard is put into service with all circuit-breakers and switches open, all fuse-links for pilot lamps, earth fault-indicating lamps, voltmeters, etc. removed and voltage coils temporarily disconnected where otherwise damage may result.

3.4 Generators and motors

3.4.1 The insulation resistance of generators and motors, in normal working condition and with all parts in place, is to be measured and recorded.

3.4.2 The test is to be carried out with the machine hot immediately after running with normal load.

3.4.3 The insulation resistance of generator and motor connection cables, field windings and starters is to be at least 1 MΩ.

4 Earth

4.1 Electrical constructions

4.1.1 Tests are to be carried out, by visual inspection or by means of a tester, to verify that all earth-continuity conductors and earthing leads are connected to the frames of apparatus and to the hull, and that in socket-outlets having earthing contacts, these are connected to earth.

4.2 Metal-sheathed cables, metal pipes or conduits

4.2.1 Tests are to be performed, by visual inspection or by means of a tester, to verify that the metal coverings of cables and associated metal pipes, conduits, trunking and casings are electrically continuous and effectively earthed.

5 Operational tests

5.1 Generating sets and their protective devices

5.1.1 Generating sets are to be run at full rated load to verify that the following are satisfactory:
- electrical characteristics
- commutation (if any)
- lubrication
- ventilation
- noise and vibration level.

5.1.2 Suitable load variations are to be applied to verify the satisfactory operation under steady state and transient conditions (see Ch 2, Sec 4, [2]) of:
- voltage regulators
- speed governors.

5.1.3 Generating sets intended to operate in parallel are to be tested over a range of loading up to full load to verify that the following are satisfactory:
- parallel operation
- sharing of the active load
- sharing of the reactive load (for a.c. generators).

Synchronizing devices are also to be tested.

5.1.4 The satisfactory operation of the following protective devices is to be verified:
- overspeed protection
- overcurrent protection (see Note 1)
- load-shedding devices
- any other safety devices.

For sets intended to operate in parallel, the correct operation of the following is also to be verified:
- reverse-power protection for a.c. installations (or reverse-current protection for d.c. installations)
- minimum voltage protection.

Note 1: Simulated tests may be used to carry out this check where appropriate.

5.1.5 The satisfactory operation of the emergency source of power and of the transitional source of power, when required, is to be tested. In particular, the automatic starting and the automatic connection to the emergency switchboard, in case of failure of the main source of electrical power, are to be tested.

5.2 Switchgear

5.2.1 All switchgear is to be loaded and, when found necessary by the attending Surveyor, the operation of overcurrent protective devices is to be verified (see Note 1).

Note 1: The workshop test is generally considered sufficient to ensure that such apparatus will perform as required while in operation.

5.2.2 Short-circuit tests may also be required at the discretion of the Society in order to verify the selectivity characteristics of the installation.

5.3 Consuming devices

5.3.1 Electrical equipment is to be operated under normal service conditions (though not necessarily at full load or simultaneously) to verify that it is suitable and satisfactory for its purpose.

5.3.2 Motors and their starters are to be tested under normal operating conditions to verify that the following are satisfactory:

- power
- operating characteristics
- commutation (if any)
- speed
- direction of rotation
- alignment.

5.3.3 The remote stops foreseen are to be tested.

5.3.4 Lighting fittings, heating appliances etc. are to be tested under operating conditions to verify that they are suitable and satisfactory for their purposes (with particular regard to the operation of emergency lighting).

5.4 Communication systems

5.4.1 Communication systems, order transmitters and mechanical engine-order telegraphs are to be tested to verify their suitability.

5.5 Installations in areas with a risk of explosion

5.5.1 Installations and the relevant safety certification are to be examined to ensure that they are of a type permitted in the various areas and that the integrity of the protection concept has not been impaired.

5.6 Voltage drop

5.6.1 Where it is deemed necessary by the attending Surveyor, the voltage drop is to be measured to verify that the permissible limits are not exceeded (see Ch 2, Sec 3, [9.11.4]).

Part C
Machinery, Systems and Fire Protection

CHAPTER 3
AUTOMATION

Section 1 General Requirements

1 General

1.1 Field of application

1.1.1 The following requirements apply to automation systems, installed on all ships, intended for essential services as defined in Ch 2, Sec 1. They also apply to systems required in Part C, Chapter 1 and Part C, Chapter 2, installed on all ships.

1.1.2 This chapter is intended to avoid that failures or malfunctions of automation systems associated with essential and non-essential services cause danger to other essential services.

1.1.3 Requirements for unattended machinery spaces and for additional notations are specified in Part E.

1.2 Regulations and standards

1.2.1 The regulations and standards applicable are those defined in Ch 2, Sec 1.

1.3 Definitions

1.3.1 Unless otherwise stated, the terms used in this chapter have the definitions laid down in Ch 2, Sec 1 or in the IEC standards. The following definitions also apply:

- Alarm indicator is an indicator which gives a visible and/or audible warning upon the appearance of one or more faults to advise the operator that his attention is required.
- Alarm system is a system intended to give a signal in the event of abnormal running condition.
- Application software is a software performing tasks specific to the actual configuration of the computer based system and supported by the basic software.
- Automatic control is the control of an operation without direct or indirect human intervention, in response to the occurrence of predetermined conditions.
- Automation systems are systems including control systems and monitoring systems.
- Basic software is the minimum software, which includes firmware and middleware, required to support the application software.
- Cold standby system is a duplicated system with a manual commutation or manual replacement of cards which are live and non-operational. The duplicated system is to be able to achieve the operation of the main system with identical performance, and be operational within 10 minutes.
- Control station is a group of control and monitoring devices by means of which an operator can control and verify the performance of equipment.
- Control system is a system by which an intentional action is exerted on an apparatus to attain given purposes.
- Fail safe is a design property of an item in which the specified failure mode is predominantly in a safe direction with regard to the safety of the ship, as a primary concern.
- Full redundant is used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function and operate simultaneously.
- Hot standby system is used to describe an automation system comprising two (identical or non-identical) independent systems which perform the same function, one of which is in operation while the other is on standby with an automatic change-over switch.
- Instrumentation is a sensor or monitoring element.
- Local control is control of an operation at a point on or adjacent to the controlled switching device.
- Manual control is control of an operation acting on final control devices either directly or indirectly with the aid of electrical, hydraulic or mechanical power.
- Monitoring system is a system designed to observe the correct operation of the equipment by detecting incorrect functioning (measure of variables compared with specified value).
- Safety system is a system intended to limit the consequence of failure and is activated automatically when an abnormal condition appears.
- Redundancy is the existence of more than one means for performing a required function.
- Remote control is the control from a distance of apparatus by means of an electrical or other link.
- Inspection of components (only hardware) from sub-suppliers: proof that components and/or sub-assemblies conform to specification.
- Quality control in production: evidence of quality assurance measures on production.

- Final test reports: reports from testing of the finished product and documentation of the test results.
- Hardware description:
  - system block diagram, showing the arrangement, input and output devices and interconnections
  - connection diagrams
  - details of input and output devices
  - details of power supplies.
- Failure analysis for safety related functions only (e.g. FMEA): the analysis is to be carried out using appropriate means, e.g.:
  - fault tree analysis
  - risk analysis
  - FMEA or FMECA.

  The purpose is to demonstrate that for single failures, systems will fail to safety and that systems in operation will not be lost or degraded beyond acceptable performance criteria when specified by the Society.

1.4 General

1.4.1 The automation systems and components, as indicated in Ch 2, Sec 15, [2], are to be type approved according to the applicable requirements of these Rules and in particular those stated in this Chapter

Case by case approval may also be granted at the discretion of the Society, based on submission of adequate documentation and subject to the satisfactory outcome of any required tests.

1.4.2 Main and auxiliary machinery essential for the propulsion, control and safety of the ship shall be provided with effective means for its operation and control.

1.4.3 Control, alarm and safety systems are to be based on the fail-to-safety principle.

1.4.4 Failure of automation systems is to generate an alarm.

1.4.5 Detailed indication, alarm and safety requirements regarding automation systems for individual machinery and installations are to be found in tables located in Part C, Chapter 1 and in Part E, Chapter 3.

Each row of these tables is to correspond to one independent sensor.

2 Documentation

2.1 General

2.1.1 Before the actual construction is commenced, the Manufacturer, Designer or Shipbuilder is to submit to the Society the documents (plans, diagrams, specifications and calculations) requested in this Section.

2.2 Documents to be submitted

2.2.1 The documents listed in Tab 1 are to be submitted.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Documentation
1	I	The general specification for the automation of the ship
2	A	The detailed specification of the essential service systems
3	A	The list of components used in the automation circuits, and references (Manufacturer, type, etc.)
4	I	Instruction manuals
5	I	Test procedures for control, alarm and safety systems
6	A	A general diagram showing the monitoring and/or control positions for the various installations, with an indication of the means of access and the means of communication between the positions as well as with the engineers
7	A	The diagrams of the supply circuits of automation systems, identifying the power source
8	A	The list of monitored parameters for alarm/monitoring and safety systems
9	A	Diagram of the engineers' alarm system
10	I	List of computerized systems as mentioned in Ch 3, Sec 3, [1.2.1]
11	A/I	Documentation as mentioned in Ch 3, Sec 3, Tab 2
12	I	Software registry as mentioned in Ch 3, Sec 3, [4.3.1]

(1) A = to be submitted for approval
I = to be submitted for information.

2.3 Documents for type approval of equipment

2.3.1 Documents to be submitted for type approval of equipment are listed hereafter:

- a request for type approval from the manufacturer or his authorized representative
- the technical specification and drawings depicting the system, its components, characteristics, working principle, installation and conditions of use and, when there is a computer based system, the documents listed in Ch 3, Sec 3, Tab 2
- any test reports previously prepared by specialised laboratories.

2.3.2 Modifications

Modifications are to be documented by the manufacturer. For computer based systems, requirements are mentioned in Ch 3, Sec 3.

3 Environmental and supply conditions

3.1 General

3.1.1 General

The automation system is to operate correctly when the power supply is within the range specified in Ch 3, Sec 2.

3.1.2 Environmental conditions

The automation system is to be designed to operate satisfactorily in the environment in which it is located. The environmental conditions are described in Ch 2, Sec 2.

3.1.3 Failure behaviour

The automation system is to have non-critical behaviour in the event of power supply failure, faults or restoration of operating condition following a fault. If a redundant power supply is used, it must be taken from an independent source.

3.2 Power supply conditions

3.2.1 Electrical power supply

The conditions of power supply to be considered are defined in Ch 2, Sec 2.

3.2.2 Pneumatic power supply

For pneumatic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

3.2.3 Hydraulic power supply

For hydraulic equipment, the operational characteristics are to be maintained under permanent supply pressure variations of ± 20% of the rated pressure.

Detailed requirements are given in Ch 1, Sec 10.

4 Materials and construction

4.1 General

4.1.1 The choice of materials and components is to be made according to the environmental and operating conditions in order to maintain the proper function of the equipment.

4.1.2 The design and construction of the automation equipment is to take into account the environmental and operating conditions in order to maintain the proper function of the equipment.

4.2 Type approved components

4.2.1 See Ch 2, Sec 15.

Section 2 Design Requirements

1 General

1.1

1.1.1 All control systems essential for the propulsion, control and safety of the ship shall be independent or designed such that failure of one system does not degrade the performance of another system.

1.1.2 Controlled systems are to have manual operation.

Failure of any part of such systems shall not prevent the use of the manual override.

1.1.3 Automation systems are to have constant performance.

1.1.4 Control, monitoring and safety systems are to be mutually independent, unless system design is such as failure of one of those system do not affect the operation of the other systems or machinery. Monitoring of safety function may be included in general monitoring function.

1.1.5 Control, monitoring and safety systems are to have self-check facilities. In the event of failure, an alarm is to be activated.

In particular, failure of the power supply of the automation system is to generate an alarm.

1.1.6 When a computer based system is used for control, alarm or safety systems, it is to comply with the requirements of Ch 3, Sec 3.

1.1.7 The automatic change-over switch is to operate independently of both systems. When change-over occurs, no stop of the installation is necessary and the latter is not to enter undefined or critical states.

1.1.8 When systems under control are required to be duplicated and in separate compartments, this is also to apply to control elements within computer based systems.

1.1.9 Emergency stops are to be hardwired and independent of any computer based system.

Note 1: Computerized systems may be admitted if evidence is given demonstrating they provide a safety level equivalent to a hardwired system.

2 Power supply of automation systems

2.1 General

2.1.1 Loss of power supplies to the automation system is to generate an alarm.

2.2 Electrical power supply

2.2.1 The power supply is to be protected against short circuit and overload for each independent automation system.

The power supply is to be isolated.

2.2.2 Automation systems are to be continuously powered.

2.2.3 The capacity of the batteries ensuring continuity of power supply is to be sufficient to allow the normal operation of the alarm, control and safety system for at least half an hour.

2.2.4 Their power sources are to be duplicated.

2.2.5 Batteries are not to be considered as power sources in respect of Article [2].

3 Control systems

3.1 General

3.1.1 In the case of failure, the control systems used for essential services are to remain in the last position they had before the failure, unless otherwise specified by these Rules.

3.2 Local control

3.2.1 Each system is to be able to be operated manually from a position located so as to enable visual control of operation. For detailed instrumentation for each system, refer to Part C, Chapter 1 and Part C, Chapter 2.

It shall also be possible to control the auxiliary machinery, essential for the propulsion and safety of the ship, at or near the machinery concerned.

3.3 Remote control systems

3.3.1 When several control stations are provided, control of machinery is to be possible at one station at a time and a hierarchy is to be defined.

3.3.2 At each location there shall be an indicator showing which location is in control of the propulsion machinery.

3.3.3 Remote control is to be provided with the necessary instrumentation, in each control station, to allow effective control (correct function of the system, indication of control station in operation, alarm display).

3.3.4 When transferring the control location, no significant alteration of the controlled equipment is to occur. Transfer of control is to be protected by an audible warning and acknowledged by the receiving control location. The main control location is to be able to take control without acknowledgement.

3.4 Automatic control systems

3.4.1 Automatic starting, operational and control systems shall include provisions for manually overriding the automatic controls.

3.4.2 Automatic control is to be stable in the range of the controller in normal working conditions.

3.4.3 Automatic control is to have instrumentation to verify the correct function of the system.

4 Control of propulsion machinery

4.1 Remote control

4.1.1 The requirements mentioned in Article [3] are to be applied for propulsion machinery.

The highest priority of propulsion control is to be assigned to the central position nearer to the principal machinery.

4.1.2 The design of the remote control system shall be such that in case of its failure an alarm will be given.

4.1.3 Supply failure (voltage, fluid pressure, etc.) in propulsion plant remote control is to activate an alarm at the control position. In the event of remote control system failure and unless the Society considers it impracticable, the preset speed and direction of thrust are to be maintained until local control is in operation. This applies in particular in the case of loss of electric, pneumatic or hydraulic supply to the system.

4.1.4 Propulsion machinery orders from the navigation bridge shall be indicated in the main machinery control room, and at the manoeuvring platform.

4.1.5 The control shall be performed by a single control device for each independent propeller, with automatic performance of all associated services, including, where necessary, means of preventing overload of the propulsion machinery. Where multiple propellers are designed to operate simultaneously, they must be controlled by one control device.

4.1.6 Indicators shall be fitted on the navigation bridge, in the main machinery control room and at the manoeuvring platform, for:

- propeller speed and direction of rotation in the case of fixed pitch propellers; and
- propeller speed and pitch position in the case of controllable pitch propellers.

4.1.7 The main propulsion machinery shall be provided with an emergency stopping device on the navigation bridge which shall be independent of the navigation bridge control system.

4.2 Remote control from navigating bridge

4.2.1 Where propulsion machinery is controlled from the navigating bridge, the remote control is to include an automatic device such that the number of operations to be carried out is reduced and their nature is simplified and such that control is possible in both the ahead and astern directions. Where necessary, means for preventing overload and running in critical speed ranges of the propulsion machinery is to be provided.

4.2.2 On board ships fitted with remote control, direct control of the propulsion machinery is to be provided locally. The local direct control is to be independent from the remote control circuits, and takes over any remote control when in use.

4.2.3 Each local control position, including partial control (e.g. local control of controllable pitch propellers or clutches) is to be provided with means of communication with the remote control position. The local control positions are to be independent from remote control of propulsion machinery and continue to operate in the event of a blackout.

4.2.4 Remote control of the propulsion machinery shall be possible only from one location at a time; at such locations interconnected control positions are permitted.

4.2.5 The transfer of control between the navigating bridge and machinery spaces shall be possible only in the main machinery space or the main machinery control room. The system shall include means to prevent the propelling thrust from altering significantly, when transferring control from one location to another.

4.2.6 At the navigating bridge, the control of the routine manoeuvres for one line of shafting is to be performed by a single control device: a lever, a handwheel or a push-button board. However each mechanism contributing directly to the propulsion, such as the engine, clutch, automatic brake or controllable pitch propeller, is to be able to be individually controlled, either locally or at a central monitoring and control position in the engine room.

4.2.7 Remote starting of the propulsion machinery is to be automatically inhibited if a condition exists which may damage the machinery, e.g. shaft turning gear engaged, drop of lubrication oil pressure or brake engaged.

4.2.8 As a general rule, the navigating bridge panels are not to be overloaded by alarms and indications which are not required.

4.2.9 Automation systems shall be designed in a manner which ensures that threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems shall control, monitor, report, alert and take safety action to slowdown or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.

4.3 Automatic control

4.3.1 The requirements in Article [3] are applicable. In addition, the following requirements are to be considered, if relevant.

4.3.2 Main turbine propulsion machinery and, where applicable, main internal combustion propulsion machinery and auxiliary machinery shall be provided with automatic shutoff arrangements in the case of failures such as lubricating oil supply failure which could lead rapidly to complete breakdown, serious damage or explosion.

4.3.3 The automatic control system is to be designed on a fail safe basis, and, in the event of failure, the system is to be adjusted automatically to a predetermined safe state.

4.3.4 Operations following any setting of the bridge control device (including reversing from the maximum ahead service speed in case of emergency) are to take place in an automatic sequence and with acceptable time intervals, as prescribed by the manufacturer.

4.3.5 For steam turbines, a slow turning device is to be provided which operates automatically if the turbine is stopped longer than admissible. Discontinuation of this automatic turning from the bridge is to be possible.

4.4 Automatic control of propulsion and manoeuvring units

4.4.1 When the power source actuating the automatic control of propelling units fails, an alarm is to be triggered. In such case, the preset direction of thrust is to be maintained long enough to allow the intervention of engineers. Failing this, minimum arrangements, such as stopping of the shaft line, are to be provided to prevent any unexpected reverse of the thrust. Such stopping may be automatic or ordered by the operator, following an appropriate indication.

4.5 Clutches

4.5.1 Where the clutch of a propulsion engine is operated electrically, pneumatically or hydraulically, an alarm is to be given at the control station in the event of loss of energy; as far as practicable, this alarm is to be triggered while it is still possible to operate the equipment.

4.5.2 When only one clutch is installed, its control is to be fail-set. Other arrangements may be considered in relation to the configuration of the propulsion machinery.

4.6 Brakes

4.6.1 Automatic or remote controlled braking is to be possible only if:

- propulsion power has been shut off
- the turning gear is disconnected
- the shaftline speed (r.p.m.) is below the threshold stated by the builder.

5 Communications

5.1 Communications between navigating bridge and machinery space

5.1.1 At least two independent means are to be provided for communicating orders from the navigating bridge to the position in the machinery space or in the control room from which the speed and the direction of the thrust of the propellers are normally controlled; one of these is to be an engine room telegraph, which provides visual indication of the orders and responses both in the machinery space and on the navigating bridge, with audible alarm mismatch between order and response.

5.1.2 Appropriate means of communication shall be provided from the navigating bridge and the engine room to any other position from which the speed and direction of thrust of the propellers may be controlled. The second means for communicating orders is to be fed by an independent power supply and is to be independent of other means of communication.

5.1.3 Where the main propulsion system of the ship is controlled from the navigating bridge by a remote control system, the second means of communication may be the same bridge control system.

5.1.4 The engine room telegraph is required in any case, even if the remote control of the engine is foreseen, irrespective of whether the engine room is attended. An alarm is to be given at the navigation bridge in the event of failure of power supply to the engine room telegraph.

For ships assigned with a restricted navigation notation these requirements may be relaxed at the Society's discretion.

5.2 Engineers' alarm

5.2.1 An engineers' alarm shall be provided to be operated from the engine control room or at the manoeuvring platform as appropriate, and shall be clearly audible in the engineers' accommodation

6 Remote control of valves

6.1

6.1.1 The following requirements are applicable to valves whose failure could impair essential services.

6.1.2 Failure of the power supply is not to permit a valve to move to an unsafe condition.

6.1.3 An indication is to be provided at the remote control station showing the actual position of the valve or whether the valve is fully open or fully closed. This indication may be omitted for quick-closing valves.

6.1.4 When valves are remote controlled, a secondary manual means of operating them is to be provided (see Ch 1, Sec 10, [2.7.3]).

7 Alarm system

7.1 General requirements

7.1.1 Alarms are to be visual and audible and are to be clearly distinguishable, in the ambient noise and lighting in the normal position of the personnel, from any other signals.

7.1.2 Sufficient information is to be provided for proper handling of alarms.

7.1.3 The alarm system is to be of the self-check type; failure within the alarm system, including the outside connection, is to activate an alarm. The alarm circuits are to be independent from each other. All alarm circuits are to be protected so as not to endanger each other.

7.2 Alarm functions

7.2.1 Alarm activation

Alarms are to be activated when abnormal conditions appear in the machinery, which need the intervention of personnel on duty, and on the automatic change-over, when standby machines are installed.

An existing alarm is not to prevent the indication of any further fault.

7.2.2 Acknowledgement of alarm

The acknowledgment of an alarm consists in manually silencing the audible signal and additional visual signals (e.g. rotating light signals) while leaving the visual signal on the active control station. Acknowledged alarms are to be clearly distinguishable from unacknowledged alarms. Acknowledgement should not prevent the audible signal to operate for new alarm.

Alarms shall be maintained until they are accepted and visual indications of individual alarms shall remain until the fault has been corrected, when the alarm system shall automatically reset to the normal operating condition.

Acknowledgement of alarms is only to be possible at the active control station.

Alarms, including the detection of transient faults, are to be maintained until acknowledgement of the visual indication.

Acknowledgement of visual signals is to be separate for each signal or common to a limited group of signals. Acknowledgement is only to be possible when the user has visual information on the alarm condition for the signal or all signals in a group.

7.2.3 Inhibition of alarms

Manual inhibition of separate alarms may be accepted when this is clearly indicated.

Inhibition of alarm and safety functions in certain operating modes (e.g. during start-up or trimming) is to be automatically disabled in other modes.

7.2.4 Time delay of alarms

It is to be possible to delay alarm activation in order to avoid false alarms due to normal transient conditions (e.g. during start-up or trimming).

7.2.5 Transfer of responsibility

Where several alarm control stations located in different spaces are provided, responsibility for alarms is not to be transferred before being acknowledged by the receiving location. Transfer of responsibility is to give an audible warning. At each control station it is to be indicated which location is in charge.

8 Safety system

8.1 Design

8.1.1 System failures

A safety system is to be designed so as to limit the consequence of failures. It is to be constructed on the fail-to-safety principle.

The safety system is to be of the self-check type; as a rule, failure within the safety system, including the outside connection, is to activate an alarm.

8.2 Function

8.2.1 Safety activation

The safety system is to be activated automatically in the event of identified conditions which could lead to damage of associated machinery or systems, such that:

- normal operating conditions are restored (e.g. by the starting of the standby unit), or
- the operation of the machinery is temporarily adjusted to the prevailing abnormal conditions (e.g. by reducing the output of the associated machinery), or
- the machinery is protected, as far as possible, from critical conditions by shutting off the fuel or power supply, thereby stopping the machinery (shutdown), or appropriate shutdown.

8.2.2 Safety indication

When the safety system has been activated, it is to be possible to trace the cause of the safety action. This is to be accomplished by means of a central or local indication.

When a safety system is made inoperative by a manual override, this is to be clearly indicated at corresponding control stations.

Override of safety functions in certain operating modes (e;g; during start-up or trimming) is to be automatically disabled in other modes

Automatic safety actions are to activate an alarm at predefined control stations.

8.3 Shutdown

8.3.1 For shutdown systems of machinery, the following requirements are to be applied:

- when the system has stopped a machine, the latter is not to be restarted automatically before a manual reset of the safety system has been carried out
- the shutdown of the propulsion system is to be limited to those cases which could lead to serious damage, complete breakdown or explosion.

8.4 Standby systems

8.4.1 For the automatic starting system of the standby units, the following requirements are to be applied:

- faults in the electrical or mechanical system of the running machinery are not to prevent the standby machinery from being automatically started
- when a machine is on standby, ready to be automatically started, this is to be clearly indicated at its control position
- the change-over to the standby unit is to be indicated by a visual and audible alarm
- means are to be provided close to the machine, to prevent undesired automatic or remote starting (e.g. when the machine is being repaired)
- automatic starting is to be prevented when conditions are present which could endanger the standby machine.

8.5 Testing

8.5.1 The safety systems are to be tested in accordance with the requirements in Ch 3, Sec 6.

Section 3 Computer Based Systems

1 General requirements

1.1 Application

1.1.1 Systems covered

This section applies to design, construction, commissioning and maintenance of computer based systems where they depend on software for the proper achievement of their functions. These requirements focus on the functionality of the software and on the hardware supporting the software. These requirements apply to the use of computer based systems which provide control, alarm, monitoring, safety or internal communication functions which are subject to classification requirements.

Navigation systems required by SOLAS Chapter V, Radio-communication systems required by SOLAS Chapter IV, and vessel loading instrument/stability computer are not in the scope of these requirements.

Note 1: For loading instrument/stability computer, see Pt B, Ch 10, Sec 2, [4].

1.2 Requirement for ship

1.2.1 List of computerized systems

List of computerized systems covered by this section as described [1.1.1] are to be submitted to the Society as soon as possible during design stage of the ship. This list shall include:

- designation of system involved
- category of system according to [2.3]
- manufacturer of system (if available)
- supplier of control system (if available).

1.2.2 Software registry

Initial release of software registry as defined in [4.3.1] is to be submitted for information to the Society after ship sea trials.

1.3 Requirements for computerized systems

1.3.1 Computerized systems shall follow requirements mentioned in Articles [4], [5], [6], [8]and [9].

1.3.2 The response time between the detection of an event and the related action or signalization is to be compatible with the application. As a general requirement without other specification, this time is to be less than 5 seconds.

1.4 References

1.4.1 For the purpose of application of the requirements contained in this section, the following identified standards can be used for the development of hardware/software of computer based systems. Other industry standards may be considered:

- IEC 61508: Functional safety of electrical/electronic/programmable electronic safety-related systems
- ISO/IEC 12207: Systems and software engineering - Software life cycle processes
- ISO 9001:2008 Quality Management Systems - Requirements
- ISO/IEC 90003: Software engineering - Guidelines for the application of ISO 9001:2008 to computer software
- IEC 60092-504: Electrical installations in ships - Part 504: Special features - Control and instrumentation
- ISO/IEC 25000: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Guide to SQuaRE
- ISO/IEC 25041: Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - Evaluation guide for developers, acquirers and independent evaluators
- IEC 61511: Functional safety - Safety instrumented systems for the process industry sector
- ISO/IEC 15288: Systems and software engineering - System life cycle process

2 Definitions

2.1 Stakeholders

2.1.1 Owner

The Owner is responsible for contracting the system integrator and/or suppliers to provide a hardware system including software according to the owner's specification. The Owner could be the Ship Builder Integrator (Builder or Shipyard) during initial construction. After vessel delivery, the owner may delegate some responsibilities to the vessel operating company.

2.1.2 System integrator

The role of system integrator shall be taken by the Yard unless an alternative organisation is specifically contracted/assigned this responsibility. The system integrator is responsible for the integration of systems and products provided by suppliers into the system invoked by the requirements specified herein and for providing the integrated system. The system integrator may also be responsible of integration of systems in the vessel.

If there are multiple parties performing system integration at any one time a single party is to be responsible for overall system integration and coordinating the integration activities. If there are multiple stages of integration different System Integrators may be responsible for specific stages of integration but a single party is to be responsible for defining and coordinating all of the stages of integration.

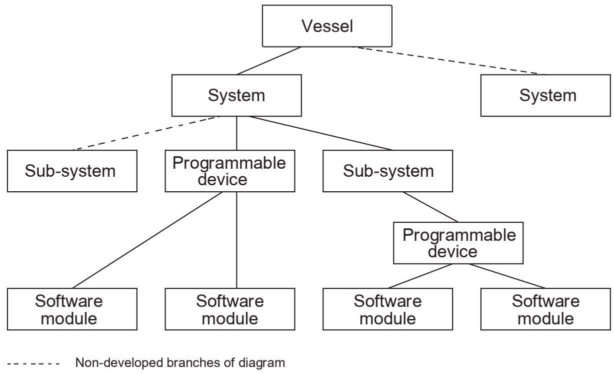
2.1.3 Supplier

The Supplier is any contracted or subcontracted provider of system components or software under the coordination of the System Integrator or Shipyard. The supplier is responsible for providing programmable devices, sub-systems or systems to the system integrator. The supplier provides a description of the software functionality that meets the Owner's specification, applicable international and national standards, and the requirements specified herein.

2.2 Objects

2.2.1 The following diagram (see Fig 1) shows the hierarchy and relationships of a typical computer based system.

Figure 1 : Illustrative System Hierarchy



2.2.2 Object definitions

a) Vessel: Ship where the system is to be installed

b) System: Combination of interacting programmable devices and/or sub-systems organized to achieve one or more specified purposes.

c) Sub-system: Identifiable part of a system, which may perform a specific function or set of functions.

d) Programmable device: Physical component where software is installed.

e) Software module: A module is a standalone piece of code that provides specific and closely coupled functionality.

2.3 System categories

2.3.1 The following Tab 1 shows how to assign system categories based on their effects on system functionality.

The following systems typically belong to Category III, the exact category being dependent on the risk assessment for all operational scenarios:

- Propulsion system of a ship, meaning the means to generate and control mechanical thrust in order to move the ship (devices used only during manoeuvring are not in the scope of this requirement such as bow tunnel thrusters)
- Steering system control system
- Electric power system (including power management system)
- Ship safety systems covering fire detection and fighting, flooding detection and fighting, internal communication systems involved in evacuation phases, ship systems involved in operation of life saving appliances equipment
- Dynamic positioning system of equipment classes 2 and 3 according to NR467, Pt F, Ch 11, Sec 5.
- Drilling systems

Table 1 : System categories

Category	Effects	Typical system functionality
I	Those systems, failure of which will not lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Monitoring function for informational/administrative tasks.
II	Those systems, failure of which could eventually lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Alarm and monitoring functions • Control functions which are necessary to maintain the ship in its normal operational and habitable conditions.
III	Those systems, failure of which could immediately lead to dangerous situations for human safety, safety of the vessel and/or threat to the environment.	• Control functions for maintaining the vessel's propulsion and steering • Vessel Safety functions.

The following systems typically belong to Category II, the exact category being dependent on the risk assessment for all operational scenarios:

- liquid cargo transfer control system
- bilge level detection and associated control of pumps
- fuel oil treatment system

  Ballast transfer valve remote control system

  Stabilization and ride control systems
- Alarm and monitoring systems for propulsion systems.

The example systems are not exhaustive.

2.4 Other terminology

2.4.1 Simulation tests

Control system testing where the equipment under control is partly or fully replaced with simulation tools, or where parts of the communication network and lines are replaced with simulation tools.

2.4.2 Expert system

Expert system is an intelligent knowledge-based system that is designed to solve a problem with information that has been compiled using some form of human expertise.

2.4.3 Integrated system

Integrated system is a system consisting of two or more subsystems having independent functions connected by a data transmission network and operated from one or more workstations.

2.4.4 Data communication link

Data communication link includes point to point links, instrument net and local area networks, normally usedfor inter-computer communication on board units. The software and hardware which support the data communication are also included.

3 Documentation and test attendance

3.1

3.1.1 Documentation to be submitted and test to be attended are listed in Tab 2.

3.1.2 User interface description

The documentation is to contain:

- a description of the functions allocated to each operator interface (keyboard/screen or equivalent)
- a description of individual screen views (schematics, colour photos, etc.)
- a description of how menus are operated (tree presentation)
- an operator manual providing necessary information for installation and use.

Table 2 : Documentation and test attendance

Requirement	Supplier involved	System integrator involved	Owner involved	Category I	Category II	Category III
Quality Plan	X	X		A**(2)**	A	A
Risk assessment report		X		I**(2)**	I**(2)**	I**(2)**
Software modules functional description and associated hardware description	X (if necessary)	X			I	I
Evidence of verification of software code	X (if necessary)	X			I	I
Evidence of functional tests for elements included in systems of Category II and III at the level of software module, sub-system and system	X	X			I	I
Test programs and procedures for functional tests and failure tests including a supporting FMEA or equivalent, at the request of the Class Society		X			A	A
Factory acceptance test event including functional and failure tests	X	X			W	W
Test program for simulation tests for final integration		X			A	A
Simulation tests for final integration		X			W	W
Test program for on board tests (includes wireless network testing)		X			A	A
On board integration tests (includes wireless network testing)		X			W	W
Documents related to simulator		X			I	I
• List and versions of software installed in system • Functional description of software • User manual including instructions during software maintenance • List of interfaces between system and other ship systems		X			I	I
Updated Software Registry		X	X		I	I
Procedures and documentation related to Security Policy					I	I
Test reports according to Ch 3, Sec 6, [2.2] requirements	X	X		A**(3)**	A	A
User interface description see [3.1.2]	X	X		I	I	I

(1) Additional documentation may be required upon request
(2) Upon request
(3) If in the scope of Class requirement
Note 1: A = to be submitted fro approval, I = to be submitted for information, W = Test to be witnessed by the Surveyor.

4 Requirements for software and supporting hardware

4.1 Life cycle approach

4.1.1 A global top to bottom approach shall be undertaken regarding software and the integration in a system, spanning the software lifecycle. This approach shall be accomplished according to software development standards as listed herein or other standards recognized by the Society.

4.1.2 Quality system

System integrators and suppliers shall operate a quality system regarding software development and testing and associated hardware such as ISO 9001 taking into account ISO 90003.

Satisfaction of this requirement shall be demonstrated by either:

- The quality system being certified as compliant to the recognized standard by an organisation with accreditation under a national accreditation scheme, or
- The Society confirming compliance to the standard through a specific assessment.

This quality system shall include:

a) Relevant procedures regarding responsibilities, system documentation, configuration management and competent staff.

b) Relevant procedures regarding software lifecycle and associated hardware:
   - Organization set in place for acquisition of related hardware and software from suppliers
   - Organization set in place for software code writing and verification
   - Organization set in place for system validation before integration in the vessel.

c) Minimum requirements for approval of Quality system:
   - Having a specific procedure for verification of software code of Category II and III at the level of systems, sub-systems and programmable devices and modules
   - Having check points for the Class Society for Category II and III systems (see Tab 2 for the minimum check points , see Note 1)
   - Having a specific procedure for software modification and installation on board the vessel defining interactions with owners.

d) Quality Plan

   A document, referred to herein as a Quality Plan, shall be produced that records how the quality management system will be applied for the specific computer based system and that includes, as a minimum, all of material required by paragraphs [4.1.2], items a) to c) inclusively.

Note 1: Examples of check points can be a required submittal of documentation, a test event, a technical design review meeting, or peer review meeting.

4.1.3 Design phase

a) Risk assessment of system

   This step shall be undertaken to determine the risk to the system throughout the lifecycle by identifying and evaluating the hazards associated with each function of the system. A risk assessment report shall upon request be submitted to the Society:

   This document shall normally be submitted by the System Integrator or the Supplier, including data coming from other suppliers.

   IEC/ISO31010 "Risk management - Risk assessment techniques" may be applied in order to determine method of risk assessment. The method of risk assessment shall be agreed by the society.

   Based on the risk assessment, a revised system category might need to be agreed between Class and the system supplier.

   Where the risks associated with a computer based system are well understood, it is permissible for the risk assessment to be omitted, however in such cases the supplier or the system integrator shall provide a justification for the omission. The justification should give consideration to:
   - how the risks are known
   - the equivalence of the context of use of the current computer based system and the computer based system initially used to determine the risks
   - the adequacy of existing control measures in the current context of use

b) Code production and testing

   The following documentation shall be provided to the Class Society for Category II and III systems:
   - Software modules functional description and associated hardware description for programmable devices. This shall be provided by Supplier and System Integrator.
   - Evidence of verification (detection and correction of software errors) for software modules, in accordance with the selected software development standard. Evidence requirements of the selected software standard might differ depending on how critical the correct operation of the software is to the function it performs (i.e. IEC 61508 has different requirements depending on SILs, similar approaches are taken by other recognized standard). This shall be supplied by the Supplier and System Integrator.
   - Evidence of functional tests for programmable devices at the software module, sub-system, and system level. This shall be supplied by the Supplier via the System Integrator. The functional testing shall be designed to test the provisions of features used by the software but provided by the operating system, function libraries, customized layer of software and any set of parameters.

4.1.4 Integration testing before installation on board

Intra-system integration testing shall be done between system and sub-system software modules before being integrated on board. The objective is to check that software functions are properly executed, that the software and the hardware it controls interact and function properly together and that software systems react properly in case of failures. Faults are to be simulated as realistically as possible to demonstrate appropriate system fault detection and system response. The results of any required failure analysis are to be observed. Functional and failure testing can be demonstrated by simulation tests.

For Category II and III systems:

a) Test programs and procedures for functional tests and failure tests shall be submitted to the Class Society. A FMEA may be requested by the Class Society in order to support containment of failure tests programs.

b) Factory acceptance test including functional and failure tests shall be witnessed by Class Society.

   Following documentation shall be provided:

   1) Functional description of software
   2) List and versions of software installed in system
   3) User manual including instructions for use during software maintenance
   4) List of interfaces between system and other ship systems
   5) List of standards used for data communication links
   6) Additional documentation as requested by the Class Society which might include an FMEA or equivalent to demonstrate the adequacy of failure test case applied.

For Category III systems:

Simulation tests required in [4.1.4] shall fulfill in following conditions :

- software of control system identical to those that shall be installed on board shall be used for testing
- the environment of the control system shall be simulated with sufficient details and accuracy to run functional and failure tests
- the devices used for simulating the environment of the control system need to be evaluated by the Society before test is undertaken.

4.1.5 Approval of programmable devices for Category II and III systems

Approval of programmable devices integrated inside a system shall be delivered to the system integrator or supplier. Approval can be granted on case by case basis, or as part of a product type approval, so long as above mentioned documents have been reviewed/approved (as per annex) and the required tests have been witnessed by the Class Society (also see Ch 3, Sec 6, [2.2] regarding hardware environmental type tests). Documentation should address the compatibility of the programmable device in the ship's application, the necessity to have on board tests during ship integration and should identify the components of system using the approved programmable devices.

4.1.6 Final integration and on board testing

Simulation tests are to be undertaken before installation, when it is found necessary to check safe interaction with other computerized systems and functions that could not be tested previously.

On board tests shall check that a computer based system in its final environment, integrated with all other systems with which it interacts is:

- performing functions it was designed for
- reacting safely in case of failures originated internally or by devices external to the system
- interacting safely with other systems implemented on board vessel.

For final integration and on board testing of Category II and III systems:

- test specifications shall be submitted to the Society for approval
- the tests shall be witnessed by the Society.

4.2 Limited approval

4.2.1 Sub-systems and programmable devices may be approved for limited applications with service restrictions by the Class Society when the ship system where they will be integrated is not known. In this case, requirements about Quality systems under paragraph [4.1.2] might need to be fulfilled as required by the Class Society. Additional drawings, details, tests reports and surveys related to the Standard declared by the Supplier may be required by the Class Society upon request.

Sub-systems and programmable devices may in this case be granted with a limited approval mentioning the required checks and tests performed.

4.3 Modifications during operation

4.3.1 Responsibilities

Organizations in charge of software modifications shall be clearly declared by Owner to the Class Society. A System integrator shall be designated by the Owner and shall fulfil requirements mentioned in paragraph [4.1]. Limited life cycle steps may be considered for modifications already considered and accepted in the scope of initial approval. The level of documentation needed to be provided for the modification shall be determined by the Society.

At the vessel level, it is the responsibility of Owner to manage traceability of these modifications; the achievement of this responsibility shall be supported by system integrators updating the Software Registry. This Software Registry shall contain:

- List and versions of software installed in systems required in [4.1.4]
- Results of security scans as described in [4.4].

4.3.2 Change management

The owner shall ensure that necessary procedures for software and hardware change management exist on board, and that any software modification/upgrade are performed according to the procedure. All changes to computer based systems in the operational phase shall be recorded and be traceable by number, date or other appropriate means.

4.4 System security

4.4.1 Owner, system integrator and suppliers shall adopt security policies and include these in their quality systems and procedures.

For Category I, II, and III systems, physical and logical security measures shall be in place to prevent unauthorized or unintentional modification of software, whether undertaken at the physical system or remotely.

Prior to installation, all artefacts, software code, executables and the physical medium used for installation on the vessel are to be scanned for viruses and malicious software. Results of the scan are to be documented and kept with the Software Registry.

5 Requirements for hardware

5.1 Requirements for hardware regarding environment

5.1.1 Evidence of environmental type testing according to Ch 3, Sec 6, [2.2] regarding hardware elements included in the system and sub-systems shall be submitted to the Class Society for Category I, II and III computer based systems. This requirement is not mandatory for Category I computer based systems not considered by Class.

5.2 Requirements for hardware regarding construction

5.2.1 General

The construction of systems is to comply with the requirements of Ch 3, Sec 4.

5.2.2 Housing

a) The housing of the system is to be designed to face the environmental conditions, as defined in Ch 2, Sec 2, [1], in which it will be installed. The design will be such as to protect the printed circuit board and associated components from external aggression. When required, the cooling system is to be monitored, and an alarm activated when the normal temperature is exceeded.

b) The mechanical construction is to be designed to withstand the vibration levels defined in Ch 2, Sec 2, depending on the applicable environmental condition.

6 Requirements for data communication links for Category II and III systems

6.1 General requirements

6.1.1 Loss of a data link shall be specifically addressed in risk assessment analysis.

6.1.2 A single failure in data link hardware shall be automatically treated in order to restore proper working of system. For Category III systems a single failure in data link hardware shall not influence the proper working of the system.

6.1.3 Characteristics of data link shall prevent overloading in any operational condition of system.

6.1.4 Data link shall be self-checking, detecting failures on the link itself and data communication failures on nodes connected to the link. Detected failures shall initiate an alarm.

6.1.5 Loss of a data communication link is not to affect the ability to operate essential services by alternative means.

6.1.6 The data communication link is to be automatically started when power is turned on, or restarted after loss of power.

6.1.7 The choice of transmission cable is to be made according to the environmental conditions. Particular attention is to be given to the level characteristics required for electromagnetic interferences.

6.1.8 The installation of transmission cables is to comply with the requirements stated in Ch 2, Sec 11. In addition, the routing of transmission cables is to be chosen so as to be in less exposed zones regarding mechanical, chemical or EMI damage. As far as possible, the routing of each cable is to be independent of any other cable. These cables are not normally allowed to be routed in bunches with other cables on the cable tray.

6.1.9 The coupling devices are to be designed, as far as practicable, so that in the event of a single fault, they do not alter the network function. When a failure occurs, an alarm is to be activated.

Addition of coupling devices is not to alter the network function.

Hardware connecting devices are to be chosen, when possible, in accordance with international standards.

When a computer based system is used with a non-essential system and connected to a network used for essential systems, the coupling device is to be of an approved type.

6.2 Specific requirements for wireless data links

6.2.1 Category III systems shall not use wireless data links unless specifically considered by the Class Society on the basis of an engineering analysis carried out in accordance with an International or National Standard acceptable to the Society.

6.2.2 Other categories of systems may use wireless data communication links with following requirements:

a) Recognised international wireless communication system protocols shall be employed, incorporating:
   - Message integrity. Fault prevention, detection, diagnosis, and correction so that the received message is not corrupted or altered when compared to the transmitted message.
   - Configuration and device authentication. Shall only permit connection of devices that are included in the system design.
   - Message encryption. Protection of the confidentiality and or criticality of the data content.
   - Security management. Protection of network assets, prevention of unauthorized access to network assets.

b) The internal wireless system within the vessel shall comply with the radio frequency and power level requirements of International Telecommunication Union and flag state requirements.

   Consideration should be given to system operation in the event of port state and local regulations that pertain to the use of radio-frequency transmission prohibiting the operation of a wireless data communication link due to frequency and power level restrictions.

c) For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not its self-fail as a result of electromagnetic interference during expected operating conditions.

7 Man-machine interface

7.1 General

7.1.1 The design of the operator interface is to follow ergonomic principles. The standard IEC 60447 Man-machine interface or equivalent recognised standard may be used.

7.2 System functional indication

7.2.1 A means is to be provided to verify the activity of the system, or subsystem, and its proper function.

7.2.2 A visual and audible alarm is to be activated in the event of malfunction of the system, or subsystem. This alarm is to be such that identification of the failure is simplified.

7.3 Input devices

7.3.1 Input devices are to be positioned such that the operator has a clear view of the related display.

The operation of input devices, when installed, is to be logical and correspond to the direction of action of the controlled equipment.

The user is to be provided with positive confirmation of action.

Control of essential functions is only to be available at one control station at any time. Failing this, conflicting control commands are to be prevented by means of interlocks and/or warnings.

7.3.2 When keys are used for common/important controls, and several functions are assigned to such keys, the active function is to be recognisable.

If use of a key may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of 2 keys, repeated use of a key, etc.).

Means are to be provided to check validity of the manual input data into the system (e.g. checking the number of characters, range value, etc.).

7.3.3 If use of a push button may have unwanted consequences, provision is to be made to prevent an instruction from being executed by a single action (e.g. simultaneous use of 2 push buttons, repeated use of push buttons, etc.). Alternatively, this push button is to be protected against accidental activation by a suitable cover, or use of a pull button, if applicable.

7.4 Output devices

7.4.1 VDU's (video display units) and other output devices are to be suitably lighted and dimmable when installed in the wheelhouse. The adjustment of brightness and colour of VDU's is to be limited to a minimum discernable level.

When VDU's are used for alarm purposes, the alarm signal, required by the Rules, is to be displayed whatever the other information on the screen. The alarms are to be displayed according to the sequence of occurrence.

When alarms are displayed on a colour VDU, it is to be possible to distinguish alarm in the event of failure of a primary colour.

The position of the VDU is to be such as to be easily readable from the normal position of the personnel on watch. The size of the screen and characters is to be chosen accordingly.

When several control stations are provided in different spaces, an indication of the station in control is to be displayed at each control station. Transfer of control is to be effected smoothly and without interruption to the service.

7.5 Workstations

7.5.1 The number of workstations at control stations is to be sufficient to ensure that all functions may be provided with any one unit out of operation, taking into account any functions which are required to be continuously available.

7.5.2 Multifunction workstations for control and display are to be redundant and interchangeable.

7.5.3 The choice of colour, graphic symbols, etc. is to be consistent in all systems on board.

7.6 Computer dialogue

7.6.1 The computer dialogue is to be as simple and self-explanatory as possible.

The screen content is to be logically structured and show only what is relevant to the user.

Menus are to be organised so as to have rapid access to the most frequently used functions.

7.6.2 A means to go back to a safe state is always to be accessible.

7.6.3 A clear warning is to be displayed when using functions such as alteration of control condition, or change of data or programs in the memory of the system.

7.6.4 A 'wait' indication is to warn the operator when the system is executing an operation.

8 Integrated systems

8.1 General

8.1.1 Operation with an integrated system is to be at least as effective as it would be with individual, stand alone equipment.

8.1.2 Failure of one part (individual module, equipment or subsystem) of the integrated system is not to affect the functionality of other parts, except for those functions directly dependant on information from the defective part.

8.1.3 A failure in connection between parts, cards connections or cable connections is not to affect the independent functionality of each connected part.

8.1.4 Alarm messages for essential functions are to have priority over any other information presented on the display.

9 Expert system

9.1

9.1.1 The expert system software is not to be implemented on a computer linked with essential functions.

9.1.2 Expert system software is not to be used for direct control or operation, and needs human validation by personnel on watch.

Section 4 Constructional Requirements

1 General

1.1 General

1.1.1 Automation systems are to be so constructed as:

- to withstand the environmental conditions, as defined in Ch 2, Sec 2, [1], in which they operate
- to have necessary facilities for maintenance work.

1.2 Materials

1.2.1 Materials are generally to be of the flame-retardant type.

1.2.2 Connectors are to be able to withstand standard vibrations, mechanical constraints and corrosion conditions as given in Ch 3, Sec 6.

1.3 Component design

1.3.1 Automation components are to be designed to simplify maintenance operations. They are to be so constructed as to have:

- easy identification of failures
- easy access to replaceable parts
- easy installation and safe handling in the event of replacement of parts (plug and play principle) without impairing the operational capability of the system, as far as practicable
- facility for adjustment of set points or calibration
- test point facilities, to verify the proper operation of components.

1.4 Environmental and supply conditions

1.4.1 The environmental and supply conditions are specified in Ch 3, Sec 1. Specific environmental conditions are to be considered for air temperature and humidity, vibrations, corrosion from chemicals and mechanical or biological attacks.

2 Electrical and/or electronic systems

2.1 General

2.1.1 Electrical and electronic equipment is to comply with the requirements of Part C, Chapter 2 and Part C, Chapter 3.

2.1.2 A separation is to be done between any electrical components and liquids, if they are in a same enclosure. Necessary drainage will be provided where liquids are likely to leak.

2.1.3 When plug-in connectors or plug-in elements are used, their contacts are not to be exposed to excessive mechanical loads. They are to be provided with a locking device.

2.1.4 All replaceable parts are to be so arranged that it is not possible to connect them incorrectly or to use incorrect replacements. Where this not practicable, the replacement parts as well as the associated connecting devices are to be clearly identified. In particular, all connection terminals are to be properly tagged. When replacement cannot be carried out with the system on, a warning sign is to be provided.

2.1.5 Forced cooling systems are to be avoided. Where forced cooling is installed, an alarm is to be provided in the event of failure of the cooling system.

2.1.6 The interface connection is to be so designed to receive the cables required. The cables are to be chosen according to Ch 2, Sec 3.

2.2 Electronic system

2.2.1 Printed circuit boards are to be so designed that they are properly protected against the normal aggression expected in their environment.

2.2.2 Electronic systems are to be constructed taking account of electromagnetic interferences.

Special precautions are to be taken for:

- measuring elements such as the analogue amplifier or analog/digital converter; and
- connecting different systems having different ground references.

2.2.3 The components of electronic systems (printed circuit board, electronic components) are to be clearly identifiable with reference to the relevant documentation.

2.2.4 Where adjustable set points are available, they are to be readily identifiable and suitable means are to be provided to protect them against changes due to vibrations and uncontrolled access.

2.2.5 The choice of electronic components is to be made according to the normal environmental conditions, in particular the temperature rating.

2.2.6 All stages of fabrication of printed circuit boards are to be subjected to quality control. Evidence of this control is to be documented.

2.2.7 Burn-in tests or equivalent tests are to be performed.

2.2.8 The programmable components are to be clearly tagged with the program date and reference.

Components are to be protected against outside alteration when loaded.

2.3 Electrical system

2.3.1 Cables and insulated conductors used for internal wiring are to be at least of the flame-retardant type, and are to comply with the requirements in Part C, Chapter 2.

2.3.2 If specific products (e.g. oil) are likely to come into contact with wire insulation, the latter is to be resistant to such products or properly shielded from them, and to comply with the requirements in Part C, Chapter 2.

3 Pneumatic systems

3.1

3.1.1 Pneumatic automation systems are to comply with Ch 1, Sec 10, [17].

3.1.2 Pneumatic circuits of automation systems are to be independent of any other pneumatic circuit on board.

4 Hydraulic systems

4.1

4.1.1 Hydraulic automation systems are to comply with Ch 1, Sec 10, [14].

4.1.2 Suitable filtering devices are to be incorporated into the hydraulic circuits.

4.1.3 Hydraulic circuits of automation systems are to be independent of any other hydraulic circuit on board.

5 Automation consoles

5.1 General

5.1.1 Automation consoles are to be designed on ergonomic principles. Handrails are to be fitted for safe operation of the console.

5.1.2 For all mimic diagram located on consoles, switchboard or on screen, the ship is to be shown as follows:

- Portrait view:
  - the fore part of the ship is to be located on the top of the mimic
  - aft part of the ship is to be located on the bottom of the mimic
  - starboard part of the ship is to be located on the right of the mimic
  - port part of the ship is to be located on the left of the mimic
- Landscape view, which can be either a top view or a side view:
  - fore part of the ship is to be located on the right of the mimic
  - aft part of the ship is to be located on the left of the mimic
  - starboard part of the ship is to be located on the lower part of the mimic
  - port part of the ship is to be located on the upper part of the mimic.

5.2 Indicating instruments

5.2.1 The operator is to receive feed back information on the effects of his orders.

5.2.2 Indicating instruments and controls are to be arranged according to the logic of the system in control. In addition, the operating movement and the resulting movement of the indicating instrument are to be consistent with each other.

5.2.3 The instruments are to be clearly labelled. When installed in the wheelhouse, all lighted instruments of consoles are to be dimmable, where necessary.

5.3 VDU's and keyboards

5.3.1 VDU's in consoles are to be located so as to be easily readable from the normal position of the operator. The environmental lighting is not to create any reflection which makes reading difficult.

5.3.2 The keyboard is to be located to give easy access from the normal position of the operator. Special precautions are to be taken to avoid inadvertent operation of the keyboard.

Section 5 Installation Requirements

1 General

1.1

1.1.1 Automation systems are to be installed taking into account:

- the maintenance requirements (test and replacement of systems or components)
- the influence of EMI. The IEC 60533 standard is to be taken as guidance
- the environmental conditions corresponding to the location in accordance with Ch 2, Sec 1and Ch 2, Sec 3, [6].

1.1.2 Control stations are to be arranged for the convenience of the operator.

1.1.3 Automation components are to be properly fitted. Screws and nuts are to be locked, where necessary.

2 Sensors and components

2.1 General

2.1.1 The location and selection of the sensor is to be done so as to measure the actual value of the parameter. Temperature, vibration and EMI levels are to be taken into account. When this is not possible, the sensor is to be designed to withstand the local environment.

2.1.2 The enclosure of the sensor and the cable entry are to be appropriate to the space in which they are located.

2.1.3 Means are to be provided for testing, calibration and replacement of automation components. Such means are to be designed, as far as practicable, so as to avoid perturbation of the normal operation of the system.

2.1.4 When replacement of automation components is not possible, duplication of these components is required.

2.1.5 A tag number is to identify automation components and is to be clearly marked and attached to the component. These tag numbers are to be collected on the instrument list mentioned in Ch 3, Sec 1, Tab 1.

2.1.6 Electrical connections are to be arranged for easy replacement and testing of sensors and components. They are to be clearly marked.

2.1.7 Low level signal sensors are to be avoided. When installed they are to be located as close as possible to amplifiers, so as to avoid external influences. Failing this, the wiring is to be provided with suitable EMI protection and temperature correction.

2.2 Temperature elements

2.2.1 Temperature sensors, thermostats or thermometers are to be installed in a thermowell of suitable material, to permit easy replacement and functional testing. The thermowell is not to significantly modify the response time of the whole element.

2.3 Pressure elements

2.3.1 Three-way valves or other suitable arrangements are to be installed to permit functional testing of pressure elements, such as pressure sensors, pressure switches, without stopping the installation.

2.3.2 In specific applications, where high pulsations of pressure are likely to occur, a damping element, such as a capillary tube or equivalent, is to be installed.

2.4 Level switches

2.4.1 Level switches fitted to flammable oil tanks, or similar installations, are to be installed so as to reduce the risk of fire.

3 Cables

3.1 Installation

3.1.1 Cables are to be installed according to the requirements in Ch 2, Sec 12, [7].

3.1.2 Suitable installation features such as screening and/or twisted pairs and/or separation between signal and other cables are to be provided in order to avoid possible interference on control and instrumentation cables.

3.1.3 Specific transmission cables (coaxial cables, twisted pairs, etc.) are to be routed in specific cable-ways and mechanically protected to avoid loss of any important transmitted data. Where there is a high risk of mechanical damage, the cables are to be protected with pipes or equivalent.

3.1.4 The cable bend radius is to be in accordance with the requirements of Ch 2, Sec 12, [7.2].

For mineral insulated cables, coaxial cables or fibre optic cables, whose characteristics may be modified, special precautions are to be taken according to the manufacturer's instructions.

3.2 Cable terminations

3.2.1 Cable terminations are to be arranged according to the requirements in Part C, Chapter 2. Particular attention is to be paid to the connections of cable shields. Shields are to be connected only at the sensor end when the sensor is earthed, and only at the processor end when the sensor is floating.

3.2.2 Cable terminations are to be able to withstand the identified environmental conditions (shocks, vibrations, salt mist, humidity, etc.).

3.2.3 Terminations of all special cables such as mineral insulated cables, coaxial cables or fibre optic cables are to be arranged according to the manufacturer's instructions.

3.2.4 The optical fibre cables are not to be cut in their total length. Where necessary, junction are to be done with approved means and appropriate tools following manufacturer requirements.

4 Pipes

4.1

4.1.1 For installation of piping circuits used for automation purposes, see the requirements in Ch 1, Sec 10.

4.1.2 As far as practicable, piping containing liquids is not to be installed in or adjacent to electrical enclosures (see Ch 3, Sec 4, [2.1.2]).

4.1.3 Hydraulic and pneumatic piping for automation systems is to be marked to indicate its function.

5 Automation consoles

5.1 General

5.1.1 Consoles or control panels are to be located so as to enable a good view of the process under control, as far as practicable. Instruments are to be clearly readable in the ambient lighting.

5.1.2 The location is to be such as to allow easy access for maintenance operations.

5.1.3 Shock absorbers are to be installed for all consoles and switchboards fitted onboard, according to service notation requirements, where necessary.

Section 6 Testing

1 General

1.1 General

1.1.1 Automation systems are to be tested for type approval, at works and on board, when required. Tests are to be carried out under the supervision of a Surveyor of the Society.

1.1.2 The type testing conditions for electrical, control and instrumentation equipment, computers and peripherals are described in Article [2].

1.1.3 Automation systems are to be inspected at works, according to the requirements of Article [3], in order to check that the construction complies with the Rules.

1.1.4 Automation systems are to be tested when installed on board and prior to sea trials, to verify their performance and adaptation on site, according to Article [4].

2 Type approval

2.1 General

2.1.1 The following requirements are applicable, but not confined, to electrical and electronic equipment which are intended to be type approved for control, monitoring, alarm and protection systems for use in ships.

2.1.2 The necessary documents to be submitted, prior to type testing, are listed in Ch 3, Sec 1, [2.3.1] and Ch 3, Sec 3, [3.1.1]. The type approval of automation systems refers to hardware type approval or software type approval, as applicable.

2.2 Hardware type approval

2.2.1 Hardware type approval of automation systems is obtained subject to the successful outcome of the tests described in Tab 1. These tests are to demonstrate the ability of the equipment to function as intended under the specified test conditions.

2.2.2 The extent of testing (i.e. selection and sequence of carrying out tests and number of pieces to be tested) is to be determined upon examination and evaluation of the equipment or component subject to testing, giving due regards to its intended usage.

Equipment is to be tested in its normal position if otherwise not specified in the test specification.

Vibration and salt mist testing may be performed on different specimens, where applicable.

Reset of the automation system is accepted between each test, where necessary.

Note 1: As used in this Section, and in contrast to a complete performance test, a functional test is a simplified test sufficient to verify that the equipment under test (EUT) has not suffered any deterioration caused by the individual environmental tests.

2.2.3 The following additional tests may be required, depending on particular manufacturing or operational conditions:

- mechanical endurance test
- temperature shock test (e.g. 12 shocks on exhaust gas temperature sensors from 20°C ± 5°C to maximum temperature of the range)
- immersion test
- oil resistance test
- shock test.

The test procedure is to be defined with the Society in each case.

2.3 Software type approval

2.3.1 Software of computer based systems are to be approved in accordance with requirements mentioned in Ch 3, Sec 3.

Table 1 : Type tests

No.	Test	Procedure **(6)**	Test parameters	Other information
1	Visual inspection	–	–	• drawings, design data
2	Performance test	Manufacturer performance test programme based upon specification and relevant rule requirements When the EUT is required to comply with an international performance standard, e.g. protection relays, verification of requirements in the standard are to be part of the performance testing required in this initial test and subsequent performance tests after environmental testing where required as per [2.2].	• standard atmosphere conditions • temperature: 25°C ± 10°C • relative humidity: 60% ± 30% • air pressure: 96 KPa ± 10 KPa	• confirmation that operation is in accordance with the requirements specified for particular automatic systems or equipment • checking of self-monitoring features • checking of specified protection against an access to the memory • checking against effect of unerroneous use of control elements in the case of computer systems
3	Power supply failure	–	• 3 interruptions during 5 minutes • switching- off time 30 s each case	• verification of the specified action of the equipment on loss and restoration of supply in accordance with the system design • verification of possible corruption of programme or data held in programmable electronic systems, where applicable • the time of 5 minutes may be exceeded if the equipment under test needs a longer time for start up, e.g. booting sequence • for equipment which requires booting, one additional power supply interruption during booting to be performed
4a	Electric A.C. power supply variations	–	COMBINATION Voltage variation permanent / Frequency variation permanent + 6% / + 5% + 6% / – 5% – 10% / – 5% – 10% / + 5% voltage transient (1,5s) / frequency transient (5s) + 20% / + 10% – 20% / – 10%	
4b	Electric D.C. power supply variations	–	Voltage tolerance continuous: ± 10% Voltage cyclic variation: 5% Voltage ripple: 10% Electric battery supply: • +30% to –25% for equipment connected to charging battery or as determined by the charging/discharging characteristics, including ripple voltage from the charging device • +20% to –25% for equipment not connected to the battery during charging	
4c	Pneumatic and hydraulic power supply variations	–	Pressure: ± 20% Duration: 15 minutes	

No.	Test	Procedure **(6)**	Test parameters	Other information
5	Dry heat**(1)**	IEC 60068-2-2 Test "Bb" for non-heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing • functional test**(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
		IEC 60068-2-2 Test "Be" for heat dissipating equipment	• Temperature: 55°C ± 2°C Duration: 16 hours, or • Temperature: 70°C ± 2°C Duration: 16 hours	• equipment operating during conditioning and testing with cooling system on if provided • functional test**(9)** during the last hour at the test temperature • for equipment specified for increased temperature the dry heat test is to be conducted at the agreed test temperature and duration.
6	Damp heat	IEC 60068-2-30 Test Db	Temperature: 55°C Humidity: 95% Duration: 2 cycles (12 + 12 hours)	• measurement of insulation resistance before test • the test shall start with 25°C ± 3°C and at least 95% humidity • equipment operating during the complete first cycle and switched off during second cycle except for functional test • functional test during the first 2 hours of the first cycle at the test temperature and during the last 2 hours of the second cycle at the test temperature; Duration of the second cycle can be extended due to more convenient handling of the functional test • recovery at standard atmosphere conditions • insulation resistance measurements and performance test
7	Vibration	IEC 60068-2-6 Test Fc	• 2 Hz ± 3/0 Hz to 13,2 Hz amplitude: ± 1mm • 13,2 Hz to 100 Hz acceleration: ± 0,7 g For severe vibration conditions such as, e. g., on diesel engines, air compressors, etc.: • 2,0 Hz to 25 Hz amplitude: ± 1,6 mm • 25 Hz to 100 Hz acceleration: ± 4,0 g Note: More severe conditions may exist for example on exhaust manifolds or fuel oil injection systems of diesel engines. For equipment specified for increased vibration levels the vibration test is to be conducted at the agreed vibration level, frequency range and duration. Values may be required to be in these cases: • 40 Hz to 2000 Hz • acceleration: ± 10,0 g at 600°C	• duration 90 minutes at 30 Hz in case of no resonance condition • duration 90 minutes at each resonance frequency at which Q ≥ 2 is recorded • during the vibration test, functional tests are to be carried out • tests to be carried out in three mutually perpendicular planes • it is recommended as a guidance that Q does not exceed 5 • duration 120 minutes where sweep test is to be carried out instead of discrete frequency test and a number of resonant frequencies is detected close to each other. Sweep over a restricted frequency range between 0.8 and 1.2 times the critical frequencies can be used where appropriate. Note: Critical frequency is a frequency at which the equipment being tested may exhibit: • malfunction and/or performance deterioration • mechanical resonances and/or other response effects occur, e.g. chatter

No.	Test	Procedure **(6)**	Test parameters	Other information
8	Inclination	IEC 60092-504	Static 22,5°	a) inclined to the vertical at an angle of at least 22,5° b) inclined to at least 22,5° on the other side of the vertical and in the same plane as in a) c) inclined to the vertical at an angle of at least 22,5° in plane at right angles to that used in a) d) inclined to at least 22,5° on the other side of the vertical and in the same plane as in c) Note: The period of testing in each position should be sufficient to fully evaluate the behaviour of the equipment
			Dynamic 22,5°	Using the directions defined in a) to d) above, the equipment is to be rolled to an angle of 22,5° each side of the vertical with a period of 10 seconds The test in each direction is to be carried out for not less than 15 minutes Note: These inclination tests are normally not required for equipment with no moving parts.
9	Insulation resistance	Rated supply voltage / Test voltage (D.C. voltage) (V) Un ≤ 65 V / 2 x Un min. 24 V Un > 65V / 500 V	Minimum insulation resistance before / after 10 Mohms / 1,0 Mohms 100 Mohms / 10 Mohms	• insulation resistance test is to be carried out before and after: damp heat test, cold test, salt mist test and high voltage test • between all phases and earth, and where appropriate between the phases Note: Certain components, e. g. for EMC protection, may be required to be disconnected for this test
10	High voltage	Rated voltage Un Up to 65 V 66 V to 250 V 251 V to 500 V 501 V to 690 V	Test voltage (A.C. voltage 50 or 60Hz) 2 x Un + 500 V 1500 V 2000 V 2500 V	• separate circuits are to be tested against each other and all circuits connected with each other tested against earth • printed circuits with electronic components may be removed during the test • period of application of the test voltage: 1 minute Note: Certain components, e. g. printed circuits with electronic components, may be required to be disconnected for this test
11	Cold	IEC 60068-2-1	• Temperature: +5°C ± 3°C Duration: 2 hours, or • Temperature: –25°C ± 3°C Duration: 2 hours (see **(2)**)	• initial measurement of insulation resistance • equipment not operating during conditioning and testing except for functional test • functional test during the last hour at the test temperature • insulation resistance measurement and the functional test after recovery

No.	Test	Procedure **(6)**	Test parameters	Other information
12	Salt mist	IEC 60068-2-52 Test Kb	Four spraying periods with a storage of seven days after each	• initial measurement of insulation resistance and initial functional test • equipment not operating during conditioning • functional test on the 7th day of each storage period • insulation resistance measurement and performance test 4 to 6h after recovery (see**(3)**) • on completion of exposure, the equipment shall be examined to verify that deterioration or corrosion (if any) is superficial in nature
13	Electrostatic discharge	IEC 61000-4-2	Contact discharge: 6 kV Air discharge: 2 kV, 4 kV, 8 kV Interval between single discharges: 1 sec. No. of pulses: 10 per polarity According to test level 3	• to simulate electrostatic discharge as may occur when persons touch the appliance • the test is to be confined to the points and surfaces that can normally be reached by the operator • performance criterion B (see**(4)**)
14	Electromagnetic field	IEC 61000-4-3	Frequency range: 80 MHz to 6 GHz Modulation**: 80% AM at 1000Hz Field strength: 10V/m Frequency sweep rate: $\leq 1{,}5.10^{-3}$ decades/s (or 1% / 3 sec) According to test level 3	• to simulate electromagnetic fields radiated by different transmitters • the test is to be confined to the appliances exposed to direct radiation by transmitters at their place of installation • performance criterion A (see**(5)**) ** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen • If an equipment is intended to receive radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller), then the immunity limits at its communication frequency do not apply, subject to the provisions in Ch 3, Sec 3, [6.2].
15	Conducted low Frequency		A.C.: • Frequency range: rated frequency to 200th harmonic • Test voltage (rms): 10% of supply to 15th harmonic reducing to 1% at 100th harmonic and maintain this level to the 200th harmonic, min 3 V r.m.s, max. 2 W D.C.: • Frequency range: 50 Hz - 10 kHz • Test voltage (rms): 10% of supply, max. 2 W	• to simulate distortions in the power supply system generated, for instance, by electronic consumers and coupled in as harmonics • performance criterion A (see**(5)**) • see figure “Test set-up” (see**(8)**) • for keeping max. 2W, the voltage of the test signal may be lower

No.	Test	Procedure **(6)**	Test parameters	Other information
16	Conducted Radio Frequency	IEC 61000-4-6	AC, DC, I/O ports and signal/ control lines Frequency range: 150 kHz - 80 MHz Amplitude: 3 V rms (see **(7)**) Modulation***: 80% AM at 1000 Hz Frequency sweep range: ≤ $1{,}5.10^{-3}$ decades/s (or 1% / 3sec.) According to test level 2	• to simulate electromagnetic fields coupled as high frequency into the test specimen via the connecting lines • performance criterion A (see**(5)**) *** If, for tests of equipment, an input signal with a modulation frequency of 1000 Hz is necessary, a modulation frequency of 400 Hz should be chosen
17	Electrical Fast Transients / Burst	IEC 61000-4-4	Single pulse time: 5ns (between 10% and 90% value) Single pulse width: 50 ns (50% value) Amplitude (peak): 2 kV line on power supply port/earth; 1 kV on I/O data control and communication ports (coupling clamp) Pulse period: 300 ms Burst duration: 15 ms Duration/polarity: 5 min According to test level 3	• arcs generated when actuating electrical contacts • interface effect occurring on the power supply, as well as at the external wiring of the test specimen • performance criterion B (see**(4)**)
18	Surge	IEC 61000-4-5	Test applicable to AC and DC power ports. Open-circuit voltage: • Pulse rise time: 1,2 µs (front time) • Pulse width: 50 µs (time of half value) • Amplitude (peak): 1 kV line/earth; 0,5kV line/line Short circuit current: • Pulse rise time: 8 µs (front time) • Pulse width: 20 µs (time of half value) Repetition rate: ≥ 1 pulse/min No of pulses: 5 per polarity Application: continuous According to test level 2	• to simulate interference generated, for instance, by switching “ON” or “OFF” high power inductive consumers • test procedure in accordance with figure 10 of the standard for equipment where power and signal lines are identical • performance criterion B (see**(4)**)

No.	Test	Procedure **(6)**	Test parameters	Other information
19	Radiated Emission	CISPR 16-2-3 IEC 60945 for 156-165 MHz	Limits below 1000MHz: • For equipment installed in the bridge and deck zone: Frequency range: (MHz) / Quasi peak limits: (dBµV/m) 0,15 - 0,30 / 80- 52 0,30 - 30 / 52- 34 30 - 1000 / 54 except for: 156 - 165 / 24 • For equipment installed in the general power distribution zone: Frequency range: (MHz) / Quasi peak limits: (dBµV/m) 0,15 - 30 / 80 - 50 30 - 100 / 60 - 54 100 - 1000 / 54 except for: 156 - 165 / 24	• procedure in accordance with the standard but distance 3 m between equipment and antenna • for the frequency band 156 MHz to 165 MHz the measurement is to be repeated with a receiver bandwidth of 9 kHz (as per IEC 60945) • alternatively the radiation limit at a distance of 3 m from the enclosure port over the frequency 156 MHz to 165 MHz shall be 30 dB micro-V/m peak (as per IEC 60945)
			Limits above 1000MHz: Frequency range: (MHz) / Average limit: (dBµV/m) 1000-6000 / 54	• procedure in accordance with the standard (distance 3 m between equipment and antenna) Equipment intended to transmit radio signals for the purpose of radio communication (e.g. wifi router, remote radio controller) may be exempted from limit, within its communication frequency range, subject to the provisions in Ch 3, Sec 3, [6.2]
20	Conducted Emission	CISPR 16-2-1	Test applicable to AC and DC power ports • For equipment installed in the bridge and deck zone: Frequency range: / Limits: (dBµV) 10 - 150 kHz / 96 - 50 150 - 350 kHz / 60 - 50 0,35 - 30 MHz / 50 • For equipment installed in the general power distribution zone: Frequency range: / Limits: (dBµV) 10 - 150 kHz / 120 - 69 150 - 500 kHz / 79 0,50 - 30 MHz / 73	
21	Flame retardant	IEC 60092-101 or IEC 60695-11-5	Flame application: 5 times 15 s each Interval between each application: 15 s or 1 time 30 s	• the burnt out or damaged part of the specimen by not more than 60mm long • no flame, no incandescence or in the event of a flame or incandescence being present, it shall extinguish itself within 30 s of the removal of the needle flame without full combustion of the test specimen • any dripping material shall extinguish itself in such a way as not to ignite a wrappin tissue. The drip height is 200 mm ± 5 mm

No.	Test	Procedure **(6)**	Test parameters	Other information

(1) Dry heat at 70 °C is to be carried out to automation, control and instrumentation equipment subject to high degree of heat, for example mounted in consoles, housings, etc. together with other heat dissipating power equipment.

(2) For equipment installed in non-weather protected locations or cold locations, test is to be carried out at –25°C.

(3) Salt mist test is to be carried out for equipment installed in weather exposed areas.

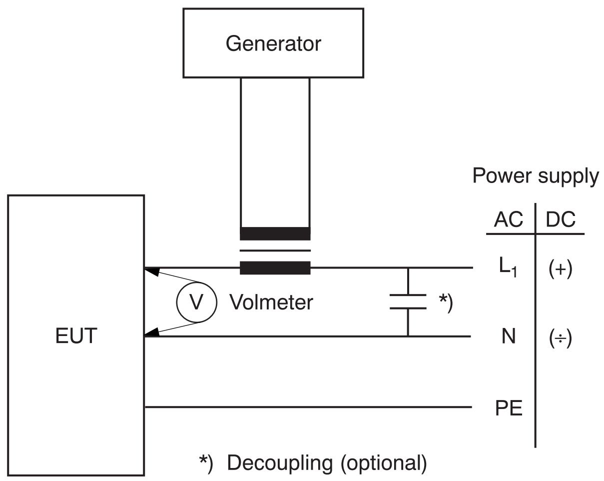
(4) Performance criterion B: (for transient phenomena): The Equipment Under Test shall continue to operate as intended after the tests. No degradation of performance or loss of function is allowed as defined in the technical specification published by the Manufacturer. During the test, degradation or loss of function or performance which is self recoverable is however allowed but no change of actual operating state or stored data is allowed.

(5) Performance criterion A (for continuous phenomena): The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed as defined in relevant equipment standard and the technical specification published by the Manufacturer.

(6) Column 3 indicates the testing procedure which is normally to be applied. However, equivalent testing procedure may be accepted by the Society provided that what is required in the other columns is fulfilled.

(7) For equipment installed on the bridge and deck zone, the test levels shall be increased to 10V rms for spot frequencies in accordance with IEC 60945 at 2,3,4,6.2, 8.2, 12.6, 16.5, 18.8, 22, 25 MHz.

(8) Figure - Test set-up for Conducted Low Frequency - Refer to IEC Publication 60945 (1996).



(9) See [2.2.2], Note 1.

2.4 Loading instruments

2.4.1 Loading instrument approval consists of:

- approval of hardware according to [2.2], unless two computers are available on board for loading calculations only
- approval of basic software according to [2.3]
- approval of application software, consisting in data verification which results in the Endorsed Test Condition according to Pt B, Ch 10, Sec 2, [4]
- installation testing according to Article [4].

3 Acceptance testing

3.1 General

3.1.1 Acceptance tests are generally to be carried out at the manufacturer's facilities before the shipment of the equipment, when requested.

Acceptance tests refer to hardware and software tests as applicable.

3.2 Hardware testing

3.2.1 Final acceptance will be granted subject to:

- the results of the tests listed in [3.2.2]
- the type test report or type approval certificate.

3.2.2 Hardware acceptance tests include, where applicable:

- visual inspection
- operational tests and, in particular:
  - tests of all alarm and safety functions
  - verification of the required performance (range, calibration, repeatability, etc.) for analogue sensors
  - verification of the required performance (range, set points, etc.) for on/off sensors
  - verification of the required performance (range, response time, etc.) for actuators
  - verification of the required performance (full scale, etc.) for indicating instruments
- endurance test (burn-in test or equivalent)
- high voltage test
- hydrostatic tests.

Additional tests may be required by the Society.

3.3 Software testing

3.3.1 Software acceptance tests of computer based systems are to be carried according to requirements mentioned in Ch 3, Sec 3

4 On board tests

4.1 General

4.1.1 Testing is to be performed on the completed system comprising actual hardware components with the final application software, in accordance with an approved test program.After test completion, installed versions of computer based systems software are to be recorded inside the software registry.

4.1.2 On board tests are to be carried out on automation systems associated with essential services to verify their compliance with the Rules, by means of visual inspection and the performance and functionality according to Tab 2.

On board testing is to verify that correct functionality has been achieved with all systems integrated.

When completed, automation systems are to be such that a single failure, for example loss of power supply, is not to result in a major degradation of the propulsion or steering of the ship. In addition, a blackout test is to be carried out to show that automation systems are continuously supplied.

Upon completion of on board tests, test reports are to be made available to the Surveyor.

4.1.3 For wireless data communication equipment, tests during harbour and sea trials are to be conducted to demonstrate that radio-frequency transmission does not cause failure of any equipment and does not itself fail as a result of electromagnetic interference during expected operating conditions.

Note 1: Where electromagnetic interference caused by wireless data communication equipment is found to be causing failure of equipment required for Category II or III systems, the layout and/or equipment are/is to be changed to prevent further failures occurring.

Table 2 : On board tests

Equipment	Nature of tests
Electronic equipment	Main hardware and software functionalities with all systems integrated
Analogue sensors	Signal calibration, trip set point adjustment
On/off sensors	Simulation of parameter to verify and record the set points
Actuators	Checking of operation in whole range and performance (response time, pumping)
Reading instruments	Checking of calibration, full scale and standard reference value

Part C
Machinery, Systems and Fire Protection

CHAPTER 4
FIRE PROTECTION, DETECTION AND EXTINCTION

Section 1 General

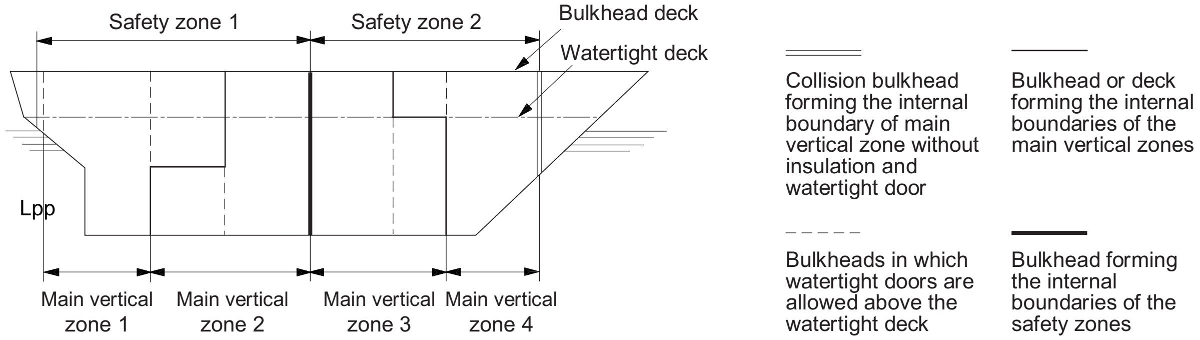
1 Application

1.1 General

1.1.1 The requirements of this Chapter apply to naval surface ships. Fire protection of naval ships shall be achieved by provisions of passive and active fire protection systems for each space and by provisions of the subdivision of the ship spaces into main vertical zones and into safety zones.

1.1.2 The arrangement of the main vertical zones and safety zones can be represented by Fig 1.

Figure 1 : Sample arrangement of main vertical zones and safety zones



1.2 Exemptions

1.2.1 The Society may, if the position of spaces and/or of rooms is such as to render the application of any specific requirement of this Chapter unreasonable or unnecessary, exempt from those requirements individual ships.

1.3 Documentation to be submitted

1.3.1 The interested party is to submit to the Society the documents listed in Tab 1.

Table 1 : Documentation to be submitted

No.	I/A **(1)**	Document **(2)**
1	A	Structural fire protection showing the purpose and category of the various spaces of the ships, the fire rating of bulkheads and decks, means of closings of openings in A and B class divisions, draught stops, and completed with the indication of material of other bulkhead and of ceilings and lining
2	A	Natural and mechanical ventilation systems showing the penetrations on A class divisions, location of dampers, means of closing, arrangements of air conditioning rooms
3	A	Means of escape and, where required, the relevant dimensioning calculation and the escape route signage
4	A	Automatic fire detection systems and manually operated call points
5	A	Fire pumps and fire main including pumps head and capacity, hydrant and hose locations **(2)**
6	A	Arrangement of fixed and semi-fixed fire-extinguishing systems **(2)**
7	A	Arrangement of sprinkler or sprinkler equivalent systems **(2)**
8	A	Fire-fighting equipment and firemen’s outfits
9	A	Electrical diagram of the fixed gas fire-extinguishing systems, fixed fire detection systems, fire alarm and emergency lighting
10	A	Electrical diagram of the sprinkler systems
11	A	Electrical diagram of power control and position indication circuits for fire devices
12	I	General arrangement plan
13	I	Safety zone plan (for information), Main Vertical Zone plan (for approval)
14	A	Fire control plan
15	I	Smoke confinement zone arrangement

No.	I/A **(1)**	Document **(2)**
(1) A = to be submitted for approval I = to be submitted for information. **(2)** Plans are to be schematic and functional and to contain all information necessary for their correct understanding and verification such as: • service pressures • capacity and head of pumps and compressors, if any • materials and dimensions of piping and associated fittings • volumes of protected spaces, for gas and foam fire-extinguishing systems • surface areas of protected zones for sprinkler and pressure water-spraying, low expansion foam and powder fire-extinguishing systems • capacity, in volume and/or in mass, of vessels or bottles containing the extinguishing media or propelling gases, for gas, sprinkler, foam and powder fire-extinguishing systems • type, number and location of nozzles of extinguishing media for gas, sprinkler, pressure water-spraying, foam and powder fire-extinguishing systems. All or part of the information may be provided, instead of on the above plans, in suitable operation manuals or in specifications of the systems.		

1.4 Type approved products

1.4.1 The following materials, equipment, systems or products in general used for fire protection, are to be type approved by the Society, except for special cases for which an authorisation of use may be given by the Society for individual ships on the basis of documented test reports or ad-hoc tests.

These products are to be installed on board in accordance with the requirements and possible limitations defined in the type approval certificate.

a) A, B class fire divisions (bulkheads or decks) and associated openings

b) C-class divisions

c) Materials for pipes penetrating A or B class divisions (where they are not of steel or other equivalent material)

d) Bulkhead or deck penetrations for electrical cables passing through A or B class divisions

e) Fire dampers

f) Prefabricated sanitary units

g) Prefabricated window casings

h) Fire door control systems

i) Flexible pipes and expansion bellows of non-conventional material for any type of fluid

j) Materials with low flame spread characteristic including paints, varnishes and similar, when they are required to have such characteristic

k) Non-combustible materials

l) Non-readily igniting materials for primary deck coverings

m) Fixed foam fire-extinguishing systems and associated foam-forming liquids

n) Fixed powder fire-extinguishing systems, including the powder

o) Equivalent water-mist fire-extinguishing systems

p) Equivalent fixed gas fire-extinguishing systems

q) Fixed water-based local application fire-extinguishing systems

r) Equivalent water-mist automatic sprinkler systems

s) Fixed fire-extinguishing systems for protection of galley cooking equipment

t) Portable fire-extinguishers

u) Non-portable and transportable extinguisher

v) Fire hoses

w) Portable foam applicators

x) Water and foam monitor

y) Foam proportioner/inductor

z) Sprinkler heads for automatic sprinkler systems

aa) Nozzles for fixed pressure water-spraying fire-extinguishing systems for machinery spaces, boiler rooms, ammunition spaces, deep fat cooking equipment fire-extinguishing systems, and spaces intended for the carriage of vehicles and for hangars

ab) Sensing heads for automatic fire alarm and fire detection systems

ac) Fixed fire detection and fire alarm systems ad) Flammable gas detection system

ae) Explosive mixture detecting systems

af) Portable explosive mixture detecting apparatus

ag) Fixed instruments for measuring the oxygen content for inert gas systems serving cargo tanks

ah) Portable instruments for measuring the oxygen content for inert gas systems serving cargo tanks

ai) Upholstered furniture, excluding the frame (for spaces in [2.29])

aj) Textile and non-textile materials suspended vertically, for example curtains (for spaces in [2.29])

ak) Bedding components (for spaces defined in [2.29])

al) Low location lighting systems

am)Inert gas systems serving cargo tanks

an) Fixed or mobile fire-extinguishing systems with twin agent.

The Society may request type approval for other materials, equipment, systems or products required by the applicable provisions for ships or installations of special types.

On the agreement of the Naval Authority, the Society may also issue a type approval certificate based on other standards recognised by the Naval Authority, and accept this certificate in equivalence of the type approval certificates issued for the classification of not military steel ships.

2 Definitions

2.1 A class divisions

2.1.1 A class divisions are those divisions formed by bulkheads and decks which comply with the following:

a) they shall be constructed of steel or other equivalent material

b) they shall be suitably stiffened

c) they shall be so constructed as to be capable of preventing the passage of smoke and flame to the end of the one-hour standard fire test

d) they shall be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

- class "A-60" : 60 minutes
- class "A-30" : 30 minutes
- class "A-15" : 15 minutes
- class "A-0" : 0 minutes

e) the Society shall require a test of a prototype bulkhead or deck in accordance with the “Fire Test Procedures Code” (see [2.17]) to ensure that it meets the above requirements for integrity and temperature rise.

2.1.2 The products indicated in Tab 2 may be installed without testing or approval. Accordingly to the relevant provisions of this chapter, alternative designs may also be accepted in equivalence.

Table 2 :

Classification	Product description
Class A-0 bulkhead	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 60 x 60 x 5 mm spaced at 600 mm or structural equivalent
Class A-0 deck	A steel bulkhead with dimensions not less than the minimum dimensions given below: • thickness of plating: 4 mm • stiffeners 95 x 65 x 7 mm spaced at 600 mm or structural equivalent
Class A-0 to A-60 door	A steel watertight door when used below the bulkhead deck.

2.2 Accommodation spaces

2.2.1 Accommodation spaces are those spaces used for public spaces, corridors, stairs, lavatories, cabins, offices, hospitals, secretariats, meeting rooms, pantries containing no cooking appliances and similar spaces.

2.2.2 Pantries or isolated pantries containing no cooking appliances may contain:

- toasters, microwave ovens, induction heaters and similar appliances each of them with a maximum power of 5 kW; and
- electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 2 kW and a surface temperature not above 150°C.

These pantries may also contain coffee machines, dish washers and water boilers with no exposed hot surfaces regardless of their power. A dining room containing such appliances should not be regarded as a pantry.

2.3 Aircraft deck

2.3.1 Aircraft deck is a purpose-built aircraft landing and take-off deck located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of aircrafts.

2.4 Ammunition spaces

2.4.1 Ammunition spaces are the spaces (integral magazines, independent magazines, small magazines, magazines lockers, magazines boxes and pyrotechnics lockers) used for the storage of ammunition (missiles, shells, mines, demolition stores, etc. charged with explosives, propellant, pyrotechnics, initiating compositions or nuclear, biological or chemical material) for use in conjunction with offensive, defensive, training or non operating purposes, including those parts of the weapons systems containing explosives. Lifting spaces for ammunition are to be considered as ammunition spaces for the purpose of this chapter.

2.5 B class divisions

2.5.1 B class divisions are those formed by bulkheads, decks, ceilings or linings which comply with the following:

a) they shall be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test

b) they shall have an insulation value such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:
   - class “B-15” : 15 minutes
   - class “B-0” : 0 minutes

c) they shall be constructed of approved non-combustible materials and all materials entering into the construction and erection of B class divisions shall be non-combustible, with the exception that combustible veneers may be permitted provided they meet the other relevant requirements of this Chapter

d) the Society shall require a test of a prototype bulkhead or deck in accordance with the Fire Test Procedures Code (see [2.17]) to ensure that it meets the above requirements for integrity and temperature rise.

2.5.2 In order to be defined as B class, a metal division is to have plating thickness not less than 3 mm when constructed of steel, and not less than 4 mm when constructed of light alloy, and is to have suitable stiffeners or beams.

Lower thickness may be accepted on a case by case basis provided structural calculation accounting also impacts, shocks and vibrations are carried out. Such calculation are to be submitted to the Society for approval.

2.6 Bulkhead deck

2.6.1 The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

2.7 C class divisions

2.7.1 C class divisions are constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet the other relevant requirements of this Chapter.

2.8 Cargo spaces

2.8.1 Cargo spaces are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.9 Closed ro-ro spaces

2.9.1 Closed ro-ro spaces are those ro-ro spaces which are neither open ro-ro spaces nor weather decks.

2.10 Closed vehicle spaces

2.10.1 Closed vehicle spaces are those vehicle spaces which are neither open vehicle spaces nor weather decks.

2.11 Continuous B class ceilings and linings

2.11.1 Continuous B class ceilings and linings are those B class ceilings and linings which terminate only at an A or B class division.

2.12 Control stations

2.12.1 Control stations are those spaces in which the ship's radio equipment for safety or ship navigation communication, the ship's main navigating equipment or the emergency source of power are located or where the fire recording or fire control equipment is centralized.

2.13 Damage control station

2.13.1 A damage control station is a control station (see [2.12]) in which the controls and indicators of functions and operations for fire, flooding, alarms, essential machineries, CBRN protection, intercommunication system, etc. as indicated in the present Rules, are centralized.

2.13.2 The list of the references for requirements concerning controls and indicators required to be centralized in the damage control stations as defined in [2.13.1] is indicated in Tab 3.

Table 3 : Controls and/or indicators required in damage control stations

Requirement reference	Related systems
Ch 4, Sec 2, [2.1.1]	Controls and indicators of ventilation systems and fire and smoke damper controls and monitoring
Ch 4, Sec 3, [8.2.1]	Fire detection alarms (see also Ch 4, Sec 3, [3.2.1]) and monitoring, position of fire doors, control and monitoring of ventilation fans
Ch 4, Sec 4, [2.1.3]	Controls for smoke release
Ch 4, Sec 5, [1.2.4]	Opening or closed position of any horizontal enclosure of stairway
Ch 4, Sec 5, [3.1.1], items d) and e)	Remote release of fire doors and status of the fire doors as appropriate
Ch 4, Sec 5, [5.1.1]	Position of fire doors leading to or from vehicle or ro-ro space
Ch 4, Sec 6, [3.2.1]	Controls for closing of ventilation openings and associated monitoring for spaces protected by fixed gas fire-extinguishing systems
Ch 4, Sec 6, [4.6.3]	Alarm of activation of any fixed water-based local application fire-extinguishing system
Ch 4, Sec 12, [2.1.2]	Controls of power ventilation systems for closed vehicle spaces and ro-ro spaces
Ch 4, Sec 12, [2.1.3]	Indication of any loss of capacity of the ventilation systems of close vehicle or ro-ro spaces
Ch 4, Sec 12, [4.1.2]	Position of discharge valves for scuppers in vehicle and ro-ro spaces when protected by water-based fire-extinguishing systems. Visual and audible alarm if fire-extinguishing system operating while the valves are closed
Ch 4, Sec 13, [5.1.4]	Visual and audible alarm in case of activation of local carbon dioxide systems
Ch 4, Sec 13, [6.1.2], items b) 4) and b) 5)	Controls and alarm for activation of high expansion foam fire-extinguishing system
Ch 4, Sec 13, [7.3.1], items l) and o)	Controls and alarms for equivalent water-based fire-extinguishing systems
Ch 4, Sec 13, [7.4.2], item e)	Means of control and monitoring of fixed thick water fire-extinguishing systems
Ch 4, Sec 13, [7.4.2], item i)	Indication of foam concentrate level for thick water systems
Ch 4, Sec 13, [8.2.1], item a)	Means of control of the valves connecting the sprinkler system to the fire main
Ch 4, Sec 13, [8.2.1], items h) and i) Ch 4, Sec 13, [8.3.5], item b) 1)	Visual and audible alarm in case of activation of any manual or automatic sprinkler section valve
Ch 4, Sec 13, [9.1.5], item a) 2)	Control panel for fire detection and fire alarm system
Pt E, Ch 1, Sec 4, [2.1.2], items b) 3) and d), Pt E, Ch 1, Sec 4, [2.3.4], item c), Pt E, Ch 1, Sec 4, [2.4.3]	For ships having the additional class notation **FFS**, position indicator for isolating valves, if provided and overboard discharge valves.
Pt E, Ch 8, Sec 3, [6] and **Tab 3**	For ships to be assigned the additional class notation **CBRN** or **CBRN-AIRBLAST RESISTANCE**, monitoring and control for the CBRN protection systems

2.14 Evacuation stations

2.14.1 The evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

2.15 Fire damper

2.15.1 Fire damper is a device installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of fire. In using the above definition the following terms may be associated:

a) automatic fire damper is a fire damper that closes independently in response to exposure to fire products

b) manual fire damper is a fire damper that is intended to be opened or closed by the crew by hand at the damper itself; and

c) remotely operated fire damper is a fire damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.16 Fire Safety Systems Code

2.16.1 Fire Safety Systems Code means the International Code for Fire Safety Systems as adopted by the Maritime Safety Committee of the IMO by Resolution MSC.98(73).

2.17 Fire Test Procedures Code

2.17.1 Fire Test Procedures Code means the "International Code for Application of Fire Test Procedures, 2010" (2010 FTP Code) as adopted by the Maritime Safety Committee of the IMO by resolution MSC.307(88), as may be amended by the IMO.

2.18 Flashpoint

2.18.1 Flashpoint is the temperature in degrees Celsius (closed cup test) at which the product will give off enough flammable vapour to be ignited, as determined by an approved flashpoint apparatus.

2.19 Fuel oil unit

2.19.1 The fuel oil unit is the equipment used for the preparation of fuel oil for delivery to an oil fired boiler, fuel cell systems or equipment used for the preparation for delivery of heated oil to an internal combustion engine and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 MPa.

2.19.2 "Fuel oil unit" includes any equipment used for the preparation and delivery of fuel oil, whether or not heated, to boilers (including inert gas generators) and engines (including gas turbines) at a pressure of more than 0,18 MPa. Fuel oil transfer pumps are not considered as oil fuel units.

2.20 Low flame spread

2.20.1 Low flame spread means the surface thus described will adequately restrict the spread of flame, this being determined in accordance with the “Fire Test Procedures Code (see [2.17])”.

2.20.2 Non-combustible materials are considered as low flame spread. However, due consideration will be given by the Society to the method of application and fixing.

2.21 Machinery spaces

2.21.1 Machinery spaces are all machinery spaces of category A and all other spaces containing propulsion machinery, boilers, fuel cells systems, fuel oil units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air conditioning machinery, and similar spaces, and trunks to such spaces.

2.22 Machinery spaces of category A

2.22.1 Machinery spaces of category A are those spaces and trunks to such spaces which contain:

a) internal combustion machinery used for main propulsion, or

b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW or

c) Any oil fired boiler or fuel oil unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc., or

d) gas turbines.

2.23 Main passageways

2.23.1 The main passageways are the corridors giving access to the evacuation stations and located on the same deck level.

2.24 Main vertical zones

2.24.1 Main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by A class divisions, the mean length and width of which on any deck does not in general exceed 40 m.

2.25 Non-combustible material

2.25.1 Non-combustible material is a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, this being determined in accordance with the "Fire Test Procedures Code (see [2.17]). Any other material is a combustible material.

2.25.2 In general, products made only of glass, concrete, ceramic products, natural stone, masonry units, common metals and metal alloys are considered as being non-combustible and may be installed without testing and approval.

2.26 Open ro-ro spaces

2.26.1 Open ro-ro spaces are those ro-ro spaces which are either open at both ends, or open at one end and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides (the total area of the space sides excludes the deck areas of the space).

2.27 Open vehicle spaces

2.27.1 Open vehicle spaces are those vehicle spaces which are either open at both ends, or open at one end and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deckhead or from above, having a total area of at least 10% of the total area of the space sides (the total area of the space sides excludes the deck areas of the space).

2.28 Public spaces

2.28.1 Public spaces are those portions of the accommodation which are used for halls, dining rooms, lounges recreational areas, ward rooms, brief rooms, print rooms and similar permanently enclosed spaces.

2.29 Rooms containing furniture and furnishings of restricted fire risk

2.29.1 Rooms containing furniture and furnishings of restricted fire risk are those rooms containing furniture and furnishings of restricted fire risk (whether cabins, public spaces, offices or other types of accommodation) in which:

a) all case furniture such as desks, wardrobes, dressing tables, bureaux, or dressers are constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm may be used on the working surface of such articles

b) all free-standing furniture such as chairs, sofas, or tables are constructed with frames of non-combustible materials

c) all draperies, curtains and other suspended textile materials have, to the satisfaction of the Society, qualities of resistance to the propagation of flame not inferior to those of wool having a mass of 0,8 kg/m^2, this being determined in accordance with the Fire Test Procedures Code (see [2.17])

d) all floor coverings have low flame-spread characteristics

e) all exposed surfaces of bulkheads, linings and ceilings have low flame-spread characteristics

f) all upholstered furniture has qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.17]), and

g) all bedding components have qualities of resistance to the ignition and propagation of flame, this being determined in accordance with the Fire Test Procedures Code (see [2.17]).

2.30 Ro-ro spaces

2.30.1 Ro-ro spaces are spaces containing vehicles using internal combustion engines with fuel in their tanks for their own propulsion or vehicles using electrical motors for their own propulsion where power cell loading can be proceeded inside the space; spaces containing landing barges or similar spaces in which vehicles can be loaded and unloaded with their own propulsion and helicopter hangars except small helicopter hangars containing not more than two helicopters without any refuelling facility inside the space.

2.31 Safety zones

2.31.1 Safety zones are damage control zone(s) delimited by watertight bulkheads and decks and fitted with independent ventilation systems and independent fire detection, fire fighting and sea water flooding fighting systems.

2.32 Service spaces

2.32.1 Service spaces are those spaces used for galleys, pantries containing cooking appliances, lockers, mail and specie rooms, storerooms, laundries, waste compactors, ironing rooms, laboratories, oven, workshops other than those forming part of the machinery spaces, and similar spaces and trunks to such spaces.

2.32.2

a) Main pantries and pantries containing cooking appliances may contain:
   1) toasters, microwave ovens, induction heaters and similar appliances each of them with a power of more than 5 kW; and
   2) electrically heated cooking plates and hot plates for keeping food warm each of them with a maximum power of 5 kW.
   These pantries may also contain coffee machines, dish washers and water boilers regardless of their power.

b) Spaces containing any electrically heated cooking plate or hot plate for keeping food warm with a power of more than 5 kW are to be regarded, for the purpose of Ch 4, Sec 5, as galleys.

2.33 Smoke confinement zone

2.33.1 A smoke confinement zone is a smoke sector consisting of a space or group of spaces, in which it is possible to confine and extract the smoke out of the ship.

2.34 Smoke damper

2.34.1 Smoke damper is a device complying with a recognized standard and installed in a ventilation duct, which under normal conditions remains open allowing flow in the duct, and is closed during a fire, preventing the flow in the duct to restrict the passage of smoke and hot gases. A smoke damper is not expected to contribute to the integrity of a fire rated division penetrated by a ventilation duct.

In using the above definition the following terms may be associated:

a) automatic smoke damper is a smoke damper that closes independently in response to exposure to smoke or hot gases
b) manual smoke damper is a smoke damper intended to be opened or closed by the crew by hand at the damper itself; and
c) remotely operated smoke damper is a smoke damper that is closed by the crew through a control located at a distance away from the controlled damper.

2.35 Standard fire test

2.35.1 The standard fire test is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods shall be in accordance with the Fire Test Procedures Code (see [2.17]).

2.36 Steel or other equivalent material

2.36.1 Where the words "steel or other equivalent material" occur, "equivalent material" means any non-combustible material which, by itself or due to insulation provided, had structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. aluminium alloy without magnesium and with appropriate insulation).

2.37 Vehicle spaces

2.37.1 Vehicle spaces are spaces intended for the carriage of vehicles such as tenders, rescue boats or operational boats having fuel in their tanks for their own propulsion but not using their own propulsion for being loaded or unloaded inside the space; or spaces containing vehicles using electrical motors for their own propulsion where no power cell loading is proceeded inside the space and small helicopter hangars containing not more than two helicopters and without any refuelling facility inside the space.

Note 1: Note 1: Where a connection to the helicopter refuelling piping is fitted inside the helicopter hangar, it is to be considered that the hangar does not fall under the definition of a "vehicle space" but is to be considered as a "ro-ro space" as defined in [2.30].

2.38 Vulnerability zones

2.38.1 Vulnerability zones are damage control zone(s), delimited by watertight bulkheads and decks, which may be specified by the Naval Authority according to its own vulnerability requirements.

2.39 Weather deck

2.39.1 Weather deck is a deck which is completely exposed to the weather from above and from at least two sides.

Section 2 Prevention of Fire and Explosion

1 Probability of ignition

1.1 Arrangements for fuel oil, lubrication oil, JP5-NATO (F44) and other flammable oils

1.1.1 Limitation in the use of oils as fuel

See Ch 1, Sec 1, [2.9].

1.2 Arrangements for fuel oil and JP5-NATO (F44)

1.2.1 See Ch 1, Sec 10.

1.3 Arrangements for lubricating oil

1.3.1 See Ch 1, Sec 10.

1.4 Arrangements for other flammable oils

1.4.1 See Ch 1, Sec 10.

1.5 Use of gaseous fuel for domestic purpose

1.5.1 The use of gaseous fuel for domestic purpose is not allowed.

1.6 Miscellaneous items of ignition sources and ignitability

1.6.1 Electric radiators

Electric radiators, if used, shall be fixed in position and so constructed as to reduce fire risks to a minimum. No such radiators shall be fitted with an element so exposed that clothing, curtains, or other similar materials can be scorched or set on fire by heat from the element.

1.6.2 Cellulose-nitrate based films

Cellulose-nitrate based films shall not be used for cinematograph installations.

1.6.3 Waste receptacles

All waste receptacles shall be constructed of non-combustible materials with no openings in the sides or bottom.

1.6.4 Insulation surfaces against oil penetration

In spaces where penetration of oil products is possible, the surface of insulation shall be impervious to oil or oil vapours.

1.6.5 Primary deck coverings

Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not readily ignite, this being determined in accordance with the Fire Test Procedures Code (see Ch 4, Sec 1, [2.17]).

1.7 Non-sparking fans

1.7.1 General

Where non-sparking fans are required by the Rules, the provisions of the following [1.7.2] and [1.7.3] are also to be complied with.

1.7.2 Design criteria

a) The air gap between the impeller and the casing is to be not less than 1/10 of the shaft diameter in way of the impeller bearing and in any case not less than 2 mm, but need not exceed 13 mm.

b) Protective screens with square mesh of not more than 13 mm are to be fitted to the inlet and outlet of ventilation ducts to prevent objects entering the fan housing.

1.7.3 Materials

a) Except as indicated in the fourth bullet of item c) below, the impeller and the housing in way of the impeller are to be made of spark-proof materials which are recognised as such by means of an appropriate test to the satisfaction of the Society.

b) Electrostatic charges, both in the rotating body and the casing, are to be prevented by the use of antistatic materials. Furthermore, the installation on board of ventilation units is to be such as to ensure their safe bonding to the hull

c) Tests may not be required for fans having the following material combinations:
- impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity
- impellers and housings of non-ferrous materials
- impellers of aluminium alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous material is fitted in way of the impeller
- any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm design tip clearance.

d) The following impeller and housing combinations are considered as sparking and therefore are not permitted:
- impellers of an aluminium alloy or a magnesium alloy and a ferrous housing, regardless of tip clearance
- housings made of an aluminium alloy or a magnesium alloy and a ferrous impeller, regardless of tip clearance
- any combination of ferrous impeller and housing with less than 13 mm design tip clearance.

e) Complete fans are to be tested in accordance either with the Society's requirements or national or international standards accepted by the Society.

2 Fire growth potential

2.1 Control of air supply and flammable liquid to the space

2.1.1 Application

The devices and means in [2.1.2] and [2.1.3] and fire and smoke dampers as required in the present Chapter, in addition to be operable as stated therein, are to be operable from a continuously manned damage control station.

2.1.2 Closing appliances and stopping devices of ventilation

a) The main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated.

The controls are to be easily accessible as well as prominently and permanently marked and are to indicate whether the shut-off is open or closed.

Ventilation inlets and outlets located at outside boundaries are to be fitted with closing appliances as required above and need not comply with Ch 4, Sec 5, [6.4.2].

b) Power ventilation of any space shall be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served.

c) All power ventilation, except for ventilation of machinery space and vehicle and ro-ro spaces and any alternative system which may be required under Ch 4, Sec 4, [1.1.1], shall be fitted with controls so grouped that all fans may be stopped from either of two separate positions which shall be situated as far apart as practicable. Controls provided for the power ventilation serving machinery spaces shall also be grouped so as to be operable from two positions, one of which shall be outside such spaces. Fans serving power ventilation systems to vehicle and ro-ro spaces shall be capable of being stopped from a safe position outside such spaces.

2.1.3 Means of control in machinery spaces

a) Means of control shall be provided for closure of openings in funnels which normally allow exhaust ventilation, and closure of ventilator dampers.

b) Means of control shall be provided for stopping ventilating fans. The means provided for stopping the power ventilation of the machinery spaces shall be entirely separate from the means provided for stopping ventilation of other spaces.

Note 1: The ventilation fans and the fire dampers serving a machinery room equipped with internal combustion engines taking their combustion air directly inside the room are not to be automatically stopped or closed, in order to prevent depressurization of the room.

c) Means of control shall be provided for stopping forced and induced draught fans, fuel oil transfer pumps including JP5 pumps, fuel oil unit pumps and other similar fuel pumps.

This applies also to lubricating oil pumps and oil separators (purifiers) except oily water separators.

d) The controls required in a) to c) above shall be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve.

In machinery spaces of category A, controls to close off ventilation ducts and pipes are to be installed with due regard to the hot gases produced by a fire in the space concerned.

e) The controls required in the above items a) to d) and in Ch 4, Sec 4, [2.1.2] and in Ch 4, Sec 5, [4.2.2] and the controls for any required fire-extinguishing system shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society.

Means for stopping the fuel oil transfer pumps including JP5 pumps required in item c) are also to be capable of being operated from the inside of the space in which the pumps are situated.

2.2 Fire protection materials

2.2.1 Use of non-combustible materials

a) Insulating materials

Except in refrigerated compartments, insulating materials shall be non-combustible. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings, for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

Cold service means refrigeration systems and chilled water piping for air conditioning systems.

b) Ceilings and linings

Except in refrigerated compartments, all linings, grounds, draught stops, ceilings shall be of non combustible materials. Partial bulkheads or decks used to subdivide a space for utility shall also be of non-combustible material.The floor plating of normal passageways in machinery spaces of category A is to be made of steel.

2.2.2 Use of combustible materials

a) General

"A", "B" or "C" class divisions, which are faced with combustible materials and combustible facing, moulding, decorations, veneers and paints, may be used in accordance with the provisions of b) to d) and [3] below.

b) Maximum calorific value of combustible materials

Materials used on surfaces, and covered by the requirement of item a), shall not have a calorific value exceeding 45 MJ/m^2 of the area for the thickness used.

This requirement does not apply to the surfaces of furniture fixed to the linings and the walls.

c) Total volume of combustible materials

When combustible materials are used as permitted in the previous item a), the total volume of combustible components (facings, mouldings, decorations and veneers in any accommodation and service space) shall not exceed a volume equivalent to 2,5 mm veneer on the combined area of the walls and ceiling linings.

Furniture fixed to linings and walls or decks need not be included in the calculation of the maximum calorific values and volume of combustible material.

d) Low flame spread characteristics of surfaces

The following surfaces shall have low flame spread characteristics in accordance with the Fire Test Procedures Code:

1) exposed surfaces (deck, ceilings and bulkheads) in all spaces of the ship
2) surfaces including grounds in concealed or inaccessible spaces in all spaces of the ship.

2.2.3 Furniture

Furniture shall not be permitted in corridors and in stairway enclosures forming escape routes.

3 Smoke generation potential and toxicity

3.1 General

3.1.1 The following equipment/materials shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the Fire Test Procedures Code, in all spaces of the ship:

- deck coverings and floor coverings
- veneers
- ceiling facings
- paints, varnishes and other finishes.

In general, non-combustible materials are considered to comply with the requirements for smoke generation potential and toxicity without further testing.

3.2 Primary deck coverings

3.2.1 Primary deck coverings, if applied within accommodation and service spaces and control stations, shall be of approved material which will not give rise to toxic or explosive hazards at elevated temperatures, this being determined in accordance with the Fire Test Procedures Code.

Section 3 Suppression of Fire and Explosion: Detection and Alarm

1 General

1.1 Minimum number of detectors

1.1.1 Where a fixed fire detection and fire alarm system is required for the protection of spaces other than those specified in [4.1.1], at least one detector complying with the requirements given in Ch 4, Sec 13 shall be installed in each such space.

2 Initial and periodical test

2.1 General

2.1.1 After installation the function of the fire detection system required in the relevant sections of this chapter shall be tested under varying conditions of ventilation and engine operation. However, the arrangement of the fire detectors is not required to be tested for each space but only for a representative sampling of spaces.

Each detector is to be individually tested.

2.1.2 The function of the detection system shall be periodically tested to the satisfaction of the Society by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond.

3 Protection of machinery spaces

3.1 Installation

3.1.1 A fixed fire detection and fire alarm system complying with the relevant provisions given in Ch 4, Sec 13 shall be installed in any machinery space (see Ch 4, Sec 1, [2.21.1]).

For fire detecting system for unattended machinery spaces, see also to Pt E, Ch 4, Sec 1.

3.1.2 Both smoke and flame detectors are to be installed in machinery spaces of category A.

3.2 Design

3.2.1 The fire detection system required in [3.1.1] shall be so designed and the detectors so positioned as to detect rapidly the onset of fire in any part of those spaces and under any normal conditions of operation of the machinery and variations of ventilation as required by the possible range of ambient temperatures. Except in recesses and in spaces of restricted height and where their use is specially appropriate, detection systems using only thermal detectors are not permitted.

The detection system shall initiate audible and visual alarms distinct in both respects from the alarms of any other system not indicating fire, in sufficient places to ensure that the alarms are heard and observed on the navigating bridge and in the damage control station(s) (see Ch 4, Sec 1, [2.13.1]and Ch 4, Sec 1, [2.31]).

4 Protection of accommodation, service spaces and control stations

4.1

4.1.1 A fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in service spaces, control stations and accommodation spaces, including corridors and stairways. Smoke detectors need not be fitted in private bathrooms.

4.1.2 In order to avoid any false alarm, installation of smoke detectors is not suitable for spaces where smoke, dust or fumes are regularly present and consequently special detectors adapted to the environmental conditions are to be selected. For instance, heat detectors may be installed in lieu of smoke detectors in galleys and laundries.

5 Protection of ammunition spaces

5.1 Application and general requirements

5.1.1 Ammunition spaces are to be provided with a fixed fire detection and alarm system complying with the requirements of Ch 4, Sec 13.

The detection system has to include smoke, temperature and temperature gradient detections.

Information concerning the surveillance and monitoring thresholds for temperature and temperature gradient is to be clearly indicated on the outside of main access points to these spaces and is to be available at a suitable continuously manned control position.

Smoke detectors are to be fitted in ammunition lifts trunks.

5.1.2 Sidescuttles may be fitted in the bulkheads or doors of ammunition spaces in order to provide clear view from outside of the space. In this case, the sidescuttle and its arrangement is to ensure that the strength and fire integrity of the division is maintained.

6 Manually operated call point

6.1 General requirements

6.1.1 Manually operated call points complying with the requirements of Ch 4, Sec 13, if required by the Naval Authority, shall be installed throughout the accommodation spaces, service spaces and control stations as follows:

- One manually operated call point shall be located at each exit of escape routes.
- Manually operated call points shall be readily accessible in the corridors of each deck so that no part of the corridor is more than 20 m from a manual call point.

Consideration is to be given to the installation of additional manually operated call points in spaces where high fire risk operations are conducted.

7 Inspection hatches and radiotelephone apparatus

7.1 Inspection hatches

7.1.1 The construction of ceiling and bulkheading shall be such that it will be possible, without impairing the efficiency of the fire protection, for the fire patrols to detect any smoke originating in concealed and inaccessible places.

7.2 Radiotelephone apparatus

7.2.1 Each member of the fire patrol shall be provided with a two-way portable radiotelephone apparatus.

7.2.2 Two-way portable telephone apparatuses are to be audible from most parts of the vessel. As a minimum, they are to be audible in areas where the fire patrol make their rounds such as key box locations and the routes specified on fire patrol check lists. If necessary, extra antennas are to be fitted to obtain effective communication.

8 Receiving systems of fire alarm

8.1 Control panel

8.1.1 The control panel of a fixed fire detection and fire alarm system shall be designed on the fail-safe principle, e.g. an open detector circuit shall cause an alarm condition.

8.2 Position of detection alarms, remote control and control panels

8.2.1 Ships shall have the detection alarms for the systems required in this Section centralized in a damage control stations. In addition, controls for shutting down the ventilation fans and, when remote closing appliances are provided for fire doors, the controls of those fire doors for remote closing of the fire doors and shutting down the ventilation fans shall be centralized in the same location. The ventilation fans shall be capable of reactivation by the crew at the continuously manned damage control stations. The control panels in the damage control stations shall be capable of indicating open or closed positions of fire doors, if any, closed or off status of the detectors, alarms and fans. The control panel shall be continuously powered and should have an automatic change-over to standby power supply in the event of loss of normal supply. The control panel shall be powered from at least two electrical switchboards which cannot be put out of service at the same time by any event. The separated feeders shall be so arranged as to avoid galleys, machinery spaces, ammunition spaces and other high fire risk spaces except in so far as it is necessary to reach the appropriate switchboards.

Section 4 Suppression of Fire and Explosion: Control of Smoke Spread

1 Protection of control stations outside machinery spaces

1.1 General

1.1.1 Practicable measures shall be taken for control stations, as defined in Ch 4, Sec 1, [2.12.1], outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained so that, in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply shall be provided and air inlets of the two sources of supply shall be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. At the discretion of the Society, such requirements need not apply to control stations situated onto, an open deck or where local closing arrangements would be equally effective.

1.1.2 Equally effective local closing arrangements means that in the case of ventilators these are to be fitted with fire dampers or smoke dampers which are to be easily closed within the control station in order to maintain the absence of smoke in the event of fire.

2 Release of smoke from machinery spaces

2.1 General

2.1.1 Suitable arrangements shall be made to permit the release of smoke in the event of fire, from the space to be protected.

Usual ventilation systems are acceptable as arrangements for permitting the release of smoke.

2.1.2 Means of control shall be provided for permitting the release of smoke and the controls shall be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve.

2.1.3 The controls of [2.1.2] shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society. Furthermore controls of item [2.1.2] shall be also situated in the damage control station(s).

3 Draught stops

3.1 General

3.1.1 Air spaces enclosed behind ceilings, panelling or linings shall be suitably divided by close-fitting draught stops not more than 14 m apart. In the vertical direction, such enclosed air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

4 Smoke extraction system

4.1 General

4.1.1 The purpose of the smoke extraction system is to confine the smoke during the fire-fighting operations and to extract out of the ship the smoke produced by a fire after the fire-fighting operations.

The ship is to be divided in smoke confinement zones (SCZ) in which the smoke is confined.

The smoke extraction after the fire-fighting operations shall be proceeded by means of portable, semi-fixed or fixed equipment.

The use of the machinery space ventilation system can be considered for smoke clearance during the fire-fighting operations provided that, at the end of the operation, the smoke to be extracted is not confined in any other space.

Drawings dealing with smoke extraction system are submitted to the Society for information.

4.2 Smoke confinement zones

4.2.1 A smoke confinement zone is not to extend out from a main vertical zone.

4.2.2 The smoke confinement zone is to be built within the existing A class bulkheads and decks as defined in Ch 4, Sec 5, including shell and hull boundaries.

Under the watertight deck, watertight sections constitute smoke confinement zones.

All enclosed spaces of the ship are to be included in the smoke confinement zones.

When it is not practical and to the satisfaction of the Society, individual spaces having direct access to the exterior may be excluded from the smoke confinement zones.

4.2.3 When a bulkhead acting as a boundary of a smoke confinement zone is fitted with a door, this door is to be provided with a curtain made of non combustible materials in order to contain the smoke in the smoke confinement zone when the door is opened.

It is not necessary to provide curtains on doors opening to the exterior of the ship.

4.2.4 When a deck acting as a boundary of a smoke confinement zone is fitted with a deck panel, this panel is to be provided with a blanket made of non combustible materials in order to contain the smoke in the smoke confinement zone when the panel is opened.

It is not necessary to provide curtains on panels opening to the exterior of the ship.

4.2.5 Ventilation ducts or balancing openings penetrating the boundaries of smoke confinement zones are to be provided with smoke dampers.

4.3 Means of smoke extraction

4.3.1

a) General

1) Above the highest waterline, some exterior openings on the ship shell side are to be provided to exhaust the smoke out of the ship. At least one such opening is to be provided for each main vertical zone.

Note 1: If the part of the ship located forward the collision bulkhead is a main vertical zone, the above requirement need not be complied with in this main vertical zone.

2) It is to be provided a sufficient number of portable flexible exhaust ducts of a sufficient length which can be easily connected to the fixed or portable exhaust fans and connected the ones to the others in order to conduct smoke from the smoke confinement zone to the exterior of the ship. In any case, the portable flexible exhaust ducts are to have a length of not less than the moulded depth of the ship.

3) Where the portable flexible exhaust ducts can not be connected directly to the exterior openings mentioned in 1) above, there shall be provided some fixed exhaust ducts upstream the exterior openings. These fixed exhaust ducts are to comply with the applicable requirements of Ch 4, Sec 5, [6].

4) There is to be provided at least a portable or fixed smoke exhaust fan for each safety zone. The number and position of the fixed or portable exhaust fans is to be such that in no part of the smoke confinement zones, it is necessary to use in length more than 30 m of portable flexible ducts.

5) Where the smoke to extract from a smoke confinement zone can contain any explosive vapours, the impeller of the fan is to be of a non-sparking type.

6) Fixed or portable exhaust fans and their portable flexible or fixed exhaust ducts are to be suitable for smoke temperature greater than 300°C. They are to be of a type easy to operate after the fire-fighting operations. The size of the portable flexible exhaust ducts is to be such as not to prevent from handling other safety equipment

b) Additional requirements

In machinery spaces of category A and in ro-ro spaces, the exhaust fans are to be sized such that the entire volume within the space can be exhausted in less than 10 minutes.

Section 5 Suppression of Fire and Explosion: Containment of Fire

1 Thermal and structural boundaries

1.1 Thermal and structural division

1.1.1 The ship shall be subdivided into spaces by thermal and structural divisions having regard to the fire risk of the space.

1.2 Main vertical zones and horizontal zones

1.2.1

a) The interior of the hull, superstructure and deckhouses shall be divided (see Ch 4, Sec 1, [2]) into main vertical zones by A-30 class divisions unless the requirements of Tab 1 and Tab 2 are more stringent. Steps and recesses shall be kept to a minimum, but where they are necessary, they shall have the same fire integrity of the vertical limits of the main vertical zones. Where a category (5), (9) or (10) space defined in item b) of [1.2.3] is on one side or where fuel or diesel oil or JP 5 NATO (F44) tanks or water capacities are on both sides of the division, the standard can be reduced to A-0.

b) As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck shall be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck. The length and width of the main vertical zones may be extended to a maximum of 50 m to the satisfaction of the Society, as it may be necessary in order to bring the ends of the main vertical zones to coincide with watertight subdivision bulkheads or in order to accommodate a large space extending for the whole length of the main vertical zone, provided the total area of the main vertical zone is not greater than 1600 m^2 on any deck.

   The length or width of a main vertical zone is the maximum distance between the furthermost points of the bulkheads bounding it.

   If a stairway serves two main vertical zones, the maximum length of any one main vertical zone need not be measured from the far side of the stairway enclosure. In this case all boundaries of the stairway enclosure are to be insulated as main vertical zone bulkheads and access doors leading into the stairway are to be protected from the two outside zones.

Note 1: Locally, when the length or the width of one main vertical zone is more than 50 m and the total area is more than 1600 m^2, following the procedure mentioned in Ch 4, Sec 11, the Society may accept an alternative arrangement provided that additional measures are taken for the escape and fire-fighting.

Note 2: If the part of the ship located forward of the collision bulkhead forms one main vertical zone, this main vertical zone need comply neither with the requirements of Ch 4, Sec 4, [4.3.1], item a) 1), neither with those of [6.3.7] of the present Section or of Ch 4, Sec 6, [8.2].

c) Such bulkheads shall extend from deck to deck and to the shell or other boundaries.

d) Not withstanding the provisions of Ch 4, Sec 12, on spaces designed for special purpose, such as vehicle and ro-ro spaces where the provisions of main vertical zone bulkheads would defeat the purpose for which such spaces are intended, equivalent means for controlling and limiting a fire shall be substituted and specifically approved by the Society.

1.2.2 Bulkheads within a main vertical zone and within a safety zone

a) All bulkheads which are not required to be A class divisions shall be at least B class or C class divisions as prescribed in Tab 1 and Tab 2.

b) Bulkheads required to be B class divisions shall extend from deck to deck and to the shell or other boundaries. However, where continuous B class ceiling or lining is fitted on both sides of a bulkhead which is at least of the same resistance as the adjoining bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

1.2.3 Fire integrity of bulkheads and decks

a) In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned in [1.2.1] and [1.2.2], the minimum fire integrity of all bulkheads and decks shall be as prescribed in Tab 1 and Tab 2. Where, due to any particular structural arrangements in the ship, difficulty is experienced in determining from the Tables the minimum fire integrity value of any divisions, such values shall be determined to the satisfaction of the Society.

b) The following requirements govern application of the tables:

   1) Tab 1 and Tab 2 shall apply, respectively, to the bulkheads and decks separating adjacent spaces.

   2) For determining the appropriate fire integrity standards to be applied to boundaries between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) to (15) below. Where the contents and use of a space are such that there is a doubt as to its classification for the purpose of this Section, it shall be treated as a space within the relevant category having the most stringent boundary requirements. Smaller, enclosed rooms within a space that have

less than 30% communicating openings to that space are considered separate spaces. The fire integrity of the boundary bulkheads and decks of such smaller rooms shall be as described in Tab 1 and Tab 2. The title of each category is intended to be typical rather than restrictive. The number in parentheses preceding each category refers to the applicable column or row in the tables.

- (1) Control stations and equivalent spaces

  Space containing damage control equipment.

  Spaces containing emergency sources of power and lighting, if any (see also Ch 2, Sec 3, [2.3.1]).

  Wheelhouse and chartroom.

  Spaces containing the ship's radio equipment for safety or ship navigation communication.

  Fire-extinguishing rooms, fire control rooms and fire recording stations.

  Control room for propulsion machinery when located outside the propulsion machinery space.

  Spaces containing centralized fire alarm equipment.

  Spaces containing network cabinets for computer and control centers, electronic cabinet systems or control computers managing data related to the control of the ship.

  Spaces containing centralized emergency public address system stations and equipment.

  For the purpose of this section, the spaces normally manned containing naval systems for detection, command, defence, offence, communication, combat (e.g. COC) or weapon control/operation; aviation control room; bridge for command, defence, operation or planning rooms and spaces containing centralised ship's operation equipment (e.g. COP) are assimilated as a control station.

  In addition, the Naval Authority may specify a list of additional spaces judged critical for naval operations, to be considered as control stations.

- (2) Stairways

  Interior stairways, lifts, totally enclosed emergency trunks and escalators (other than those wholly contained within the machinery spaces or ammunition spaces or ro-ro spaces) for persons and enclosures thereto.

  In this connection a stairway which is enclosed at only one level shall be regarded as part of the space from which it is not separated by a fire door. Interior emergency exit ladders.

- (3) Corridors

  Lobbies and corridors including recess to punctually accommodate safety equipment.

Note 1: Electrical distribution boards may be located within accommodation spaces including corridors and stairway enclosures, without the need to categorize the space, provided no provision is made for storage.

- (4) Evacuation stations and external escape routes

  Survival craft stowage area.

  Open deck spaces and passageway forming lifeboat and liferaft embarkation and lowering stations.

  External stairs and open decks used for escape routes.

  The ship’s side to the waterline in the lightest condition including superstructures and deckhouse sides situated below the evacuation areas.

  Internal and external assembly stations.

  The Note 2 to Note 3 of the category (5) below are also applicable for this category (4).

- (5) Open deck spaces

  Open deck spaces other than those defined in category (4) above.

  Open deck spaces for the stowage of any embarkation such as tender or operational boat excluding rescue boats, lifeboats and liferafts.

  Air spaces (the spaces outside superstructures and deckhouses).

Note 2: Non-enclosed spaces naturally ventilated can be assimilated to an open deck.

Note 3: Non-enclosed spaces are spaces for which their boundaries are provided with permanent openings with the exterior, reaching a minimum area of at least 30% of the total area of their boundaries adjacent to the exterior.

Note 4: The containers for the storage of the combustible oil used for the embarkations are allowed to be located in the category (4) and (5) spaces as far as practical of the embarkations.

Note 5: In case weapon systems are installed on open deck, specific requirements regarding structural fire protection and fire fighting to be applied to the weapon system area and adjacent spaces, may be defined by the Naval Authority.

In absence of specific requirement from Naval Authority, these areas are considered as open deck spaces.

- (6) Accommodation spaces of minor fire risk

  Cabins containing furniture and furnishings of restricted fire risk.

  Offices and dispensaries containing furniture and furnishings of restricted fire risk.

  Public spaces and berthing spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than 50 m^2.

- (7) Service spaces and accommodation spaces of moderate fire risk

  Spaces as in category (6) above but containing furniture and furnishings of other than restricted fire risk.

Public spaces and berthing spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m² or more.

Laboratories in which flammable liquids are not stowed.

Isolated lockers and stores in accommodation spaces in which flammable liquids are not stored and having a deck area of less than 4 m².

Cleaning gear lockers (in which flammable liquids are not stowed).

Pharmacies containing medicines in quantity not exceeding the daily use.

Operating rooms and other rooms for such purpose.

- (8) Accommodation spaces of greater fire risk

  Public and berthing spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m² or more.

- (9) Sanitary and similar spaces

  Communal sanitary facilities, showers, baths, water closets, etc.

  Small laundries.

  Drying rooms having a deck area of 4 m² or less.

  Isolated pantries containing no cooking appliances in accommodation spaces.

  Private sanitary facilities shall be considered a portion of the space in which they are located.

- (10) Tanks, voids and auxiliary machinery spaces having little or no fire risk

  Water tanks forming part of the ship's structure.

  Voids and cofferdams.

  Auxiliary machinery spaces which do not contain machinery having a pressure lubrication system and where storage of combustibles is prohibited, such as:

  - ventilation and air-conditioning rooms
  - windlass room
  - steering gear room
  - stabilizer equipment room
  - electric propulsion motor room having in the aggregate a total power output of not more than 1500 kW
  - rooms containing section switchboards and purely electrical equipment other than oil-filled electrical transformers (above 10 kVA)
  - shaft alleys and pipe tunnels
  - spaces for pumps and refrigeration machinery (not handling or using flammable liquids).

  Technical galleries not serving as an escape route and not giving direct access to accommodation spaces, service spaces, control stations, vehicle and ro-ro spaces.

  Closed trunks serving the spaces listed above.

  Other closed trunks such as pipe and cable trunks.

- (11) Auxiliary machinery spaces and other similar spaces of moderate fire risk

  Refrigerated chambers.

  Fuel oil and JP5 tanks (where installed in a separate space with no machinery).

  Shaft alleys and pipe tunnels allowing storage of combustibles.

  Auxiliary machinery spaces as in category (10) which contain machinery having a pressure lubrication system or where storage of combustibles is permitted and rooms containing electrical motors having in the aggregate a total power output of more than 1500 kW.

  Pump rooms for the internal combustion machinery used for the purpose onboard the ship (such as, for propulsion, electrical power generation, etc., and excluding the internal combustion machinery of the vehicles carried onboard).

  Spaces containing oil-filled electrical transformers (above 10 kVA).

  Spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines of power output up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.

  Vehicle spaces not forming a main horizontal zone.

  Rooms containing main low voltage and high voltage switchboards (above 600kW).

  Closed trunks serving the spaces listed above.

- (12) Machinery spaces of category A and equivalent spaces of high fire risk

  Machinery spaces as defined in Ch 4, Sec 1, [2.22.1].

  Auxiliary machinery spaces other than those in categories (10) and (11) which contain internal combustion machinery or other oil-burning, heating or pumping units.

  Main galleys and annexes.

Opened trunks to the spaces listed above.

Storage tanks for oil having a flash-point below 60°C.

Aircraft refuelling stations, JP5 pump rooms and other pump rooms used for the refuelling of vehicles carried onboard.

Note 6: If fire insulation is required above a machinery space of category A, this fire insulating material is not to be provided above the steel deck like for a floating floor but under the steel deck on the stiffened side of the steel deck.

- (13) Service spaces of high fire risk

  Main pantries not annexed to galleys as defined in Ch 4, Sec 1, [2.32.2].

  Garbage rooms.

  Main laundries.

  Drying rooms having an area greater than 4 m^2.

  Workshops other than those forming part of machinery spaces.

  Isolated lockers and store rooms having a deck area of more than 4 m^2 in which flammable liquids are not stowed.

- (14) Special purpose spaces

  Laboratories, isolated lockers and store rooms in which flammable liquids are stowed.

  Pharmacies other than those defined in (7).

  Paint lockers.

  Ro-ro spaces not forming a main horizontal zone.

  Aircraft or helicopter decks.

- (15) Ammunition spaces and other equivalent spaces

  Ammunition spaces as defined in Ch 4, Sec 1, [2.4.1] and ammunition transfer chambers and lifts to such spaces.

3) The Society shall determine in respect of category (5) spaces whether the insulation values in Tab 1 shall apply to ends of deckhouses and superstructures, and whether the insulation values in Tab 2 shall apply to weather decks. In no case shall the requirements of category (5) necessitate enclosure of spaces which in the opinion of the Society need not be enclosed.

1.2.4 Protection of stairways and lifts in accommodation spaces, service spaces and control stations

a) Stairways and lift trunks which penetrate more than one single deck are to be within enclosures formed of "A" class divisions, in accordance with Tab 1 and Tab 2, and be protected by self-closing doors at all levels.

b) A stairway connecting only two decks need not be enclosed, provided the integrity of the deck is maintained by proper bulkheads or self-closing doors in one `tweendeck space. When a stairway is closed in one `tweendeck space, the stairway enclosure is to be protected in accordance with Tab 2.

   The door provided at this stairway enclosure is to be of the self-closing type.

c) For the application of items a) and b), a deck fitted with a deck hatch at a stairway penetration is not considered to be penetrated by the stairway provided the deck hatch meets the following requirements:

   1) The hatch has the same fire integrity as the deck on which it is fitted.

   2) Indication is provided at the fire door indicator panel in the continuously manned damage control station whether the deck hatch is opened or closed.

   3) An instruction is given to the crew that the hatch is to be closed in case of fire detection in the main fire zone containing the deck hatch.

   4) The hatch is to be fitted with a notice indicating the normal position of the hatch at sea, to the satisfaction of the Society.

Note 1: The arrangement of item c) will not be accepted if the deck forms the boundary of a main vertical zone.

d) Lift trunks shall be so fitted as to prevent the passage of smoke and flame from one ‘tweendeck to another and shall be provided with means of closing so as to permit the control of draught and smoke. Machinery for lifts located within the stairway enclosures shall be arranged in a separate room, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts which open into spaces other than corridors, public spaces, ro-ro spaces, stairways and external areas shall not open into stairways included in the means of escape.

1.2.5 Protection of ammunition spaces

Fire insulation for the boundaries of ammunition spaces is to be installed outside of the ammunition spaces as much as possible.

Table 1 : Bulkheads not bounding neither vertical zones nor horizontal zones nor safety zones

SPACES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces (1)	A-0 [e]	A-0	A-0	A-0	A-0	A-0	A-30 [c]	A-30 [c]	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Stairways (2)		A-0 [d]	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-15	A-30	A-15	A-30	A-30
Corridors (3)			C	A-0	A-0	B-0	B-0 [a]	B-0	B-0	A-0	A-15	A-30	A-15	A-30	A-30
Evacuation stations and external escape routes (4)				*	A-0	A-0	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-60	A-30
Open deck spaces (5)					*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [b]
Accommodation spaces of minor fire risk (6)						C	C [a]	C	C	A-0	A-15	A-30	A-0	A-15	A-30
Services spaces and accommodation spaces of moderate fire risk (7)							C [a], [d]	C [a]	C [a]	A-0	A-15	A-60	A-15	A-30	A-30
Accommodation spaces of greater fire risk (8)								C	C	A-0	A-30	A-60	A-15	A-60	A-30
Sanitary and similar spaces (9)									C	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, void and auxiliary machinery spaces having little or no fire risk (10)										A-0 [d]	A-0	A-0	A-0	A-0	A-30 [b]
Auxiliary machinery spaces and other similar spaces of moderate fire risk (11)											A-0 [d]	A-0	A-0	A-0	A-30
Machinery spaces of category A and equivalent spaces of high fire risk (12)												A-0 [d]	A-60	A-60	A-60
Service spaces of high fire risk (13)													A-0 [d]	A-30	A-30
Special purpose spaces (14)														A-0	A-30
Ammunition spaces and other equivalent spaces (15)															A-30

[a] : If a laboratory, an isolated locker or a store having deck area of more than 4 m^2 and not containing liquid is concerned, a fire division of at least “A-0” fire class standard is required.

[b] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only “A-0” fire class standard is required.

[c] : If the ship is provided with the additional class notation **FIRE** the fire class standard can be reduced to “A-0” fire class standard.

[d] : Where adjacent spaces are in the same numerical category and subscript [d] appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g. a galley next to a galley does not require a bulkhead but a galley next to a paint room requires an “A-0” bulkhead.

[e] : Bulkheads separating the wheelhouse, chartroom and radio room from each other can have only a “B-0” rating.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of “A” class standard. However, where a deck, except an open deck of category (5), is penetrated for the passage of electrical cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

Note 1: (to be applied to Tab 1 and Tab 2, as appropriate).

Table 2 : Decks not forming steps in main vertical zones nor bounding horizontal zones nor safety zones

SPACE below	SPACE above														
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Control stations and equivalent spaces (1)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-60	A-15	A-30	A-30
Stairways (2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-0	A-30
Corridors (3)	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-0	A-30
Evacuation stations and external escape routes (4)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Open deck spaces (5)	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30 [b]
Accommodation spaces of minor fire risk (6)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-15	A-30
Services spaces and accommodation spaces of moderate fire risk (7)	A-30 [c]	A-0	A-0	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-30
Accommodation spaces of greater fire risk (8)	A-30 [c]	A-15	A-0	A-30	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-30
Sanitary and similar spaces (9)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30
Tanks, void and auxiliary machinery spaces having little or no fire risk (10)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-0	A-30 [b]
Auxiliary machinery spaces and other similar spaces of moderate fire risk (11)	A-60 [f]	A-15 [f]	A-15 [f]	A-60 [f]	A-0	A-0	A-0	A-0	A-0	A-0	A-0 [d]	A-0	A-0	A-0	A-30 [f]
Machinery spaces of category A and equivalent spaces of high fire risk (12)	A-60	A-60	A-60	A-60	A-0	A-60	A-60	A-60	A-0	A-0	A-30	A-30 [d]	A-60	A-60	A-60
Service spaces of high fire risk (13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-30	A-0	A-0	A-0	A-0	A-30	A-30
Special purpose spaces (14)	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-30	A-30	A-0	A-30
Ammunition spaces and other equivalent spaces (15)	A-30	A-30	A-30	A-30	A-30 [b]	A-30	A-30	A-30	A-30	A-30 [b]	A-30	A-60	A-30	A-30	A-30

[a] : If a laboratory, an isolated locker or a store having deck area of more than 4 m² and not containing liquid is concerned, a fire division of at least “A-0” fire class standard is required.

[b] : When an ammunition space is adjacent or above a water tank, or adjacent to the shell of the ship below the lowest possible waterline, only “A-0” fire class standard is required.

[c] : If the ship is provided with the additional class notation **FIRE** the fire class standard can be reduced to “A-0” fire class standard.

[d] : Where adjacent spaces are in the same numerical category and subscript [d] appears, a bulkhead of the rating shown in the tables is only required when the adjacent spaces are for a different purpose (e.g. a galley next to a galley does not require a bulkhead but a galley next to a paint room requires an “A-0” bulkhead.

[e] : Bulkheads separating the wheelhouse, chartroom and radio room from each other can have only a “B-0” rating.

[f] : Where fuel oil and JP5 fuel tanks (where installed in a separate space with no machinery) category (11) are located below, if permitted, the deck is only required to be of "A-0" class integrity.

* : Where an asterisk appears in the tables, the division is required to be of steel or other equivalent material but is not required to be of “A” class standard. However, where a deck, except an open deck of category (5), is penetrated for the passage of electrical cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

Note 1: The notes of Tab 1 apply to Tab 2, as appropriate.

2 Penetration in fire-retarding divisions and prevention of heat transmission

2.1 Penetrations in A class divisions

2.1.1 Unless otherwise specified, where A class divisions are penetrated, such penetrations shall be tested in accordance with the Fire Test Procedure Code.

2.1.2 A ventilation duct penetrating an A class division accordingly to the provisions of [6.3] below need not to be tested.

2.1.3 A pipe penetrating an A class division according to the provisions of [2.3.1] need not be tested.

2.1.4 Where A class divisions are penetrated by electrical cables, such penetrations shall always be tested in accordance with the Fire Test Procedure Code.

2.1.5 Specific requirements for shaft line penetrations in A-class divisions are detailed in Ch 1, Sec 7, [3.1.4].

2.2 Penetrations in B class divisions

2.2.1 Where B class divisions are penetrated for the passage of electrical cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements shall be made to ensure that the fire resistance is not impaired.

2.2.2 Where B class division divisions are penetrated for the passage of ventilation ducts, the provisions of [6.3] below are to be complied with.

2.2.3 Where B class ceilings are penetrated for the fitting of ventilation units, the assembly of the ventilation unit with the ceiling is to be tested in accordance with the Fire Test Procedure Code.

2.2.4 A pipe made of steel or cooper that penetrates B class divisions need not be tested. A pipe penetrating a B class division according to the provisions of [2.3.1] need not be tested. Other pipe penetrations through B class divisions shall be tested in accordance with the Fire Test Procedure Code.

2.2.5 Where B class divisions are penetrated by electrical cables, such penetrations shall always be tested in accordance with the Fire Test Procedure Code.

2.3 Pipes penetrating A or B class divisions

2.3.1 Where A or B class divisions are penetrated by pipes, such penetrations shall be tested in accordance with the Fire Test Procedures code. However the following arrangement, if adequately justified and installed, may be dispensed with the fire test:

a) In case of a pipe penetrating an A class fire division:
   1) the pipe is made of steel or other equivalent material, and
   2) the insulation provided for retarding the heat transmission is extended up to 450 mm from the fire division, and
   3) if the free cross-sectional area of the pipe is equal to or less than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 3 mm and a length of at least 200 mm (preferably divided into 100 mm on each side of the fire division) and there are no openings
   4) if the free cross-sectional area of the pipe is more than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 3 mm and a length of at least 900 mm (preferably divided into 450 mm on each side of the fire division) and there are no openings.

Note 1: For the provisions of this item, copper may be accepted as equivalent to steel, to the satisfaction of the Society.

b) In case of a pipe other than steel or copper penetrating a B class fire division:
   1) if the free cross-sectional area of the pipe is equal to or less than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 1,8 mm and a length of at least 600 mm (preferably divided into 300 mm on each side of the fire division)
   2) if the free cross-sectional area of the pipe is more than 0,02 m^2, the pipe penetration is fitted with a sheet sleeve made of steel or other equivalent material having a thickness of at least 1,8 mm and a length of at least 900 mm (preferably divided into 450 mm on each side of the fire division)
   3) the pipe is connected to the ends of the sleeve by flanges or coupling; or any clearance between pipe and sleeve is made tight by means of non combustible or other suitable material.

c) Uninsulated metallic pipes are of a material having a melting temperature which exceeds 950°C for A-0 and 850°C for B-0 class divisions.

Note 2: The term “free cross-sectional area” means, even in the case of a pre-insulated pipe, the area calculated on the basis of the inner diameter of the pipe.

2.3.2 Where the Society may permit the conveying of oil or combustible liquids through accommodation and service spaces, the pipes conveying oil or combustible liquids shall be of a material approved by the Society having regard to the fire risk. The pipes conveying oil or combustible liquids shall not pass through ammunition spaces.

2.4 Prevention of heat transmission

2.4.1 In approving structural fire protection details, the Society shall have regard to the risk of heat transmission at intersections and terminal points of required thermal barriers. The insulation of a deck or a bulkhead shall be carried past the penetration, intersection or terminal point for a distance of at least 450 mm in the case of steel and aluminum structures. If a space is divided with a deck or a bulkhead of A class standard having insulation of different values, the insulation with the higher value shall continue on the deck or bulkhead with the insulation of the lesser value for a distance of at least 450 mm.

3 Protection of openings in fire-resisting divisions

3.1 Openings in bulkheads and decks

3.1.1 Openings in A class divisions

a) Except for hatches between store and the weather decks, all openings shall be provided with permanently attached means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted.

b) The construction of all doors and door frames, as well as horizontal hatches and hatch coaming, in A class divisions, with the means of securing them when closed, shall provide resistance to fire as well as to the passage of smoke and flame equivalent to that of the bulkhead or deck in which the doors or hatches are situated, this being determined in accordance with the Fire Test Procedures Code. Such doors and door frames, as well as horizontal hatches and hatch coaming, shall be constructed of steel or other equivalent material. Watertight doors and hatches need not be qualified for fire resistance when intended for use below the bulkhead deck. Alternative designs may also be accepted subject to the provisions of this Chapter.

Note 1: Horizontal watertight hatches located within the bulkhead deck can be assimilated to below the bulkhead deck.

Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 12 mm. A non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

c) The maximum force needed to open the hatch covers is not to exceed 150 N. A suitable device on the hinge side to reduce the force needed for opening is acceptable.

d) Fire doors in main vertical zone bulkheads, galley boundaries and stairway enclosures other than watertight doors and those which are normally locked, shall satisfy the following requirements:

1) the doors shall be self-closing or normally closed and be capable of closing against an angle of inclination of up to 3,5° opposing closure

Note 2: A normally closed door is a door kept closed, used if authorized by the notice affixed on the door, and closed again after use.

2) the doors shall be fitted with a notice to show if the door is normally open, normally closed or permanently closed.

3) The doors, except those for emergency escape trunks, shall be capable of remote release from the continuously manned damage control station, either simultaneously or in groups, and shall be capable of release also individually from a position near the door. Release switches shall have an on-off function to prevent automatic resetting of the system.

Note 3: In case it is necessary to keep some doors in open position for smoke extraction, means of re-activation of the release switches is to be provided for this group of doors only, independently of other fire doors.

4) hold-back hooks not subject to remote release from the continuously manned damage control station are prohibited.

5) indication shall be provided at the fire door indicator panel in the continuously manned damage control station whether the door is opened or closed.

e) In any case horizontal hatches, exterior doors and machinery spaces doors shall be provided with a system signalling their closed position in the continuously manned damage control station.

Note 4: Weathertight exterior doors of spaces not opening onto other spaces need not be provided with such indication system.

f) The requirements for A class integrity of the outer boundaries of a ship shall not apply to glass partitions, windows. The requirements for A class integrity of the outer boundaries of the ship shall not apply to exterior doors and hatches, except for those in superstructures and deckhouse facing life-saving appliances, embarkation and external assembly station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

g) Except for watertight doors, weathertight doors (semi-watertight doors), doors leading to the open deck and doors which need to be reasonably gas-tight, all A class doors located in stairways, public spaces, main vertical zone bulkheads and limit of safety zones shall be equipped with a self-closing hose port. The material, construction and fire-resistance of the hose port shall be equivalent to the door into which it is fitted, and shall be a 150 mm square clear opening with the door closed and shall be inset into the lower edge of the door, opposite the door hinges or, in the case of sliding doors, adjacent to the opening edge of the door.

h) A class doors other than watertight doors and exterior doors, provided with hold back device are to comply with item d).

3.1.2 Openings in B class divisions

a) Doors and door frames in B class divisions and means of securing them shall provide a method of closure which shall have resistance to fire equivalent to that of the divisions, this being determined in accordance with the Fire Test Procedures Code, except that ventilation openings may be permitted in the lower portion of such doors. Where such opening is in or under a door, the total net area of any such opening or openings shall not exceed 0,05 m^2. Alternatively, a non-combustible air balance duct arrangement between a cabin and a corridor, which is located below the sanitary unit leading through the corridor bulkhead, is permitted in order to achieve air balance of supply and exhaust air for the cabin provided that the cross-sectional area of the duct does not exceed 0,05 m^2. All ventilation openings shall be fitted with a grill made of non-combustible material. Doors shall be non-combustible.

Doors approved without the sill being part of the frame shall be installed such that the gap under the door does not exceed 25 mm.

b) Cabin doors in B class divisions shall be of a self-closing type. Hold-backs hooks are not permitted.

c) The requirements for B class integrity of the outer boundaries of a ship shall not apply to glass partitions windows and sidescuttles.

4 Protection of openings in machinery space boundaries

4.1 Application

4.1.1 The provisions of Article [4] shall apply to machinery spaces of category A and, to the satisfaction of the Society, to other machinery spaces.

4.2 Protection of openings in machinery space boundaries

4.2.1 The number of doors, ventilators, openings in funnels to permit exhaust ventilation and other openings to machinery spaces shall be reduced to a minimum consistent with the needs of ventilation and the proper and safe working of the ship.

4.2.2 Means of control shall be provided for closing power-operated doors, when provided or actuating the release mechanism on doors other than watertight doors. The control shall be located outside the space concerned, where it will not be cut off in the event of fire in the space it serves.

4.2.3 The control required in [4.2.2] shall be situated at one control position or grouped in as few positions as possible to the satisfaction of the Society.

4.2.4 Doors other than power-operated watertight doors and watertight doors shall be arranged in compliance with [3.1.1] item d) except for item d) 3).

4.2.5 Windows shall not be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery spaces.

5 Protection of vehicle and ro-ro spaces

5.1 Indicators

5.1.1 Indicators shall be provided in the continuously manned damage control station which shall indicate when any fire door leading to or from vehicle and ro-ro spaces is closed.

6 Ventilation systems

6.1 Application

6.1.1 Ventilation systems intended to be used during normal operation are to comply with the requirements of the present article. This article is not intended to apply to alternative configurations used solely in casualty situations. In any case, arrangements intended for use solely in casualty situations are not to impair compliance of the ventilation systems intended for normal operation with the requirements of the present Article.

6.1.2 For ships provided with CBRN protection (Chemical, Biological, Radiological and Nuclear protection), parts of the ventilation system not fully complying with the requirements of the present article may be accepted provided that:

- they are used solely during CBRN operation, and suitably marked to this end, and
- they are separated from parts of the ventilation system that will be used during normal operation, to the satisfaction of the Society, and

- the ventilation system in use during normal operation is fully compliant with the requirements of the present Article, and
- suitable arrangements are provided to prevent the fire extinguishing medium, especially CO_2, from leaving the protected space in case of release during CBRN operation or normal operation.

Attention is drawn to the provisions of Pt E, Ch 8, Sec 3, [2] for ships to be assigned the **CBRN** additional class notation.

6.2 Duct and dampers

6.2.1 Ventilation ducts, including single and double wall ducts, shall be of steel or equivalent material except flexible bellows of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in [6.2.7], any other material used in the construction of ducts, including insulation, shall also be non-combustible. However, short ducts, not generally exceeding 2 m in length and with a free cross sectional area not exceeding 0,02 m^2, need not be of steel or equivalent material, subject to the following conditions:

a) the ducts shall be made of non-combustible material, which may be faced internally and externally with membranes having low flame-spread characteristics and, in each case, a calorific value not exceeding 45 MJ/m^2 of their surface area for the thickness used;

b) the ducts are only used at the end of the ventilation device; and

c) the ducts are not situated less than 600 mm, measured along the duct, from an opening in an “A” or “B” class division, including continuous “B” class ceiling.

Note 1: The term free cross-sectional area means, even in the case of a pre-insulated duct, the area calculated on the basis of the inner dimensions of the duct itself and not the insulation.

6.2.2 The following arrangements shall be tested in accordance with the Fire Test Procedure Code:

a) fire dampers, including relevant means of operation. However, the testing is not required for dampers located at the lower end of the duct in exhaust ducts for galley ranges, which must be of steel and capable of stopping the draught in the duct; and

b) duct penetrations through A class divisions. However the test is not required where steel sleeves complying with [6.4.1] and [6.4.4] are directly joined to ventilation ducts by means of riveted or screwed connections or by welding.

6.2.3 Ventilation ducts are to comply with Pt B, Ch 2, Sec 1, [5] when crossing a watertight bulkhead or deck.

6.2.4 Fire dampers shall be easily accessible. Where they are placed behind ceilings or linings, these ceilings or linings shall be provided with an inspection hatch on which the identification number of the fire damper is marked. The fire damper identification number shall also be marked on any remote controls provided.

6.2.5 Ventilation ducts shall be provided with hatches for inspection and cleaning. The hatches shall be located near the fire dampers.

6.2.6 The main inlets and outlets of ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate the operating position of the closing device.

6.2.7 Combustible gaskets in flanged ventilation duct connections are not permitted within 600 mm of openings in “A” or “B” class divisions and in ducts required to be of "A" class construction.

6.2.8 Ventilation openings or air balance ducts between two enclosed spaces shall not be provided except as permitted by [3.1.2].

6.3 Arrangements of ducts

6.3.1 Ducts for machinery spaces of category A, galleys, vehicle and ro-ro spaces

a) The ventilation systems for machinery spaces of category A, vehicle and ro-ro spaces, and galleys shall in general be separated from each other and from ventilation systems serving other spaces.

b) Ducts provided for the ventilation of machinery spaces of category A, vehicle and ro-ro spaces, and galleys shall not pass through accommodation spaces, service spaces, or control stations unless they comply with [6.3.4].

6.3.2 Ducts for accommodation spaces, service spaces and control stations

Ducts provided for the ventilation of accommodation spaces, service spaces or control stations shall not pass through machinery spaces of category A, vehicle and ro-ro spaces or galleys unless they comply with [6.3.4].

6.3.3 Ducts for ammunition spaces

a) The ventilation systems serving ammunition spaces shall be separated from the ventilation systems serving other types of space. No ventilation duct shall pass through any ammunition space except the ducts provided for the ventilation of this ammunition space. Torpedo magazines shall be provided with a dedicated ventilation system capable of being stopped locally.

Note 1: If a common duct serves several ammunition spaces, this common duct is to be located outside the served spaces.

b) Ducts provided for the ventilation of ammunition spaces shall not pass through other spaces unless:
   1) the ducts comply with [6.3.4] item a) 1) and item a) 2); and
   2) the penetrations of the ammunition space boundary comply with [6.3.6], and
   3) penetrations of main vertical zone divisions, if any, comply with [6.3.9], and
   4) the air conditioning units serving the ammunition spaces are located in ventilation rooms or other spaces of category (10).

6.3.4 As permitted by [6.3.1] item b) and [6.3.2], ducts shall be either:

a)
   1) constructed of steel having a thickness of at least 3 mm for ducts with a free cross-sectional area of less than 0,075 m^2, at least 4 mm for ducts with a free cross-sectional area of between 0,075 m^2 and 0,45m^2, and at least 5 mm for ducts with a free cross-sectional area of over 0,45 m^2;
   2) suitably supported and stiffened;
   3) fitted with automatic fire dampers close to the boundaries penetrated; and
   4) insulated to a standard in line with the most stringent fire insulation requirement between Tab 1 and Tab 2 from the boundaries of the spaces they serve to a point at least 5 m beyond each fire damper; or

b)
   1) constructed of steel in accordance with item a) 1) and item a) 2); and
   2) insulated to a standard in line with the most stringent fire insulation requirement between Tab 1 and Tab 2 throughout the spaces they pass through.

6.3.5 For the purposes of [6.3.4], item a) 4) and [6.3.4], item b) 2), ducts shall be insulated over their entire cross-sectional external surface. Ducts that are outside but adjacent to the specified space, and share one or more surfaces with it, shall be considered to pass through the specified space, and shall be insulated over the surface they share with the space for a distance of 450 mm past the duct.

6.3.6 Galley ventilation systems are to be independent from ventilation systems serving other spaces except on ships of less than 4,000 gross tonnage, for which the galley ventilation systems need not be completely separated from other ventilation systems, but may be served by separate ducts from a ventilation unit serving other spaces. In such a case, an automatic fire damper shall be fitted in the galley ventilation duct near the ventilation unit.

6.3.7 In general, the ventilation fans shall be so arranged that the ducts reaching the various spaces remain within a main vertical zone. The air inlets and outlets may be common for more than one main vertical zone but the air inlets and outlets are not permitted to be common for more than one safety zone.

6.3.8 Stairway enclosures shall be served by an independent ventilation fan and duct system (exhaust and supply) which shall not serve any other spaces in the ventilation systems.

6.3.9 Where it is necessary that a ventilation duct passes through a main vertical zone division, an automatic fire damper shall be fitted adjacent to the division. The damper shall also be capable of being manually closed from each side of the division. The control location shall be readily accessible and be clearly and prominently marked so that it will be visible under white or red lighting conditions, as relevant. The duct between the division and the damper shall be constructed of steel in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2) and insulated to at least the same fire integrity as the division penetrated. The damper shall be fitted on at least one side of the division with a visible indicator showing the operating position of the damper.

The duct shall be insulated to A-30 class standard throughout the main vertical zone which is not served by the ventilation duct.

6.4 Details of fire dampers and duct penetrations

6.4.1 Ducts passing through "A" class divisions shall meet the following requirements:

a) Where a thin plated duct with a free cross sectional area equal to, or less than, 0,02 m^2 passes through "A" class divisions, the opening shall be fitted with a steel sheet sleeve having a thickness of at least 3 mm and a length of at least 200 mm, divided preferably into 100 mm on each side of the bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated;

b) Where ventilation ducts with a free cross-sectional area exceeding 0,02 m^2, but not more than 0,075 m^2, pass through "A" class divisions, the openings shall be lined with steel sheet sleeves. The ducts and sleeves shall have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length shall be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, shall be provided with fire insulation. The insulation shall have at least the same fire integrity as the division through which the duct passes.

   Equivalent penetration protection may be provided to the satisfaction of the Society, and

c) Automatic fire dampers shall be fitted in all ducts with a free cross-sectional area exceeding 0,075 m^2 that pass through "A" class divisions. Each damper shall be fitted close to the division penetrated and the duct between the damper and the division penetrated shall be constructed of steel in accordance with [6.3.4], item a) 1) and [6.3.4], item a) 2). The fire damper shall operate automatically, but shall also be capable of being closed manually from both sides of the division. The damper shall be fitted with a visible indicator which shows the operating position of the damper. Fire dampers are not required, however, where ducts pass through spaces surrounded by “A” class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they penetrate. A duct of cross- sectional area exceeding 0,075 m^2 shall not be divided into smaller ducts at the penetration of an “A” class division and then recombined into the original duct once through the division to avoid installing the damper required by this provision.

6.4.2 A duct, irrespective of its cross-section, serving more than one 'tween-deck accommodation space, service space or control station, shall be fitted, near the penetration of each deck of such spaces, with an automatic smoke damper that shall also be capable of being closed manually from the protected deck above the damper. Where a fan serves more than one 'tween-deck space through separate ducts within a main vertical zone, each dedicated to a single 'tween-deck space, each duct shall be provided with a manually operated smoke damper fitted close to the fan.

6.4.3 Vertical ducts shall, if necessary, be insulated as required by Tab 1 and Tab 2. Ducts shall be insulated as required for decks between the space they serve and the space being considered, as applicable.

6.4.4 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through “B” class bulkheads shall be lined with steel sheet sleeves of 900 mm in length, divided preferably into 450 mm on each side of the bulk- heads unless the duct is of steel for this length.

6.4.5 All fire dampers shall be capable of manual operation. The dampers shall have a direct mechanical means of release or, alternatively, be closed by electrical, hydraulic, or pneumatic operation. All dampers shall be manually operable from both sides of the division. Automatic fire dampers, including those capable of remote operation, shall have a failsafe mechanism that will close the damper in a fire even upon loss of electrical power or hydraulic or pneumatic pressure loss. Remotely operated fire dampers shall be capable of being reopened manually at the damper.

Note 1: Manual closing may be achieved by mechanical means of release or by remote operation of the fire damper by means of a failsafe electrical switch or pneumatic release (spring-loaded, etc) on both sides of the division.

6.4.6 Duct penetration of ammunition space boundaries

All ventilation ducts serving ammunition spaces shall be provided with automatic fire dampers and flame arresters, in compliance with a recognized standard. The automatic fire damper shall be operable from outside the space. The automatic fire dampers and the flame arresters are to be fitted close to the boundaries of the ammunition space, on the outside of the space.

6.5 Exhaust ducts from galley ranges

6.5.1 In addition to the requirements in [6.2], [6.3] and [6.4], exhaust ducts from galley ranges shall be constructed in accordance with [6.3.4], item b) 1) and [6.3.4], item b) 2). They shall also be fitted with:

a) A grease trap readily removable for cleaning unless an alternative approved grease removal system is fitted.

b) A fire damper located in the lower end of the duct at the junction between the duct and the galley range hood which is automatically and remotely operated and, in addition, a remotely operated fire damper located in the upper end of the duct close to the outlet of the duct.

c) A fixed means for extinguishing a fire within the duct.

d) Remote-control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in item b) and for operating the fire-extinguishing system, which shall be placed in a position outside the galley close to the entrance to the galley. Where a multi-branch system is installed, a remote means located with the above controls shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system; and

e) Suitably located hatches for inspection and cleaning, including one provided close to the exhaust fan and one fitted in the lower end where grease accumulates.

The requirements given in item a) to item e) apply to all exhaust ducts from galley ranges in which grease or fat is likely to accumulate from galley ranges.

6.6 Ventilation rooms serving machinery spaces of category A containing internal combustion machinery

6.6.1 Where a ventilation room serves only such an adjacent machinery space and there is no fire division between the ventilation room and the machinery space, the means for closing the ventilation duct or ducts serving the machinery space shall be located outside of the ventilation room and machinery space.

6.6.2 Where a ventilation room serves such a machinery space as well as other spaces and is separated from the machinery space by a “A-0” class division, including penetrations, the means for closing the ventilation duct or ducts for the machinery space can be located in the ventilation room.

6.7 Ventilation systems for spaces containing dryers

6.7.1 Exhaust ducts from spaces of category (9) and category (13), as defined in [1.2.3], item b), containing dryers shall be fitted with:

a) filters readily removable for cleaning purposes

b) a fire damper located in the lower end of the duct which is automatically and remotely operated

c) remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in item b); and

d) suitably located hatches for inspection and cleaning.

6.8 Capacity of the ventilation systems

6.8.1 Ammunition spaces

Ammunition spaces are to be fitted with a mechanical ventilation system in order to avoid the formation of condensation inside the space. The ventilation system is to be such as to provide at least 0,5 air change per hour.

6.8.2 Spaces for the storage of gas fire-extinguishing medium

Spaces dedicated to the storage of bottles or vessels containing the gas fire-extinguishing medium as mentioned in Ch 4, Sec 6, [3.1.1], item a), are to be fitted with a mechanical ventilation system designed to exhaust air from the bottom of the space and capable of providing at least 6 air changes per hour unless access to the space is provided from the open deck.

6.8.3 Battery rooms

Spaces for the storage of batteries are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.3] and Ch 2, Sec 11, [6.5]. When the formula of Ch 2, Sec 11, [6.5.2] has not been applied, the ventilation system is to be capable of providing at least 15 air changes per hour.

6.8.4 Spaces dedicated to the storage of flammable liquids

Spaces dedicated to the storage of flammable liquids in closed containers are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.4] and capable of providing at least 6 air changes per hour.

6.8.5 Workshops for the handling of flammable liquids

Workshops which can be used for the handling of flammable liquids are to be fitted with a mechanical ventilation system capable of providing at least 10 air changes per hour.

6.8.6 Spaces containing welding gas (acetylene) bottles

In addition to the requirements of Ch 1, Sec 10, [18.4.1] applicable to the spaces for the storage of welding gas (acetylene), spaces for the storage of welding gas bottles, including the workshops where welding operations are performed, are to be fitted with a mechanical ventilation system complying with the requirements of Ch 2, Sec 3, [10.5] and capable of providing at least 6 air changes per hour.

6.8.7 Workshops for the maintenance of internal combustion machinery

Workshops for the maintenance of any internal combustion machinery using fuel having a flash-point below 60°C are to be fitted with a mechanical ventilation system capable of providing at least 15 air changes per hour.

Section 6 Suppression of Fire and Explosion: Fire-Fighting

1 Water supply systems

1.1 General

1.1.1 Every ship shall be provided with fire pumps, fire mains, hydrants and hoses complying as applicable with the requirements of this Section.

1.1.2 For the purpose of this Section, hydrants and fire stations have the same meaning.

1.2 Fire mains and hydrants

1.2.1 General

Materials rendered ineffective by heat shall not be used for fire mains and hydrants unless adequately protected. The pipes and hydrants shall be so placed that the fire hoses may be easily coupled to them. The arrangements of pipes and hydrants shall be such as to avoid the possibility of freezing. In ships where deck cargo may be carried, the positions of the hydrants shall be such that they are always readily accessible and the pipes shall be arranged as far as practicable to avoid the risk of damage by such cargo.

1.2.2 Ready availability of water supply

The arrangements for the ready availability of water supply shall be such that at least two effective jets of water are immediately available from any two hydrants and so as to ensure the continuation of the output of water by the automatic starting of one required fire pump.

1.2.3 Diameter of the fire mains

The diameter of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge of water from fire pumps feeding simultaneously four hydrants, the most demanding fire-extinguishing systems and other systems supplied by the fire main.

The fire main shall be of type: single main, horizontal loop system, composite loop system or a combination thereof.

1.2.4 Isolating valves and relief valves

a) The firemain is to be divided at least as follows:
   1) Isolating valves are to be fitted on the boundaries of the space containing the fire pumps and if the space containing the fire pump is a machinery space the isolating valves are to be fitted outside the machinery space.
   2) At least one isolating valve is to be fitted at each safety zone bulkhead penetrated. It shall be possible to operate the isolating valve from both sides of the safety zone bulkhead unless isolating valves are fitted on both sides of the division.
   3) The fire main is to be so arranged that when the isolation valves of a space containing a fire pump are shut, all the hydrants on the ship, except those in this space, can be supplied with water by the remaining pumps.
   4) The fire main is to be so arranged that when the isolation valves of the safety zone bulkheads as requiremed in item 2) are shut, all the hydrants within each safety zone can be supplied with water by the pumps required in [1.3.2].
   5) Isolating valves are to be readily accessible and located outside of fire risk spaces. They shall be controlled and operated from the continuously manned damage control station and, in the case of operating energy failure, they shall remain in the previous closed or open position. Manual operation of isolating valves from above the damage control deck as mentioned in Pt B, Ch 1, Sec 2, [6.5.1] shall also be possible.

Note 1: If the part of the ship located forward of the collision bulkhead forms one safety zone, this safety zone need not to comply with item a) 4).

b) A valve shall be fitted to serve each fire hose so that any fire hose may be removed while the fire pumps are at work.
c) Relief valves shall be provided in conjunction with all fire pumps. These valves shall be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
d) Non return check valves shall be fitted on the delivery side of fire pumps and as well as isolating valves on their suction side.

1.2.5 Number and position of hydrants

a) The number and position of hydrants shall be such that with one hose length connected to any hydrant and with two hose lengths connected to the nearby hydrant it shall be possible to reach any part of the ship normally accessible to the crew while the ship is navigating as well as any part of vehicle and ro-ro spaces.

Furthermore, hydrants, as far as it is practicable, shall be located near the accesses to the protected spaces.

For the purpose of this item [1.2.5] at least two hydrants are to be provided in machinery spaces of category A which shall be located near the escape exit of the space.

b) In addition, ships shall comply with the following:

1) In the accommodation, service, machinery spaces, vehicle and ro-ro spaces, the number and position of hydrants shall be such that the requirements of item a) above may be complied with when all watertight doors and all doors in safety zones bulkheads are closed.

2) Where access is provided to a machinery space of category A at a low level from an adjacent shaft tunnel, two hydrants shall be provided external to, but near the entrance of that machinery space. Where such access is provided from other spaces, in one of those spaces two hydrants shall be provided near the entrance to the machinery space of category A. Such provision need not be made where the tunnel or adjacent spaces are not part of the escape route.

c) The safety zone bulkheads in between decks shall be provided with:

1) A stub pipe passage of not less than 70 mm internal diameter provided on both side of the bulkhead with two couplings for 45 mm diameter fire hose, or

2) Two stub pipe passages of not less 45 mm internal diameter provided on both sides of the bulkhead with coupling for 45mm diameter fire hose.

The couplings shall be provided with screw plugs.

1.2.6 Pressure at hydrants

With any two pumps simultaneously delivering, through nozzles specified in [1.4.3], the quantity of water specified in [1.2.3], through any adjacent hydrants, the pressure at all hydrants shall be at least 7 bar.

The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire hose can be demonstrated.

1.2.7 International shore connection

Ships shall be provided with at least one international shore connection, complying with Ch 4, Sec 13. Facilities shall be available enabling such a connection to be used on either side of the ship.

1.3 Fire pumps

1.3.1 Pumps accepted as fire pumps

Sanitary, bilge or general service pumps are accepted as fire pumps provided that they are not used for pumping oil.

1.3.2 Number of fire pumps

Each vertical safety zone is to be equipped with one pump for continuous pressurization and at least:

- for ships less than 3000 t displacement, one large capacity pump
- for ships above 3000 t, two large capacity pumps.

1.3.3 Capacity of fire pumps

The large capacity fire pumps of each safety zone required by [1.3.2] shall be capable of supplying, at the pressure stated in [1.2.6], four hydrants and the ship most demanding fire-fighting system using the fire main as the main supply of sea water, including bilge pumping if bilge ejectors are used as mentioned in Ch 1, Sec 10, [6].

Note 1: The expression “the ship most demanding systems” means the most demanding room associated with its adjacent ammunition stores.

The fire-fighting system plan shall indicate the water systems to be in operation at the same time and the relevant water demand.

1.4 Fire hoses and nozzles

1.4.1 Specification of hoses

a) Fire hoses shall be of non-perishable material approved by the Society and shall have a length of at least 10 m, but not more than:
   - 15 m in machinery spaces
   - 20 m in other spaces and open decks, and
   - 25 m for open decks on ships with a maximum breath in excess of 30 m.

b) Each hose shall be provided with a nozzle and the necessary couplings and, together with any necessary fittings and tools, shall be kept ready for use in conspicuous positions near the water service hydrant.

c) One fire hose shall be provided for each hydrant of the ship and be connected at all times.

1.4.2 Diameter of hydrants and fire stations

Hydrants diameter shall be either 45 mm or 70 mm.

Fire station shall be equipped in accordance with Naval Authority standards.

1.4.3 Size and type of nozzles

a) Nozzles shall be in accordance with standards of the Naval Authority. In absence of such standards, nozzles sizes shall be 12 mm, 14 mm and 16 mm or as near thereto as possible. Larger diameter nozzles may be permitted at the discretion of the Society.

b) For accommodation and service spaces, a nozzle size greater than 12 mm need not be used.

c) For machinery spaces and exterior locations the nozzle size, not exceeding 19 mm, shall be such as to obtain the maximum discharge possible from two jets at the pressure mentioned in [1.2.6] from the smallest pump.

d) All nozzles shall be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2 Portable fire extinguishers

2.1 Type and design

2.1.1 All fire extinguishers are to comply with the requirements of Ch 4, Sec 13.

2.2 Arrangement of fire extinguishers

2.2.1 Fire extinguishers shall be provided as follows:

- In the proximity of the main electric switchboards a semi-portable CO_2 fire extinguisher of a capacity of at least 18 kg of CO_2 shall be provided.
- In the proximity of any section board having a power of 20 kW and upwards at least one powder extinguisher or CO_2 extinguisher.
- Any service space where deep fat cooking equipment is installed shall be fitted with at least one powder fire extinguisher.
- In the proximity of any paint or flammable locker at least one powder or foam type extinguisher shall be provided.
- In control stations at least one CO_2 fire extinguisher shall be provided.

2.3 Periodical test

2.3.1 Fire extinguishers shall be periodically examined and subjected to such tests as the Society may require.

See Part A, Chapter 3.

3 Fixed fire-extinguishing systems

3.1 Types of fixed fire-extinguishing systems

3.1.1 A fixed fire-extinguishing system could be any of the following systems:

a) a fixed gas fire-extinguishing system complying with the provisions of Ch 4, Sec 13

b) a fixed high expansion foam fire-extinguishing system complying with the provisions of Ch 4, Sec 13

c) a fixed pressure water-spraying, thick water spraying or an equivalent water-based fire-extinguishing system complying with the provisions of Ch 4, Sec 13

d) in addition to the required systems in a), b) and c), a low expansion foam system, a thick water system, or any other approved system, is to be provided for the protection of bilge spaces under the machinery floors

e) any other fire-extinguishing system considered appropriate by the Society and the Naval Authority.

3.1.2 Where a fixed fire-extinguishing system not required by this Chapter is installed, such system shall meet the relevant requirements of this Chapter.

3.1.3 Fire-extinguishing systems using Halon 1211, 1301, and 2402 and perfluorocarbons are prohibited.

3.2 Closing appliances for fixed gas fire-extinguishing systems

3.2.1 Where a fixed gas fire-extinguishing system is used, means shall be provided to close, at the starting of the system, all openings which may admit air to or allow gas to escape from a protected space.

For machinery spaces, controls for the closing of those openings and associated monitoring means are to be operable from the damage control stations. These controls are to be operable even in the event of failure of the supply from the main source of electrical power. In addition, manual closing of those openings is to be possible.

3.3 Storage rooms for fire-extinguishing medium

3.3.1 Gas fire-extinguishing medium bottles or containers for fixed or semi-fixed systems shall have their safety device (rupture disc), and where appropriate their main safety valve (or rupture disc) provided with an exhausted pipe discharging to the open.

Dedicated storage rooms for gas fire-extinguishing medium bottles, or containers and foam concentrate tanks, shall have fire integrity complying with Ch 4, Sec 5, considering such rooms as control stations, and complying also with [3.3.2].

The arrangements of non dedicated storage rooms shall comply with the requirements for dedicated rooms as the Society may consider practicable and reasonable.

In any case the requirements of Ch 4, Sec 13 shall be comply with.

3.3.2 Requirements for dedicated storage room for fire-extinguishing medium

When the fire-extinguishing medium is stored outside a protected space, it shall be stored in a room which is located behind the forward collision bulkhead, and is used for no other purposes. Any entrance to such a storage room shall preferably be from the open deck and shall be independent of the protected space. If the storage space is located below deck, it should be located not more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck. Spaces which are located below deck or spaces where access from the open deck is not provided shall be fitted with a mechanical ventilation system designed to take exhaust air from the bottom of the space and shall be sized to provide at least 6 air changes per hour. Access doors shall open outwards, and bulkheads and decks, including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjacent enclosed spaces, shall be gastight.

3.4 Water pumps for other fire-extinguishing systems

3.4.1 Pumps other than those serving the fire main, required for the provision of water for other fire-extinguishing systems required by this chapter, their sources of power and their controls shall be installed outside the space or spaces protected by such systems and shall be so arranged that a fire in the space or spaces protected will not put any such system out of action.

4 Fire-extinguishing arrangements in machinery spaces

4.1 Machinery spaces arrangement

4.1.1 General

a) The arrangement of machinery spaces is to be such that safe storage and handling of flammable liquids is ensured.

b) All spaces where oil-consuming installations, settling tanks or daily service fuel tanks are located are to be easily accessible and well ventilated.

c) Where leakage of flammable liquids may occur during normal service or routine maintenance work, a special arrangement is to be made to prevent these fluids from reaching other parts of the machinery where danger of ignition may arise.

d) Materials used in machinery spaces are not normally to have properties increasing the fire potential of these rooms. Neither combustible nor oil-absorbing materials are to be used as flooring, bulkhead lining, ceiling or deck in the control room, machinery spaces, shaft tunnel or rooms where oil tanks are located. Where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours.

e) Water extinguishing systems as mentioned in Ch 1, Sec 10, [11.5.1], item c), Note 2, are to be fitted to protect the bulkheads of service tanks located within machinery spaces from a fire. The effective average distribution of water is to be in compliance with Ch 4, Sec 13, [7.1.1].

4.1.2 Segregation of fuel oil purifiers, JP5-NATO (F44) purifiers and other systems for preparing flammable liquids

a) The system (such as purifiers) for preparing flammable liquids for use in boilers and machinery, and separate oil systems with working pressure above 1,5 MPa which are not part of the main engines, auxiliary engines or boilers etc., are subject to the following additional requirements.

b) The main components in the systems are to be placed in a separate room, enclosed by steel bulkheads extending from deck to deck and provided with self-closing steel doors.

c) Rooms in which flammable liquids are handled as specified in a) above are to be provided with:

- independent mechanical ventilation or ventilation arrangements which can be isolated from the machinery space ventilation
- a fire detecting system
- a fixed fire-extinguishing installation. The extinguishing installation is to be capable of being activated from outside the room. The extinguishing system is to be separated from the room, but may be a part of the main fire-extinguishing system for the machinery space. Closing of ventilation openings is to be effected from a position close to where the extinguishing system is activated.

d) Where the size of the engine room makes it impracticable to locate the main components of such systems in a separate space, specific measures with regard to the location, containment of possible leakages and shielding of the components, and to ventilation, are to be provided to the satisfaction of the Society, such as:
   - fitting of drip trays and shielding for leakage containment
     location close to ventilation exhaust so as to avoid flammable gas accumulation in vicinity
   - fitting of dedicated hood above for ventilation exhaust

   A local fixed fire-extinguishing system is to be provided, capable of being activated automatically or activated manually from the machinery control position or from another suitable location. If automatic release is provided, additional manual release is to be arranged.

4.2 Machinery spaces containing oil fired boilers or fuel oil units

4.2.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing oil fired boilers or fuel oil units shall be provided with any one of the fixed fire-extinguishing systems in [3.1].

In each case if the engine and boiler rooms are not entirely separate, or if fuel oil can drain from the boiler room into the engine room, the combined engine and boiler rooms shall be considered as one compartment.

4.2.2 Additional fire-extinguishing arrangements

a) There shall be in each boiler room at least one set of portable foam applicator units complying with the provisions of Ch 4, Sec 13.

b) There shall be at least two portable foam extinguishers or equivalent in each firing space in each boiler room and in each space in which a part of the fuel oil installation is situated. There shall be not less than one approved foam-type extinguisher of at least 135 l capacity or equivalent in each boiler room.

   For fire extinguishers in the proximity of any electric switchboard or section board see item [2.2.1].

c) The portable foam applicator in item a) and the 135 l capacity extinguisher in item b) may be omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

d) A fixed fire-extinguishing system for the protection of bilge spaces shall be provided, as required in [3.1.1], item d).

4.3 Machinery spaces containing internal combustion machinery

4.3.1 Fixed fire-extinguishing systems

Machinery spaces of category A containing internal combustion machinery (such as gas turbines) shall be provided with one of the fire-extinguishing systems required in [3.1].

4.3.2 Additional fire-extinguishing arrangements

a) At least one set of portable foam applicator units complying with the provisions of Ch 4, Sec 13.

b) In each such space approved foam-type fire extinguishers, each of at least 45 l capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards.

c) In the case of machinery spaces containing both boilers and internal combustion engines [4.2] and [4.3] apply, with the exception that one of the foam fire extinguishers of at least 45 l capacity or equivalent may be omitted provided that the 135 l extinguisher can efficiently and readily protect the area covered by the 45 l extinguishers.

d) For fire extinguishers in the proximity of electric switchboard or section board see item [2.2.1].

e) The portable foam applicator in item a) and the fire extinguishers 45 l and 135 l in item b) may be omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

f) A fixed fire-extinguishing system for the protection of bilge spaces shall be provided, as required in [3.1.1], item d).

4.4 Machinery spaces containing steam turbines or enclosed steam engines

4.4.1 Fixed fire-extinguishing systems

In spaces containing steam turbines or enclosed steam engines used either for main propulsion or for other purposes when such machinery has in the aggregate a total power output of not less than 375 kW there shall be provided one of the fire-extinguishing systems required by [3.1] where such spaces are periodically unattended.

4.4.2 Additional fire-extinguishing arrangements

a) Approved foam fire extinguishers each of at least 45 l capacity or equivalent sufficient in number to enable foam or its equivalent to be directed on to any part of the pressure lubrication system, on to any part of the casings enclosing pressure lubricated parts of the turbines, engines or associated gearing, and any other fire hazards. However, such extinguishers shall not be required if protection at least equivalent to that required by this item is provided in such spaces by a fixed fire-extinguishing system fitted in compliance with [3.1].

b) The 45 l capacity or equivalent fire extinguishers in item a) may be also omitted where the fire stations, see item [1.1.2], are provided with foam making arrangements by the appropriate fire hose.

c) For fire extinguishes in the proximity of electric switchboard or section board see item [2.2.1].

4.5 Other machinery spaces

4.5.1 Where in the opinion of the Society, a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in [4.2], [4.3] and [4.4], there shall be provided in, or adjacent to, that space such a number of approved portable fire extinguishers or other means of fire extinction as the Society may deem sufficient.

4.6 Fixed local application fire-extinguishing systems

4.6.1 Machinery spaces of category A above 500 m^3 in volume shall, in addition to the fixed fire-extinguishing system required in the present Section, be protected by a fixed water-based or equivalent local application fire-extinguishing system complying with the provisions of Ch 4, Sec 13. In the case of periodically unattended machinery spaces, the fire-extinguishing system shall have both automatic and manual release capabilities. In the case of continuously manned machinery spaces, the fire-extinguishing system is only required to have a manual release capability.

4.6.2 Fixed local application fire-extinguishing systems are to protect areas such as the following without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces:

- the hazard portions of internal combustion machinery
- boiler fronts
- oil fired equipment
- thermal oil heaters
- the fire hazard portions of incinerators, and
- purifiers for heated fuel oil.

4.6.3 Activation of any local application system shall give a visual and distinct audible alarm in the protected space, at a continuously manned damage control station. The alarms shall indicate the specific system activated. The alarm requirements described within this sub-article [4.6] are in addition to, and not to substitute for, the detection and fire alarm system required elsewhere in this Chapter.

4.6.4 The automatic release should be activated by a detection system capable of reliably identifying the local zones. Two different types of detectors should be fitted for each zone and the activation of both detectors shall be necessary for the release of the system. Other consideration should be given to avoid any accidental activation of the system.

5 Fire-extinguishing arrangements in accommodation spaces, service spaces and control stations

5.1 Sprinkler systems

5.1.1 Ships provided with the additional class notation **FIRE** shall comply with the requirements of Pt E, Ch 10, Sec 3.

5.1.2 Where accommodation spaces, service spaces or control stations are fitted with a fixed sprinkler system, this system shall be of an approved type complying with Ch 4, Sec 13, [8].

5.2 Spaces containing flammable liquid

5.2.1 Paint lockers and flammable liquid lockers shall be protected by an appropriate fire-extinguishing arrangement approved by the Society which could be any of the following systems:

a) a carbon dioxide system, designed to give a minimum volume of free gas equal to 40% of the gross volume of the protected space

b) a dry powder system, designed for at least 0,5 kg powder/m^3

c) a water spraying or sprinkler system, designed for 5 l/m^2 min. Water spraying systems may be connected to the fire main of the ship, or

d) a system providing equivalent protection, as determined by the Society.

In all cases, the system shall be operable from outside the protected space.

5.3 Equipment for frying

5.3.1 Deep-fat cooking equipment shall be fitted with the following:

a) an automatic or manual fire-extinguishing system which has been tested in conformity with an international standard and considered acceptable by the IMO.

Note 1: See the recommendations of the International Standards Organization, in particular the ISO 15371:2015 publication (Fire-extinguishing systems for protection of galley cooking equipment).

b) a primary and backup thermostat with an alarm to alert the operator in the event of failure of either thermostat

c) arrangements for automatically shutting off the electrical power upon activation of the fire-extinguishing system

d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed, and

e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

6 Fire-extinguishing arrangements in ammunition spaces

6.1 Fixed fire-extinguishing systems

6.1.1 Ammunition spaces excluding lifts and transfer chambers shall be provided with a fixed water-spraying fire-extinguishing system complying with the provisions of Ch 4, Sec 13, [7].

a) spraying nozzles are to be provided in order to ensure the spraying of ceilings, bulkheads and shells above the waterline. The nozzles are to be arranged so as allow the spraying of the ceilings with a flow of at least 1000 l/h/m^2, and of the bulkheads and shells with a flow of at least 500 l/h/m^2.

b) pieces of equipment are to be watered by the water falling down from the ceilings.

6.1.2 For ammunition spaces located below the waterline, the waterspraying system may be fitted with an automatic closing system of the water supply valve when the water level reaches the top of the storage area.

The boundaries of the ammunition space and the ventilation ducts serving the space are to be designed according to Part B, Chapter 7 for the maximum water pressure.

7 Protection of fuel pump rooms

7.1 Fixed fire-extinguishing systems

7.1.1 Each fuel, diesel or JP5-NATO (F44) pump room shall be provided with a fixed pressure water-spraying system or an equivalent fixed water based fire-extinguishing system complying with the provisions of the Ch 4, Sec 13.

7.1.2 In addition to the system required in [7.1.1] and with consideration of the floor arrangement and of the fuel, diesel or JP5-NATO (F44) pump room, one of the fixed fire-extinguishing systems required in [3.1.1], item d) is to be provided for the fire protection under the machinery floor.

7.2 Quantity of fire-extinguishing medium

7.2.1 Where the extinguishing medium used in the fuel pump room system is also used in systems serving other spaces, the quantity of medium provided or its delivery rate need not be more than the maximum required for the largest compartment.

8 Firefighter’s outfits

8.1 Types of firefighter’s outfits

8.1.1 Firefighter’s outfits shall comply with Ch 4, Sec 13.

8.2 Number of firefighter’s outfits

8.2.1 Each safety zone shall be provided with at least 6 firefighter’s outfits.

8.3 Storage of firefighter’s outfits

8.3.1 The firefighter’s outfits or sets of personal protecting equipment shall be so stored as to be easily accessible and ready for use.

8.4 Means of communications between fire-fighting teams

8.4.1 Four two-way portable radiotelephone apparatus shall be provided in each safety zone. These apparatus are to be of an explosion proof type and intrinsically safe.

Section 7 Suppression of Fire and Explosion: Structural Integrity

1 Material of hull, superstructures, structural bulkheads, decks and deckhouses

1.1 General

1.1.1 The hull, superstructure, structural bulkheads, decks and deckhouses shall be constructed of steel or other equivalent material. For the purpose of applying the definition of steel or other equivalent material as given in Ch 4, Sec 1, [2.36.1], the "applicable fire exposure" shall be according to the integrity and insulation standards given in Tables 1 to 4 of Ch 4, Sec 5. Where an A class division is required by such Tables the applicable fire exposure shall be of an hour and where an B class division is required by the same Tables the applicable fire exposure shall be 30 minutes. Where steel is substituted by aluminium alloy, which is a non-combustible material, in item [2.1.1] a) the acceptance condition are given. Where other materials are intended to be used and are acceptable for Part B, the Society will determine the fire tests to which prototypes have to undergone as well as the additional fire safety measures to be provided accounting of international experiences and procedures to be applied when prescriptive requirements are substituted by performance requirements.

2 Structure of aluminium alloy

2.1 General

2.1.1 Unless otherwise specified in [1.1.1], in cases where any part of the structure is of aluminium alloy, the following shall apply:

a) The insulation of aluminium alloy components of A or B class divisions, except structures which, in the opinion of the Society, are non-load-bearing, shall be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure to the standard fire test.

b) Special attention shall be given to the insulation of aluminium alloy components of columns, stanchions and other structural member required to support A class divisions (see Sec 5, Tab 1) to ensure that the temperature rise limitation specified in the preceding item a) shall apply at the end of one hour.

c) With reference to item a) above:

   1) When spaces of categories 1 to 10 in Sec 5, [1.2.3] are located on top of aluminium decks, the deck does not need to be insulated from the upper side.

   2) A load-bearing division is a deck or bulkhead including stiffeners, pillars, stanchions and other structural members which, if eliminated, would adversely affect the designated structural strength of the ship.

   3) Where spaces of low fire risks are concerned, upon special consideration by the Society, divisions may be insulated from one side only, depending on the nature and function of the space. Such arrangement shall be to the satisfaction of the Society.

3 Crowns and casings of machinery spaces of category A

3.1 General

3.1.1 Crowns and casings of machinery spaces of Category A shall be of steel construction adequately insulated and openings therein, if any, shall be suitably arranged and protected to prevent the spread of fire.

4 Materials of overboard fittings

4.1 General

4.1.1 Materials readily rendered ineffective by heat shall not be used for overboard scuppers, sanitary discharges, and other outlets.

Section 8 Escape and Circulation

1 Notification of crew

1.1 General emergency alarm system

1.1.1 A general emergency alarm system as required in Ch 2, Sec 3 shall be installed to notify crew of a fire.

1.1.2 An inter-communication system shall be fitted in such a way as to be clearly heard throughout the accommodation and service spaces, control stations and open decks.

2 Means of escape

2.1 Purpose

2.1.1 The purpose of the following requirements of this section is to provide means of escape so that persons on board can safely and swiftly escape to adjacent main vertical zone, adjacent safety zone and to the evacuation stations. For this purpose, the following functional requirements shall be met:

- escape routes shall be maintained in a safe condition, clear of obstacles, and
- additional aids for escape shall be provided as necessary to ensure accessibility, clear marking and adequate design for emergency situations.

Note 1: Means of escape are all the available means to exit from any space continuously or occasionally manned at sea.

Note 2: Evacuation routes or escape routes are all the main and secondary ways to escape from any space to adjacent main vertical zones, adjacent safety zones and to evacuation stations.

Note 3: Evacuation stations are the areas from which the persons to be evacuated have access to the liferafts when launched at sea.

2.1.2 Application

For the provisions of this Section, "stairway" means either a stairway enclosure of category (2) or stairways penetrating a single deck and included in a corridor or lobby as permitted in Ch 4, Sec 5, [1.2.4].

2.2 General requirements

2.2.1 Lifts shall not be considered as forming one of means of escape required in this section.

2.2.2 All stairways and ladders shall be of steel frame construction.

Inclined ladders/stairways with open treads in machinery spaces of category A being part of or providing access to escape routes but not located within a protected enclosure shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

2.3 Means of escape from accommodation spaces, service spaces and control stations

2.3.1 General requirements

a) As far as practicable and reasonable, a corridor, lobby, or part of a corridor from which there is only one escape route should not be built.

   No dead-end corridors having a length more 7 m shall be accepted. As an exception, when it is not practical, this length may be increased up to 9 m.

b) In general, at least two separated means of escape are to be provided from all spaces or group of spaces. For a given space, a secondary exit door may be requested with regard to its shape and deck area. The main doors or hatches shall have width appropriate to the number of persons.

c) Doors in escape routes shall, in general, open in way of the direction of escape, except that:
   - Individual cabin doors may open into the cabin in order to avoid injury to persons in the corridor when the door is opened, and
   - Doors in vertical emergency escape trunks may open out of the trunk in order to permit the trunk to be used both for escape and for access.

d) Normally locked doors that form part of an escape route

   Cabin and stateroom doors shall not require keys to unlock them from inside the room. Neither shall there be any doors along any designated escape route which require keys to make unlock them when moving in the direction of escape.

2.3.2 Means of escape

a) General

Stairways and ladders shall be so arranged as to provide ready means of escape to the evacuation stations from all the accommodation and service spaces and control stations in which the crew is normally employed.

b) Escape from spaces below the damage control deck

Below the damage control deck, two means of escape shall be provided, per deck, from each watertight compartment, at least one of which shall be a stairway. However when the greatest dimension of the compartment is not more than 5 m there may be provided only one means of escape.

c) Escape from spaces above the damage control deck

Above the damage control deck there shall be at least two means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which shall give access to a stairway leading to the evacuation station.

Note 1: For the main vertical zones in the fore or aft end of the ship which are constituted by spaces mainly located below the bulkhead deck, it may be accepted to have a vertical steel ladder between the damage control deck and the bulkhead deck instead of the required stairway, provided the other escape route leads to the evacuation station through an adjacent main vertical zone.

Such arrangement shall be to the satisfaction of the Society.

Note 2: In spaces where no personnel are normally employed, the stairway required in item b) and f) may be replaced by a vertical steel ladder.

d) Escape from spaces on the damage control deck

In addition to the means of escape required in item c) above, two means of escape shall be provided on the damage control deck from each watertight compartment or similarly restricted group of spaces.

In general, at least one of those means of escape is to be independent of watertight doors.

However, those means of escape may be watertight doors in auxiliary watertight bulkheads as defined in Pt B, Ch 1, Sec 2, [6.5], provided the following requirements 1) to 4) are met:

1) The ship is fitted with a sea water flooding detection system such that each watertight compartment is fitted with water level detectors.
2) An alarm is given in the damage control stations in the event of flooding in one of the watertight compartments. This flooding alarm is to be separated from the others, individual for each watertight compartment.
3) Means are provided to give audible warning of the flooding to the crew in throughout all the accommodation and normal crew working spaces during normal operational condition. Visual alarm may be used in spaces where audible signals are not appropriate due to high noise levels.
4) Each of the two means of escape gives access to an escape route leading to the evacuation station.

e) Direct access to stairway enclosures

Where provided, stairway enclosures in accommodation spaces, service spaces and control stations shall have direct access to corridors.

f) Details of means of escape

Means of escape where required by the previous items b) and c) shall be arranged as per [4.1.1] and Ch 4, Sec 5, [1.2.4]. At least one of the escape required by the previous items b) and c) shall consist of a readily accessible stairway sized as per the requirements of Article [4].

Means of closing of the horizontal opening of stairways and ladders shall be as required by the Naval Authority for naval operations.

Note 3: For limited area where room in room arrangement has been permitted by the Society, local audible alarm inter-connected to fire detectors will have to be provided in addition of other required measures if any.

g) Marking of escape routes

The means of escape including stairways and exits shall be marked by lighting or photoluminescent strip indicators placed not more than 300 mm above the deck at all points of the escape route including angles and intersections. The marking must enable crew to identify all the routes of escape and readily identify the escape exits. If electric illumination is used, it shall be supplied by the emergency source of power and it shall be so arranged that the failure of any single light or cut in a lighting strip will not result in the marking being ineffective. Additionally, all escape route signs and fire equipment location markings shall be of photoluminescent material of a type approved by the Society or marked by lighting. Such lighting or photoluminescent equipment shall be evaluated, tested and applied to the satisfaction of the Society in accordance with IMO Resolution A.752(18) and ISO 15370.

2.4 Means of escape from machinery spaces

2.4.1 Means of escape from each machinery space shall comply with the provisions given in the following items a) to d).

a) Escape from spaces below the bulkhead deck

Two sets of steel ladders and/or stairways as widely separated as possible, leading to doors or deck hatches in the upper part of the space, similarly separated and from which access is provided to the evacuation stations. For machinery spaces of category A, one of these ladders shall be located within a protected enclosure categorized (2) as per the requirements of Section 5 from the lower part of the space it serves to a safe position outside the space. Self-closing fire doors of the same fire integrity standards shall be fitted in the enclosure. The ladder shall be fixed in such a way that heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800 x 800 mm, and shall have emergency lighting provisions. Alternative arrangement may be provided to the satisfaction of the Society.

b) Escape from spaces above the bulkhead deck

The two means of escape shall be as widely separated as possible and the doors or hatches leading from such means of escape shall be in position from which access is provided to the evacuation stations.

c) Dispensation from two means of escape

This requirement does not apply for machinery spaces of category A.

The Society may dispense with one of the means of escape from any such a space including a normally unattended auxiliary machinery space, so long as either a door, a steel ladder or a stairway provides a safe escape route to the evacuation stations, due regard being paid to the nature and location of this space.

Where no personnel are normally employed in the machinery space, the second mean of escape is not required.

d) Escape from machinery control stations

Two means of escape shall be provided from a machinery control station located within a machinery space at least one of which, as far as possible and practicable, should provide continuous fire shelter to a safe position outside the machinery space.

e) Access to vehicle spaces, ro-ro vehicle spaces or hangars

One of the escape routes from the machinery spaces where the crew is normally employed shall avoid direct access to any vehicle space, ro-ro vehicle space or hangar.

f) As far as practicable, two means of escape shall be provided from the main workshop within a machinery space. At least one of these escape routes shall provide a continuous fire shelter to a safe position outside the machinery space.

2.5 Means of escape from special purpose spaces

2.5.1 In vehicle spaces, ro-ro vehicle spaces or aircraft hangars, the number and disposition of means of escape both below and above the bulkhead deck shall be to the satisfaction of the Society and in general shall be at least equivalent to that provided for in items b), c), and e) of [2.4].

2.6 Means of escape from ammunition spaces

2.6.1 Ammunition spaces need not be provided with a second means of escape, if agreed by the Naval Authority, provided that either a hatch, a door, a ladder or a stairway provides a safe access from these spaces to an escape route.

3 Emergency escape breathing devices (EEBD)

3.1 Types of EEBD

3.1.1 The emergency escape breathing devices shall be of a type approved by the Society and shall comply with Ch 4, Sec 13.

3.2 Number of EEBD

3.2.1 There shall be at least 4 EEBDs in each main vertical zone.

3.2.2 In machinery spaces of category A, there shall be at least:

a) One EEBD in the engine control room or equivalent

b) One EEBD in the workshop areas

c) One EEBD on each deck or platform level, in the vicinity of the escape ladder or stairway which is not enclosed by A class divisions.

3.2.3 In other machinery spaces, there shall be at least one EEBD on each deck or platform level, in the vicinity of the escape ladder or stairway which is not enclosed by A class divisions.

3.2.4 One additional EEBD for training is to be provided and clearly marked as limited to training use only.

4 Arrangement of the means of escape

4.1 Details of stairways, ladders and deck hatches

4.1.1

a) The minimum net width of a ladder or stairway is the minimum clearance distance between:
   - its handrails when provided on both sides; and
   - its handrail and the first obstacle on the opposite side if provided with handrail on one side only.

b) Ladders shall have a minimum net width of 400 mm between its two vertical main frames.

c) Stairways are inclined ladders having angle not more than 62° from the horizontal and provided with handrails at least at one side

d) In machinery spaces, stairways having angle up to 70° from the horizontal may be permitted

e) If a stairway used on the escape routes is not enclosed by vertical A class divisions, the net width of the horizontal hatch is not to be less than the required net width of the associated stairway.

f) In addition, for a deck hatch, consideration may be given to the minimum net length in order that a fire-fighter with his complete equipment can easily pass through this deck hatch.

g) The hatches mentioned in [2.3.2] item f), and located in internal watertight decks are to be fitted with a coaming having a height of at least 50 mm.

   Other hatches located in internal watertight decks are to be fitted with coamings having a height of at least 50 mm, unless:
   - the hatch is normally closed in all operational conditions, or
   - the hatch is located on an escape route, and its coaming would be an obstacle to safe evacuation.

4.2 Width of escape routes

4.2.1 Main passageways as defined in Ch 4, Sec 1, [2.23.1], and doors included therein, including exit door leading to the evacuation station, are not to be less than 900 mm in net width.

In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per [4.6].

4.2.2 Other passageways used as escape route, and doors included therein, are not to be less than 700 mm net width.

In addition, the net width is not to be inferior to the width calculated as per the Fire Safety Systems Code, Ch 13 [2.1.2], considering the distribution of persons as per [4.6]. Doors, stairways and hatches along these passageways are to be sized in the same manner as the passageways.

Note 1: On a case by case basis, the width of hatches and associated ladders used solely as secondary means of escape may be reduced to the satisfaction of the Society.

4.2.3 Prohibition of decrease in width in the direction to the evacuation stations

The means of escape shall not decrease in width in the direction of evacuation to the evacuation stations. Where several evacuation stations are in one main vertical zone, the means of escape width shall not decrease in the direction of the evacuation to the most distant evacuation station.

4.3 Width of doors, hatches and corridors included in the means of escape

4.3.1 Corridors and intermediate landings included in means of escape are to be sized in the same manner as stairways.

4.3.2 The clear width of doors and hatches included in means of escape may be smaller than that of the passageways they serve, provided their clear width remains above the minimum clear width required for the associated passageway.

4.4 Evacuation stations

4.4.1 Evacuation stations arrangement

At least one evacuation station is to be provided for each vertical safety zone.

The number of crew and special persons onboard shall be distributed in all the evacuation stations. Each evacuation station shall have sufficient clear deck space to accommodate all the crew and special persons assigned to evacuate from that evacuation station, but at least 0,35 m^2 per person.

4.4.2 The evacuation stations may include spaces such as corridors, landings of stairway enclosures, accommodation and service spaces but an evacuation station is not to include a control station, a machinery space, an ammunition space or a vehicle or ro-ro space. In any case, a space which requires a key for access cannot be included in an evacuation station unless the key is enclosed in a beak-glass type enclosure conspicuously located and indicated near the normally locked access door.

4.5 Evacuation analysis and escape plan

4.5.1 Evacuation analysis

For ships which have a number of persons on board considered large by the Society, the escape routes may be evaluated by an evacuation analysis early in the design process. The analysis, carried out according to the indications of the Society, shall be used to identify and eliminate, as far as practicable, congestion which may develop during an emergency situation.

4.5.2 Means of escape plans

The ships shall be provided with means of escape plans indicating the following:

a) the number of the persons on board in all normal occupied spaces

b) the number of persons expected to escape by stairway, doors, horizontal hatches and corridors

c) primary and secondary means of escape

d) net widths of ladders, stairways, doors, horizontal hatches and corridors

e) evacuation stations arrangement

f) embarkation distribution on the ship.

4.6 Distribution of persons

4.6.1 For the application of the provision of the Fire Safety System Code, Chapter 13 [2.1.2.2.2.1], cases 1 and 2 are to be replaced by:

a) Case 1 (night-time)
   - the total number of the members of crew not operating by watch in its cabins and berthing
   - 2/3 of the members of the crew operating by watch in its cabins and berthing spaces, and
   - 1/3 of the crew operating by watch in its service spaces.

b) Case 2 (daytime)
   - 1/4 of the members of crew not operating by watch in its public spaces
   - 3/4 of the members of crew not operating by watch in its service spaces
   - 1/3 of the crew operating by watch in its cabins and berthing spaces
   - 1/3 of the crew operating by watch in its service spaces, and
   - 1/3 of the crew operating by watch in its public spaces.

Note 1: For the application of the provision of Fire Safety System Code, Chapter 13 [2.1.2.1.4], the number of persons to be distributed in each public space is to be proportional to the deck area of these public spaces, as per the following formula:

$n = N \quad a / A$

where:

N : Total number of persons to be distributed in the public spaces

a : Deck area of the selected public space

A : Total deck area of the public spaces available to the total number of persons to be distributed in the public spaces.

Note 2: Other cases of distribution of persons may be considered in replacement of, or in addition to, cases 1 and 2 above by more effective scenarios given by the Naval Authority.

5 Technical corridors

5.1

5.1.1 Technical corridors or technical galleries not serving as an escape route and not giving access to accommodation spaces, service spaces, control stations, vehicle and ro-ro spaces as mentioned in category (10) of Ch 4, Sec 5, [1.2.3], item b) 1), shall have a minimum net width in order to permit to one person to circulate along this corridor.

Section 9 Fire Control Plans

1 Fire control plans

1.1 Compilation of the fire control plans

1.1.1 General arrangement plans shall be permanently exhibited for the guidance of the crew, showing clearly for each deck the main vertical zones, the horizontal zones, the safety zones, the control stations, the various fire sections enclosed by A class divisions, the sections enclosed by B class divisions together with particulars of the fire detection and fire alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc. and the ventilating system including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section, and the position of fuel oil quick-closing valve remote control and fuel oil pump stops. Alternatively, at the discretion of the Society, the aforementioned details may be set out in a booklet, a copy of which shall be supplied to crew members, and one copy shall at all times be available on board in an accessible position. Plans and booklets shall be kept up to date, any alterations being recorded therein as soon as practicable. Description in such plans and booklets shall be in the official language of the Naval Authority. If the language of the Naval Authority is not English, a translation into such language is to be included.

Note 1: The graphical symbols for the fire control plan are to be in accordance with the following standards: IMO resolution A.952 and ISO 17631:2002.

1.1.2 For ships assigned the additional class notation CBRN, in line with the requirements of Part E, Chapter 8, the following elements are to be shown:

- citadel, sub-citadels and/or shelter
- storage location of personal protective equipment
- CBRN detection system
- pre-wetting and washdown system and associated control valves.

1.2 Location of the fire control plans

1.2.1 In all ships a duplicate set of fire control plans or a booklet containing such plans shall be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

Section 10 Helicopter Facilities

1 General

1.1 Application

1.1.1 In addition to complying with the requirements of other sections of this Chapter as appropriate, ships equipped with helideck with or without hangar, carrying in total no more than two helicopters, are to comply with the requirements of this section.

1.2 Definitions

1.2.1 Helideck

For the purpose of this section, helideck is a purpose-built helicopter landing area located on a ship including all structure, fire-fighting appliances and other equipment necessary for the safe operation of helicopters.

1.2.2 Helicopter facilities

Helicopter facilities is a helideck including any refuelling and hangar facilities.

2 Structure

2.1 Construction

2.1.1 The helideck(s) surfaces are to be insulated to A-60 class standard on parts not protected by a thick water system as defined in Pt E, Ch 11, Sec 2, [3.2.2] and located above spaces of category (1), (2), (3) or (4) in accordance with Ch 4, Sec 5, [1.2.3].

2.2 Means of escape

2.2.1 A helideck, is to be provided with both a main and an emergency means of escape and access for fire-fighting and rescue personnel; these are to be located as far apart from each other as is practicable and preferably on opposite sides of the helideck.

3 Fire-fighting appliances

3.1 General

3.1.1 In order to protect the helideck against a helicopter crash, the following fire-fighting appliances are to be provided and so arranged as to permit them to reach any part of the helideck:

Note 1: The fire-fighting appliances are to be capable of simple and rapid operation and, as far as practicable, are to be located outside the helideck and in any case, are to be located outside the landing area.

a) Powder system
   1) General
      A powder system which can be part of a twin agent system, powder and foam (monotubular or bitubular), is to be provided.
      This system is to have at least two self-contained dry chemical powder pressure vessels, with associated controls, pressurizing medium fixed piping and at least two monitors or applicator nozzles fitted with hand hose lines.
      The system is to be activated by inert gas stored in pressure vessel adjacent the powder container and is to be capable to deliver dry powder to all parts of the helicopter deck.
      The discharge of one of the powder container through one monitor or applicator is not to prevent a second discharge from another monitor or applicator.
   2) Monitors
      If provided, the capacity of each monitor is to be not less than 10 kg/s.
      Powder is to be delivered in less than 20 seconds after the release order.
      The quantity of chemical powder to be provided for each monitor is not to be less than the quantity required for 1 minute discharge time.
      The fixed monitor capacity is to be function of maximum coverage distance in compliance with type approved tests, as an example, for fixed monitors of capacity of: 10, 25 and 45 kg/s the maximum distance of monitor coverage could be respectively: 10, 30 and 40 m.
      The monitor throw in still air conditions is not to be less than the 1.3 times the maximum distance of the monitor from any part of the helideck.

3) Applicators

If provided, the hand hose lines are to be non-kinkable and fitted with a nozzle (applicator) of on/off operation and discharge at rate not less than 100 kg/min.

Powder is to be delivered in less than 20 seconds after the release order.

The quantity of chemical powder to be provided for all applicators is to be not less than the quantity required for 1 minute discharge time.

The length of a hand hose line is not to exceed 33 m.

The hand hose nozzle throw in still air is not to be less than 14 m.

b) Foam system

A foam system, which can be part of a twin agent system, powder and foam (monotubular or bitubular), is to be provided.

Note 2: Refer to the International Civil Aviation Organization Airport Services Manual, part 1, Rescue and Fire-Fighting, chapter 8, Extinguishing Agent Characteristics, paragraph 8.1.5, Foam Specifications table 8-1, level 'B'.

The foam forming liquid is to be of a type approved by the Society.

The foam is to be delivered by at least two monitors or applicator nozzles fitted with hand hose lines.

The supply rate of the foam is to be not less than 200 l/min and the quantity of the foam forming liquid to be provided is not to be less than the quantity required for 10 min discharge time.

Note 3: When it is possible to supply at the required flow rate both of the monitors or applicators subsequently from one foam container, the quantity of the foam forming liquid to be provided need not be greater than the quantity required for 10 min discharge time with one monitor or applicator.

The monitors or applicators are to produce low expansion foam with expansion ratio between 5:1 and 12:1. Other expansion ratios are to be to satisfaction of the Society.

The foam is to be delivered in less than 20 seconds after the release order.

If provided, the applicator throw in still air conditions is not to be less than 15 m.

If provided, the monitor throw in still air conditions is not to be less than 1,3 times the maximum distance of the monitor from any point of the helideck.

The containers of foam forming liquid is to be made of stainless steel or other resistant material.

c) Additional applicators

Two additional applicator nozzles provided with a hand hose line are to be provided. These applicators are to be capable of delivering foam or thick water to any part of the helideck.

The additional foam applicators are to be capable of delivering foam at a rate of not less than 400 l/min during at least 5 minutes or 200 l/min during at least 10 minutes.

The expansion ratio of the foam is to be between 5:1 and 12:1.

The supply rate of the thick water is not to be less than 500 l/min.

The AFFF concentration of the thick water is to be not less than 3%.

The maximum length of the hose lines is to be 30 m.

d) At least two nozzles of an approved dual purpose (jet/ spray) and hoses sufficient to reach any part of the helideck are to be provided. However, when applicators are provided for the purpose of the provisions a) and b) above, two additional hydrants are not necessary.

e) Portable extinguishers

Carbon dioxide extinguishers of a total capacity of not less than 18 kg or equivalent are to be provided.

f) Fire fighter outfits and rescue equipment

Fire fighter outfits and rescue equipment are to be provided, in number and type, and so arranged as to comply with the requirements of the Naval Authority.

3.1.2 In close proximity to the helideck, the following equipment are to be provided and stored in a manner that permits immediate use and provides protection from the elements:

- adjustable wrench
- blanket, fire resistant
- cutters, bolt 60 cm
- hook, grab or salving
- hacksaw, heavy duty complete with 6 spare blades
- ladder
- lift line 5 mm and 15 m in length
- pliers, side-cutting
- set of assorted screw drivers, and
- harness knife complete with sheath.

3.2 Drainage facilities

3.2.1 Drainage facilities in way of helidecks are to:

- be constructed of steel,
- lead directly overboard, and
- be designed so that drainage does not fall on to any part of the ship.

Where railways are provided for the handling of the helicopter, special consideration is to be given to preventing liquids to enter into the ship through such railways.

Note 1: The drainage system is not required to avoid the spilling on the hull sides of the ship.

3.2.2 Drainage facilities from helidecks are to be independent from any other system. Common scupper pipes between a flight deck or helideck and an aircraft hangar may however be accepted provided that water seals are provided in order to prevent the passage of flammable vapours or liquid from the hangar to the flight deck and reverse.

Where water seals are installed:

- the water seals are to be capable of preventing the passage of vapours and liquids at a pressure corresponding to the maximum expected water column under normal operating conditions
- alarms on the low level of water in the water seal are to be provided at the damage control station.

4 Helicopter refuelling and hangar facilities

4.1 Fuel storage system

4.1.1 Storage area

The fuel oil for refuelling helicopters are to either have a flash point greater than 60°C, or be JP5-NATO (F44). In the present Section, the words “JP5” or “JP5-NATO (F44)” are to be interpreted as “the fuel used for the helicopters”.

Such fuel is to be stored in structural tanks as required in Part C, Chapter 1 for ship fuel oil systems.

A designed area is to be provided for the storage of fuel tanks which is to be as remote as possible from the accommodation spaces, service spaces, control stations and escape routes and evacuation stations. The fuel storage area is to be provided with arrangements whereby fuel spillage may be collected and drained to a safe location and isolated from any source of ignition.

The fuel pumping system is to incorporate a device which will prevent over-pressurization of the delivering hose.

Fixed arrangements are to be provided at the refuelling station for filtering and sampling.

4.1.2 Fuel tanks

a) Tanks and associated equipment are to be protected against physical damage and from a fire in an adjacent space or area.

b) The location of JP5 fuel tanks is to be in compliance with the requirements of Pt B, Ch 2, Sec 2. No openings are to be arranged between accommodation or service spaces and a JP5 fuel tank. On a case-by-case basis, gastight openings permanently closed at sea may be accepted between a JP5 tank and a space located directly above.

c) Where portable fuel storage tanks are used, special attention is to be given to:
   - design of the tank for its intended purpose
   - mounting and securing arrangements
   - electric bonding, and
   - inspection procedures.

4.1.3 Fuel pumping

a) Storage tank fuel pumps are to be provided with means which permit shutdown from a safe remote location in the event of fire. Gravity fed fuelling systems are not permitted.

b) The fuel pumping unit is to be connected to one tank at a time. The piping between the tank and the pumping unit is to be of steel or equivalent material, as short as possible, and protected against damage.

c) Electrical fuel pumping units and associated control equipment are to be of a type suitable for the location and potential hazards.

d) Fuel pumping units are to incorporate a device which will prevent over-pressurization of the delivery or filling hose.

4.1.4 Refuelling equipment

All equipment used in refuelling operations is to be electrically bonded. Measures related to the limitation of the production of electrostatic energy in JP5 spaces are to be taken.

In general, JP5 piping is not to pass through accommodation spaces, service spaces and control stations. When this is not possible, specific arrangement are to be submitted to the Society to avoid the flammable vapours in the concerned spaces. Means are to be provided in order to purge the piping after use.

4.2 “No smoking” signs

4.2.1 "No smoking" signs are to be displayed at appropriate locations.

4.3 Hangar, refuelling stations, refuelling and maintenance facilities

4.3.1 In general, refuelling operations are to be carried out on an open deck that is to be arranged and treated for fire protection purposes as a ship fuel filling station. In addition, the connection to the fuel piping is to be located outside of the hangar.

If refuelling is not carried out on an open deck or if the connection to the fuel piping is located inside the hangar, the helicopter hangar as well as the refuelling and maintenance facilities are to be treated as category A machinery spaces with regard to structural fire protection, fixed fire-extinguishing and detection system requirements, and electrical equipment is to comply with [4.3.2].

Note 1: In this Section, the terms "refuelling station", "refuelling installation" and "maintenance facilities" mean the spaces containing the fuel pumps and piping and associated connected equipment and do not include the spaces dedicated to the storage of refuelling equipment such as fuel hoses and nozzles which do not have a permanent connection to the fuel piping.

4.3.2 Electrical equipment and wiring

When the refuelling is intended to be carried out inside the hangar, electrical equipment and wiring inside the hangar are to be of safety type as applicable to ro-ro spaces in compliance with Ch 4, Sec 12, [2.2].

When refuelling is performed on open deck only, notwithstanding the requirements of Ch 4, Sec 12, [2.2] and Ch 4, Sec 12, [2.3], standard marine electrical equipment may be used.

Standard marine electrical equipment may be used in the refuelling station.

4.3.3 Manually operated call points are to be provided close to the exit of the JP5 pump room and helicopter hangar.

4.4 Ventilation

4.4.1 Enclosed hangar facilities or enclosed spaces containing refuelling installation are to be provided with mechanical ventilation as required in Ch 4, Sec 12, [2.1] and according to the definition of Ch 4, Sec 1, [2.30] if the hangar falls under the definition of a "enclosed ro-ro space" and Ch 4, Sec 1, [2.37] if the hangar falls under the definition of a "enclosed vehicle space".

4.4.2 When the refuelling is intended to be carried out inside the hangar, ventilation fans are to be of non sparking type.

5 Operations manual

5.1 General

5.1.1 Each helicopter facility is to have an operations manual, including a description and a checklist of safety precautions, procedures and equipment requirements. This manual may be part of the ship's emergency response procedures.

Section 11 Alternative Design and Arrangements

1 General

1.1

1.1.1 The Society may consider designs and arrangements deviating from the prescriptive requirements set out in the present chapter provided they are deemed to provide an equivalent level of fire safety, in line with the equivalence principle given in Pt A, Ch 1, Sec 1, [2.2]. Alternative fire protection, detection and extinction arrangements may be required to be assessed according to IMO Circular MSC.1/Circ.1002 as amended.

Section 12 Protection of Vehicle and Ro-ro Spaces

1 General

1.1 Application

1.1.1 The fuel used by any vehicle using internal combustion engines such as tenders, rescue boats, operational boats, landing barges, road cars, maintenance carts, aircraft and helicopter carts, fire-fighting trucks or aircrafts and helicopters stowed in a vehicle or ro-ro space shall have a flash point greater than 60°C.

1.1.2 In addition to complying with the requirements of this Section, vehicle and ro-ro spaces shall comply also with the requirements of other sections of this Chapter as appropriate.

1.2 Basic principle

1.2.1 The basic principle underlying the provisions of this section is that the normal main vertical zoning required by Ch 4, Sec 5, [1] may not be practicable in vehicle and ro-ro spaces. Therefore, equivalent protection must be obtained in such spaces on the basis of the horizontal zone concept and by the provision of an efficient fixed fire-extinguishing system. Based on this concept, a horizontal zone may include vehicle and ro-ro spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10 m.

1.2.2 The requirements of ventilation systems, openings in "A" class divisions and penetrations in "A" class divisions for maintaining the integrity of vertical zones in this Chapter shall be applied equally to decks and bulkheads forming the boundaries separating horizontal zones from each other and from the remainder of the ship.

2 Precaution against ignition of flammable vapours in closed vehicle and ro-ro spaces

2.1 Ventilation systems

2.1.1 Capacity of ventilation systems

There shall be provided an effective power ventilation system sufficient to give at least the following air changes:

- closed ro-ro spaces: 10 air changes per hour
- closed vehicle spaces: 6 air changes per hour
- during refuelling operations, operation of power cell loading of the batteries of electrical motors, process requiring to start the internal combustion engines of the vehicles inside a closed ro-ro spaces: 15 air changes per hour.

2.1.2 Performance of ventilation systems

a) The power ventilation system required in [2.1.1] for vehicle and ro-ro spaces shall be entirely separated from other ship ventilation systems and shall be in operation at all times when vehicles are in such spaces.

   Ventilation ducts serving such spaces, capable to be sealed, shall be separated for each space. The system shall be capable of being controlled locally from a position outside such spaces and from the continuously manned damage control station.

b) The ventilation system shall be such as to prevent air stratification and the formation of air pockets.

c) Fans are to be of non-sparking type.

2.1.3 Indication of ventilation systems

Means shall be provided to indicate in the continuously manned damage control station any loss of the required ventilating capacity.

2.1.4 Closing appliances and ducts of openings in ventilation systems of vehicle and ro-ro spaces

a) Arrangements shall be provided to permit a rapid shut-down and effective closure of the ventilation system from outside the space in case of fire, taking into account the weather and sea conditions.

b) Ventilation ducts, including dampers, within a common horizontal zone shall be made of steel. Ventilation ducts that pass through other horizontal zones or machinery spaces shall be A-30 class steel ducts constructed in accordance with Ch 4, Sec 5, [6.3.1].

2.2 Electrical equipment and wiring

2.2.1 Electrical equipment and wiring, if installed in vehicle and ro-ro spaces, shall be of a safety type suitable for use in an explosive petrol and air mixture.

2.2.2 In case of vehicle spaces above the bulkhead deck, notwithstanding the provisions in [2.2.1], above a height of 450 mm from the deck and from each platform of vehicles, if fitted, except platforms with openings of sufficient size permitting penetration of petrol gases downwards, electrical equipment of a type so enclosed and protected as to prevent the escape of sparks shall be permitted as an alternative.

2.3 Electrical equipment and wiring in exhaust ventilation ducts

2.3.1 Electrical equipment and wiring, if installed in ventilation ducts of vehicle and ro-ro spaces shall be of a safety type approved suitable for use in an explosive petrol and air mixture and the outlet from any exhaust duct shall be located in a safe position having regard to other possible sources of ignition.

2.4 Other electrical ignition sources

2.4.1 Other equipment which may constitute a source of ignition of flammable vapours is not permitted. However, power cell loading operations may be permitted in ro-ro spaces for recharging the batteries of electrical motors of maintenance vehicles, provided that the requirements of a battery room, as described in Ch 4, Sec 5, [6.8.3], Ch 2, Sec 3, [10.3] and Ch 2, Sec 11, [6.5], are complied with in the space where such operations are proceeded.

2.5 Scuppers and discharge

2.5.1 Scuppers shall not be led to machinery or other spaces where sources of ignition may be present.

Scuppers shall be made of steel.

3 Fire detection and alarm

3.1 Fixed fire detection and fire alarm systems

3.1.1 There shall be provided a fixed fire detection and fire-alarm system complying with the requirements of Ch 4, Sec 13. The fixed fire detection system shall be capable of rapidly detecting the onset of fire. The type of detectors and their spacing and location shall be to the satisfaction of the Society taking into account the effects of ventilation and other relevant factors. After being installed, the system shall be tested under normal ventilation conditions and shall give an overall response time to the satisfaction of the Society.

3.2 Manually operated call points

3.2.1 Manually operated call points shall be provided as necessary throughout the vehicle and ro-ro spaces so that no part of the space is more than 20 m from a manually operated call point and one shall be placed close to each exit from such spaces.

4 Fire extinction

4.1 Fixed fire-extinguishing systems

4.1.1 Vehicle and ro-ro spaces shall be fitted with a fixed high expansion foam fire-extinguishing system complying with Ch 4, Sec 13, [6.1.2] or a fixed water spraying system complying with Ch 4, Sec 13, [7.1] or a thick water system complying with Ch 4, Sec 13, [7.4].

Where necessary, the non accessible parts of vehicle and ro-ro spaces, such as spaces below gratings or platforms, shall be provided with a low expansion fire-extinguishing system complying with the requirement of Ch 4, Sec 13, [6.1.3].

As an alternative, upon agreement by the Society and upon full scale tests, in conditions simulating a flowing fuel oil fire in vehicle and ro-ro spaces or aircraft hangars, have shown not to be less effective of previous systems, one of the following systems may be fitted:

- an approved fixed clean agent fire-extinguishing system
- an approved water based fire-extinguishing system.

Furthermore, upon agreement by the Society, it may be fitted:

- in vehicle and ro-ro spaces capable of being sealed from a location outside the space, a carbon dioxide system shall be provided for each protected spaces. Its arrangements shall be such as to ensure that at least 2/3 of the gas required for the space is introduced in 10 minutes, to ensure that the quantity of gas available is at least sufficient to give a minimum volume of free gas of 45% of the gross volume of the space and shall comply with the provisions of Ch 4, Sec 13.

4.1.2 When fixed high expansion foam fire-extinguishing systems, pressure water-spraying fire-extinguishing systems, or thick water systems are provided, in view of the serious loss of stability which could arise due to the large water or high expansion foam or thick water quantities accumulating on deck or decks during the operation of the fire-extinguishing system, the following arrangement is to be provided:

a) In the vehicle and ro-ro spaces located above the bulkhead deck, scuppers, complying with IMO Circular MSC.1/Circ.1320, are to be fitted so as to ensure that such water or high expansion foam or thick water is rapidly discharged directly overboard.

Discharge valves for scuppers are to be provided and fitted with positive means of closing operated from above the damage control deck as mentioned in Pt B, Ch 1, Sec 2, [6.5.1] and above the "V" lines as defined in Pt B, Ch 1, Sec 2, [3.2.3] and Pt B, Ch 3, App 4, and are to be kept open while the ship is at sea.

An indication is to be provided in the damage control station and in the bridge to indicate whether those valves are open or closed and an alarm is to provide a visual and audible warning when the fixed fire-extinguishing system is operating and the valves referred above are closed. Any operation of valves referred in the item just above are to be recorded in the log-book.

b) In the spaces below the bulkhead deck, the Society may require pumping and drainage facilities to be provided in addition to the requirement of Ch 1, Sec 10. In such case, the drainage system is to be sized to remove no less than 125% of the combined capacity of both the fixed fire-extinguishing system pumps and the required number of fire hose nozzles, according to IMO Circular MSC.1/Circ.1320. The drainage system valves are to be operable from outside the protected space at a position in the vicinity of the fire-extinguishing system controls. Bilge wells are to be of sufficient holding capacity and are to be arranged at the side shell of the ship at a distance from each other of not more than 40 m in each watertight compartment.

4.1.3 Foam monitors may be fitted inside aircraft hangars in addition to the system required by the provisions of [4.1.1].

4.2 Portable fire extinguishers

4.2.1 Portable fire extinguishers shall be provided at each deck level in each hold or compartment where vehicles are carried, spaced not more than 20 m apart on both sides of the space. At least one portable extinguisher shall be located at each access to such a space.

4.2.2 In addition to the provision of [4.2.1], one foam applicator unit complying with the provisions of Ch 4, Sec 13 shall be provided, provided that at least two such units are available in the ship for use in such spaces.

Section 13 Fire Safety Systems

1 General

1.1 Application

1.1.1 This Section applies to fire safety systems as referred to in the Rules.

1.1.2 Piping systems included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 10, unless otherwise specified in the present section.

1.1.3 Pressure vessels included in fire safety systems covered by this Section are to comply with the requirements of Ch 1, Sec 3, unless otherwise specified in the present section.

2 International shore connection and Stanag 1169

2.1 Engineering specifications for international shore connection

2.1.1 Standard dimensions

Standard dimensions of flanges for the international shore connection shall be in accordance with Tab 1 (see also Fig 1).

Figure 1 : International shore connection

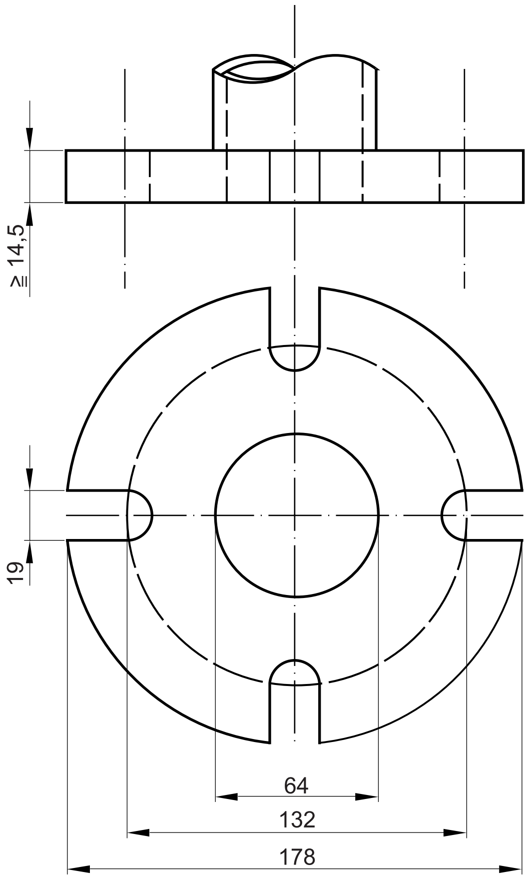


Table 1 : Standard dimensions

Description	Dimension
Outside diameter	178 mm
Inside diameter	64 mm

Description	Dimension
Bolt circle diameter	132 mm
Slots in flange	4 holes 19 mm in diameter spaced equidistantly on a bolt circle of the above diameter, slotted to the flange periphery
Flange thickness	14,5 mm minimum
Bolts and nuts	4, each of 16 mm diameter, 50 mm in length

2.1.2 Materials and accessories

The connection shall be of steel or other suitable material and shall be designed for 1,0 MPa services. The flange shall have a flat face on one side and on the other shall be permanently attached to a coupling that will fit the ship's hydrant and hose. The connection shall be kept aboard the ship together with a gasket of any material suitable for 1,0 MPa services, together with four bolts of 16 mm diameter and 50 mm in length, four nuts of 16 mm diameter, and eight washers.

2.1.3 The ship shall be provided also with a connection complying with standard Stanag 1169.

3 Personnel protection and emergency escape breathing devices

3.1 Engineering specifications

3.1.1 General

The breathing apparatus, axe in the stowage place of firefighter's equipment in each safety zone as well as the protective clothing, boots and gloves, rigid helmet and electric safety lamp of personal equipment, shall be in accordance with the requirement of the standards of the Naval Authority.

In absence of such standards the following [3.1.2] shall be complied with.

3.1.2 Personnel protection and other fittings

A firefighter's outfit shall consist of a set of personal equipment and a breathing apparatus.

a) Personal equipment

   Personal equipment shall consist of the following:

   1) Protective clothing of material to protect the skin, from the heat radiating from the fire and from burns and scalding by steam. The outer surface shall be water-resistant

   2) boots and gloves of rubber or other electrically non-conducting material, suitable for the maximum voltage installed on the ship

   3) rigid helmet providing effective protection against impact

   4) electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours, and

   5) axe with handle provided with high-voltage insulation.

b) Breathing apparatus

   A breathing apparatus of approved type is either a self-contained compressed air-operated, the volume of air contained in its cylinders is at least 1200 l, or another self-contained breathing apparatus capable of functioning for at least 30 minutes. Two complete spare sets shall be provided for each breathing apparatus. In addition, for each safety zone, a refilling station for the bottles of breathing apparatuses shall be provided capable of being put in use within 30 minutes.

c) For each breathing apparatus a fireproof lifeline of at least 30 m in length shall be provided. The lifeline shall successfully pass an approval test by statical load of 3.5 kN for 5 min without failure. The lifeline shall be capable of being attached by means of a snap-hook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the lifeline is operated.

3.1.3 Emergency escape breathing devices (EEBD)

a) The EEBD shall consist of a head covering which completely covers the head, the neck and may cover portions of the shoulders (hood piece).

b) The EEBD shall be supplied with breathable or oxygen air and shall have a service duration of at least 10 minute.

c) The hood piece shall be constructed of flame resistant materials and shall include a clear window for viewing.

d) When inactivated the EEBD shall be capable of being carried hands-free.

4 Portable fire-extinguishing appliances

4.1 Engineering specifications

4.1.1 Fire extinguisher

a) Safety requirements

Fire extinguishers are not permitted if they contain an extinguishing medium which, in the opinion of the Society, either by itself or under the expected conditions of use, gives off toxic gases in such quantities as to endanger persons or which is an ozone depleting substance.

b) Quantity of medium

1) The fire-extinguishing capability of a fire extinguisher shall be at least equivalent to that of a 9 l fluid extinguisher.

   Each power or carbon dioxide extinguisher is to have a capacity of at least 5 kg.

2) Other fire extinguishers may be accepted if considered equivalent by the Society.

4.1.2 Portable foam applicators

a) A portable foam applicator unit shall consist of a foam nozzle/branch pipe, either of a self-inducing type or in combination with a separate inductor, capable of being connected to the fire main by a fire hose, together with a portable tank containing at least 20 l of foam concentrate and at least one spare tank of foam concentrate of the same capacity.

b) System performance

1) The nozzle/branch pipe and inductor shall be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution flow rate of at least 200 l/min at the nominal pressure in the fire main.

2) The foam concentrate shall be approved.

3) The values of the foam expansion and drainage time of the foam produced by the portable foam applicator unit shall not differ more than ± 10% of that determined in item 2).

4) The portable foam applicator unit shall be designed to withstand clogging, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on ships

5 Fixed gas fire-extinguishing systems

5.1 Engineering specifications

5.1.1 General

a) Fire-extinguishing medium

1) The use of a fire-extinguishing medium which, in the opinion of the Society or the Naval Authority, either by itself or under the expected condition of use gives off toxic gas in such quantities as to endanger persons is forbidden. In any case when a fixed gas fire-extinguishing system is installed the provisions of this Article shall be complied with.

2) Where the quantity of the fire-extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected. The system shall be fitted with normally closed control valves arranged to direct the agent into the appropriate space. Adjacent spaces with independent ventilation systems not separated by at least A-0 class divisions should be considered as the same space.

3) Where the volume of free air contained in air receivers in any space is such that, if released within that space, it would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium is to be provided.

   To this end the volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively, a discharge pipe from the safety valves may be fitted and led directly to the open air.

4) Means shall be provided for the crew to safely check the quantity of medium in the containers. It shall not be necessary to move the containers completely from their fixing position for this purpose. For carbon dioxide systems, hanging bars for a weighing device above each bottle row, or other means shall be provided. For other types of extinguishing media, suitable surface indicators may be used.

5) Containers for the storage of fire-extinguishing medium and associated pressure components shall be designed to pressure codes of practice to the satisfaction of the Society, having regard to their locations and maximum ambient temperatures expected in service.

b) Installation requirements

1) The piping for the distribution of fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained. System flow calculations shall be performed using a calculation technique acceptable to the Society.

In machinery spaces, the discharge nozzles are to be positioned in the upper and lower parts of these spaces.

2) Except as otherwise permitted by the Society, pressure containers required for the storage of fire-extinguishing medium, other than steam, shall be located outside protected spaces in accordance with Ch 4, Sec 6, [3.3].

3) The storage of the fire-extinguishing medium is not permitted within spaces which may contain air/flammable gas mixtures.

4) In piping sections where valve arrangements introduce sections of closed piping, such sections shall be fitted with a pressure relief valve and the outlet of the valve shall be led to open deck.

5) All discharge piping, fittings and nozzles in the protected spaces shall be constructed of materials having a melting temperature which exceeds 925°C. The piping and associated equipment shall be adequately supported.

Note 1: Gaskets used in discharge piping inside protected spaces need not be constructed of materials having a melting temperature which exceeds 925°C.

6) A fitting shall be installed in the discharge piping to permit the air testing as required in [5.1.3], item g).

c) System control requirements

1) The necessary pipes for conveying fire-extinguishing medium into protected spaces shall be provided with control valves so marked as to indicate clearly the space to which the pipes are led. Suitable provision shall be made to prevent inadvertent release of the medium into the space.

The pipes may pass through accommodation areas provided that they are of substantial thickness and that their tightness is verified with a pressure test, after their installation, at a pressure head not less than 5 N/mm^2. In addition, pipes passing through accommodation areas shall be joined only by welding and shall not be fitted with drains or other openings within such spaces.

The pipes shall not pass through refrigerated spaces.

Control valves are to be capable of local operation.

The open or closed position of control valves is to be indicated.

Means are to be provided in order to permit the blowing through each branch line of the piping system downstream of the master (control) valves.

2) Means shall be provided for automatically giving visual and audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms should be distinguished from other audible alarms by adjustment of sound pressure or sound patterns.

The pre-discharge alarm shall be automatically activated (e.g. by opening of the release cabinet door). The alarm is to sound for the length of time needed to evacuate the space, but in no case less than 20 seconds before the medium is released.

Where audible alarms are fitted to warn of the release of fire-extinguishing medium into pump rooms, they may be of the pneumatic or electrical type:

- Pneumatically operated alarms

  The alarms may be operated by the fire-extinguishing medium or by clean and dry air.

- Electrically operated alarms

  When electrically operated alarms are used, the arrangements should be such that the electrical actuating mechanism is located outside the pump room except where the alarms are certified intrinsically safe.

  Electrically operated alarms are to be supplied from the main and an emergency source of power. They are to differ from other signals transmitted to the protected space.

3) The means of control of any fixed gas fire-extinguishing system shall be readily accessible, simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel.

4) Automatic release of fire-extinguishing medium shall not be permitted, except as allowed by the Society, under request of Naval Authority. In such case, the provision of [5.1.4] are to be complied with.

5.1.2 Carbon dioxide systems - General

a) Quantity of fire-extinguishing medium

1) For machinery spaces the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:

- 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lower part of the casing, or

- 35% of the gross volume of the largest machinery space protected, including the casing.

  In the calculation of 35% of the above mentioned volume, the net volume of the funnel shall be considered up to a height equal to the whole casing height if the funnel space is in open connection of closing means.

2) For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m3/kg.

3) For machinery spaces, the fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 minutes.

b) Controls

1) Carbon dioxide systems shall comply with the following requirements:

- two separate controls shall be provided for releasing carbon dioxide into a protected space and to ensure the activation of the alarm. One control shall be used for opening the valve of the piping which convey the gas into the protected space and a second control shall be used to discharge the gas from its storage containers. Positive means shall be provided so they can only be operated in that order; and

Note 1: The "positive means", referred to for the correct sequential operation of the controls, is to be achieved by a mechanical and/or electrical interlock that does not depend on any operational procedure to achieve the correct sequence of operation.

- the pre-discharge alarm may be activated before the two separate system release controls are operated (e.g. by a micro-switch that activates the pre-discharge alarm upon opening the release cabinet door as per [5.1.1], item c) 2). Therefore, the two separate controls for releasing carbon dioxide into the protected space (i.e. one control to open the valve of the piping which conveys the gas into the protected space and a second control used to discharge the gas from its storage containers) as per item b) 1) above can be independent of the control for activating the alarm.

  A single control for activation of the alarm is sufficient.

- the two controls shall be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box shall be located in a break-glass type enclosure conspicuously located adjacent to the box.

5.1.3 High-pressure carbon dioxide systems

a) The system is to be designed for an ambient temperature range of 0°C to 55°C, as a rule.

b) Containers for the storage of the fire-extinguishing medium are to be designed and tested in accordance with the relevant requirements of Part C, Chapter 1.

c) The filling ratio of carbon dioxide bottles is to be normally 0,67 kg/l, or less, of the total internal volume. However, for bottles to be fitted in ships which are to operate solely outside the tropical zone, the filling ratio may be up to 0,75 kg/l.

d) Piping and accessories are to generally satisfy the relevant requirements of Part. C, Chapter 1.

e) For systems where carbon dioxide is stored at ambient temperature, the thickness of steel pipes is not to be less than the values given in Tab 2.

   Slightly smaller thicknesses may be accepted provided they comply with the standards of the Naval Authority.

   The thickness of threaded pipes is to be measured at the bottom of the thread.

f) Pipes are to be appropriately protected against corrosion. Steel pipes are to be, at least, zinc or paint coated, except those fitted in machinery spaces, upon acceptance of the Society.

g) After mounting onboard, and in complement to tests and inspections at the Manufacturer's workshop, as per requirements of Part C, Chapter 1, carbon dioxide pipes and their accessories are to undergo the following tests:

1) pipe lengths between bottles and master valves:

   a hydraulic test, at the workshop or on board, at 128 bar. When the hydraulic test is carried out at the workshop, at least test with inert gas or air, at 7 bar, is to be carried out on board

2) pipe lengths between master valves and nozzles:

   a hydraulic test on board with inert gas or air, at 7 bar

3) master valves:

   a hydraulic test at 128 bar

4) a test of the free air flow in all pipes and nozzles; and

5) a functional test of the alarm equipment

5.1.4 Automatic local carbon dioxide systems for engines inside box and for unmanned rooms for switch boards or electronic or informatic equipment

The carbon dioxide bottles may be positioned inside or outside the box or the room.

The quantity of carbon dioxide inside the bottles shall be sufficient to give a minimum volume of free gas equal to 40 per cent of the gross volume of the box containing the engine(s) or of the room.

For the purpose of this item the volume of free carbon dioxide shall be calculated at 0,56 m^3/kg.

The manual or automatic release of the medium shall activate visual and audible alarms inside and outside the box or the room and in the continuously manned damage control station.

In case of access in the box or in the room the discharge of the system is to be intercept. A notice on the access door is to be fitted for such purpose.

Table 2 : Minimum wall thickness for steel pipes for CO_2 fire-extinguishing systems

External diameter of pipes (mm)	Minimum wall thickness, in mm	
	From bottles to distribution station	From distribution station to nozzles
21,3 - 26,9	3,2	2,6
30,0 - 48,3	4,0	3,2
51,0 - 60,3	4,5	3,6
63,5 - 76,1	5,0	3,6
82,5 - 88,9	5,6	4,0
101,6	6,3	4,0
108,0 - 114,3	7,1	4,5
127,0	8,0	4,5
133,0 - 139,7	8,0	5,0
152,4 - 168,3	8,8	5,6

5.1.5 Semi-fixed carbon dioxyde systems

A semi-fixed carbon dioxyde system is to consist of an applicator nozzle connected by a hose line to carbon dioxyde containers provided for the storage of the fire-extinguishing medium.

The location of any semi-fixed carbon dioxyde system is to be to the satisfaction of the Society. In any case, such systems are not to be fitted in accommodation and service spaces and control rooms.

The length of the hose line is not to exceed 33 m.

The applicator nozzle is to be of an on/off type.

Each container is to be designed and tested in accordance with the relevant requirements of Ch 1, Sec 3, and is to be fitted with a safety valve calibrated at a pressure in accordance with the location and the maximum ambient temperature expected. Furthermore, this safety valve is to be provided with a discharge pipe to the open air in accordance with Ch 4, Sec 6, [3.3.1].

5.2 Equivalent fixed gas extinguishing systems

5.2.1 Fixed gas fire-extinguishing systems equivalent to those specified in [5.1] are to be specially considered by the Society.

Note 1: Refer to IMO MSC/Circ 848 as amended by Circ.1267 for the approval of equivalent fixed gas fire-extinguishing systems.

6 Fixed foam fire-extinguishing systems

6.1 Engineering specifications

6.1.1 General

Fixed foam fire-extinguishing systems shall be capable of generating foam suitable for extinguishing oil fires.

6.1.2 Fixed high expansion foam fire-extinguishing systems

The fixed high expansion foam fire-extinguishing systems are to be designed, installed and tested in accordance with the requirement of Ch 6, §3 of IMO FSS Code, as amended.

6.1.3 Fixed low expansion foam fire-extinguishing systems

a) Quantity and performance of foam concentrates

   1) The foam concentrates of low-expansion foam fire-extinguishing systems shall be approved by the Society based on IMO MSC.1/Circ.1312, as amended.

   2) The system shall be capable of discharging through fixed discharge outlets in not more than five minutes a quantity of foam sufficient to cover to a depth of 150 mm the area over which fuel oil is liable to spread. The foam concentrate is to be enough for two discharges required for the protected area. The expansion ratio of the foam shall not exceed 12 to 1.

b) Installation requirements

1) Means shall be provided for effective distribution of the foam through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the foam to be effectively directed by fixed sprayers on the main fire hazards in the protected space. The means for effective distribution of the foam are to be proven acceptable to the Society through calculation or by testing.

2) The means of control of any such systems shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

7 Fixed pressure water-spraying, thick water and water-based fire-extinguishing systems

7.1 Fixed pressure water spraying fire-extinguishing systems

7.1.1 General requirements for all systems

a) The number and arrangement of the nozzles of any required fixed pressure water-spraying fire-extinguishing system in machinery spaces and service spaces shall be to the satisfaction of the Society and shall be such as to ensure an effective average distribution of water of at least 5 l/m^2/min in the spaces to be protected. Where increased application rates are considered necessary, these shall be to the satisfaction of the Society.

b) The number and arrangement of the nozzles of any required fixed pressure water-spraying fire-extinguishing system in vehicle and ro-ro spaces and ammunition spaces are to be such as to ensure an effective average distribution of water

- for ammunition spaces:
  - as per requirements of Ch 4, Sec 6, [6.1]; and
- for vehicle and ro-ro spaces:
  - as per requirement of [7.1.3]

c) Precautions shall be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of piping, nozzles, valves and pump.

d) The nozzles should be manufactured and tested based on the relevant sections of appendix A to circular MSC/Circ.1165, as amended.

e) The pressure water-spraying systems protecting the ammunition spaces are to be fed by the fire main.

7.1.2 Installation requirements for machinery spaces

a) Nozzles shall be fitted above bilges, tank tops and other areas over which fuel oil is liable to spread and also above other specific fire hazards in the machinery spaces.

b) The system may be divided into sections, the distribution valves of which shall be operated from easily accessible positions outside the spaces to be protected and will not be readily cut off by a fire in the protected space.

c) if the water-spraying fire-extinguishing system is not fed by the fire main the following requirements shall be complied with:

- the pump shall be capable of simultaneously supplying at the necessary pressure all sections of the system in any one compartment to be protected.
- the pump may be driven by independent internal combustion machinery but, if it is dependent upon power being supplied from the secondary generator unit fitted in compliance with the provisions of Ch 1, Sec 2, Part C, Chapter 2 as appropriate, that generator shall be so arranged as to start automatically in case of main power failure so that power for the pump is immediately available. The independent internal combustion machinery for driving the pump shall be so situated that a fire in the protected space or spaces will not affect the air supply to the machinery.
- The pump and its controls shall be installed outside the space(s) to be protected. It shall not be possible for a fire in the space(s) protected by the water-spraying system to put the system out of action.

d) The system shall be kept charged at the pressure and the pump supplying the water for the system shall be put automatically into action by a pressure drop in the system.

7.1.3 Installation requirements for vehicle and ro-ro spaces

a) The fixed pressure water-spraying system is to be designed, installed and tested in accordance with MSC.1/Circ.1430, as amended.

b) In any case, the fire main is to be connected to the fire-extinguishing system of the space to be protected by an isolating valve complying with the provisions of Ch 4, Sec 6, [1.2.4].

7.2 Fixed water-based local application fire-fighting systems

7.2.1 Fixed water-based local application fire-fighting systems are to be approved by the Society based on IMO Circular MSC.1/Circ.1387 as corrected by MSC.1/Circ.1387/Corr.1.

7.3 Equivalent water-based fire-extinguishing systems for machinery spaces and fuel or JP5-NATO (F44) pump rooms

7.3.1 Water-based fire-extinguishing systems for machinery spaces and fuel pump rooms are to be approved by the Society in compliance with the following requirements:

a) The system should be capable of manual release.

b) The system are to be capable of fire extinction, and tested to the satisfaction of the Society in accordance with Appendix B of IMO MSC/Circular1165, as amended.

c) The system shall be available for immediate use and capable of continuously supplying water for at least 30 minutes in order to prevent re-ignition or fire spread within that period of time. Systems which operate at a reduced discharge rate after the initial extinguishing period shall have a second full fire-extinguishing capability available within a 5-minute period of initial activation.

d) The system and its components shall be suitably designated to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in machinery spaces, or fuel or JP5-NATO (F44) pump-rooms, of ships; system components within the protected spaces shall be designed to withstand the elevated temperatures which could occur during a fire.

e) The system and its components shall be designed and installed in accordance with international standards acceptable to the Society and manufactured and tested to the satisfaction of the Society in accordance with appropriate elements of Appendices A and B to IMO MSC/Circular1165.

f) The nozzles location, type of nozzle and nozzle characteristics shall be within the limits tested to provide fire extinction as referred in the previous item b).

g) The electrical components of the pressure source for the system shall have a minimum rating of IP54. The system shall be supplied by at least two of the ship's electrical switchboards which cannot be put out of service in any event at the same time.

h) The system shall be provided with a redundant means of pumping or otherwise supplying the water-based extinguishing medium. The capacity of the redundant means should be sufficient to compensate for the loss of any single supply pump. Failure of any one component in the power and control system should not result in a reduction of required pump capacity. Primary pump starting equipment may be manual or automatic. Switch over to redundant means of pumping may be manual or automatic.

   The system shall be fitted with a permanent sea inlet and be capable of continuous operation using seawater.

i) The piping system shall be sized in accordance with an hydraulic calculation technique such as the Hazen-Williams Method with the following values of the friction factor "C" for different pipe types which may be considered should apply:
   - pipes in black or galvanized mild steel: C = 100
   - pipes in copper or in copper alloys: C = 150
   - pipes in stainless steel: C = 150

j) Systems capable of supplying water at the full discharge rate for 30 minutes may be grouped into separate sections within a protected space. The sectioning of the system within such spaces shall be approved by the Society in each case.

k) In all cases the capacity and the design of the system should be based on the complete protection of the space to be protected by the system demanding the greatest volume of water.

l) The system operation controls shall be available at easily accessible positions outside the spaces to be protected and from the continuously manned damage control station and shall not be liable to be cut off by a fire in the protected spaces.

m) Pressure source components of the system shall be located outside the protected spaces.

n) A means for testing the operation of the system for assuring the required pressure and flow shall be provided.

o) Activation of any water distribution valve shall give a visual and audible alarm in the protected spaces at the valves station and in the continuously manned damage control station. An alarm in the continuously manned damage control station shall indicate the specific valve activated.

p) Operating instructions for the system shall be displayed at each operating position. The operating instructions shall be in the official language of the Naval Authority.

q) Additives should not be used for the protection of normally occupied spaces unless they have been approved for fire protection service by an independent authority. The approval should consider possible adverse effects to exposed personnel, including inhalation toxicity.

7.4 Thick water systems

7.4.1 Thick water characteristics

a) The thick water is composed by sea water mixed with an AFFF emulsifier (medium forming a floating film) with 3% concentration. The Society may authorize a lower concentration if the emulsifier medium efficiency and the correct working of the system with lower concentrations are demonstrated.

b) The AFFF emulsifier shall be of a type approved by the Society.

c) This requirement applies in addition to [7.1] for fixed pressure water-spraying fire-extinguishing systems.

7.4.2 Installations requirements

a) A fixed thick water spraying system includes an emulsifier tank and a mixer connected to the sea water main. The spraying is made by open nozzles.

b) The quantity of AFFF is to be such as to ensure at least 5 min of thick water supply.

c) The number and interconnections of the thick water delivery piping, thick water generator, shall allow, at the satisfaction of the Society, an efficient production and distribution of the thick water.

d) The arrangement of the thick water generator delivery ducting shall be such that a fire in the protected space will not affect the thick water generating equipment. When the thick water generators are located near the protected space, delivery ductings shall be installed so that the generators are at a distance of at least 450 mm from the protected space.

e) The thick water generator, its sources of power supply, emulsifier liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space.

This means of control is not to be located in high fire risk spaces.

The thick water generators are to comply with the requirements of Ch 4, Sec 6, [3.3]. The manual means of control is to be located on or above the damage control deck.

The fixed thick water fire-extinguishing system is to be able to be monitored and controlled from the continuously manned damage control station.

f) Means shall be provided for effective distribution of the thick water through a permanent system of piping and control valves or cocks to suitable discharge outlets, and for the thick water to be effectively directed by fixed sprayers on the main fire hazards in the protected space. The means for effective distribution of the thick water are to be proven acceptable to the Society by calculation means or testing.

g) Particular dispositions are to be taken to prevent corrosion of the thick water fire-extinguishing systems at the satisfaction of the Society.

h) Piping shall be able to be flushed out and rinse out with fresh water after use.

i) A gauging system of the emulsifier in the tanks shall be provided. The emulsifier level shall be able to be surveyed from the continuously manned damage control station.

j) A storage and measuring out unit, or any other judged equivalent system, is required when several users are served by a same mixer, and when the flow rates vary within a range of 1 to 7. If not, an atmospheric pressure tank is considered satisfactory.

k) The distance between a fixed or semi-fixed thick water cannon and the farest end of the protected space located in front of this cannon shall not be more than 75% of the cannon range in calm air. This requirement also applies to hose nozzles.

l) The fixed and semi-fixed cannons, hoses shall be installed on port and starboard of the protected space. They shall be located at a height at the satisfaction of the Society.

m) Control valves shall be provided on the thick water main, and also on the sea water main when it is fully belonging to the thick water system, just before each cannon to allow to isolate the damaged parts of these mains.

8 Sprinkler systems

8.1 Type of systems

8.1.1 Sprinkler systems may be:

- manual systems with or without fusible element nozzles according to [8.2] or
- automatic sprinkler for detection and alarm systems according to [8.3].

When the automatic system is adopted, it is to be demonstrated that the vibrations and shock does not induce undue intervention of the system.

8.2 Manual sprinkler systems with or without fusible element nozzles

8.2.1 The sections of sprinkler systems shall be fed by sea water through valves connecting the section main pipes to the fire main which shall be at any time appropriated pressured by sea water.

The sprinkler system shall at least comply with the followings:

a) The connecting valves of system sections to the fire main shall be operated by the continuously manned damage control station. Manual operation of the section valves through the electric feeding system of sprinkler system locally shall be also possible. Such stations shall be located outside the protected area of the concerned section and shall be readily accessible, clearly and permanently marked and protected from unauthorized use.

b) The system and equipment shall be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, impact, clogging and corrosion normally encountered in ships.

c) The system and its components shall be designed and installed in accordance with international standards acceptable to the Society and manufactured and tested to the satisfaction of the Society.

d) The piping system shall be sized in accordance with an hydraulic calculation technique such as the Hazen-Williams Method with the following values of the friction factor C for different pipe types:
   - pipes in black or galvanized mild steel: C = 120
   - pipes in copper or in copper alloys: C = 150
   - pipes in stainless steel: C = 150
   - pipes in plastic: C = 150

e) Sprinklers shall be grouped into separate sections.

   If the nozzles of the system are not provided with fusible elements the deck area protected by a section shall not be greater than 80 m^2 or a space if this has a surface greater than 80 m^2.

   If the nozzles of the system are provided with fusible elements, any section of the system shall not serve more than two decks of one main vertical zone

f) Sprinkler section piping shall not be used for any other purpose.

g) The section valves of sprinkler system shall be outside category A machinery spaces.

h) The activation of each section valve of the system shall initiate a visual and audible alarms at valve location and in the continuously manned damage control station.

i) A sprinkler control plan shall be displayed in the continuously manned damage control station showing the spaces covered and the location of the ship zone in respect of each section.

j) The nozzles with or without fusible elements shall be approved by the Society.

k) In accommodation and service spaces the fusible elements of nozzles shall have a nominal temperature rating of 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the nominal temperature may be increased by not more than 30°C above the maximum deckhead temperature.

l) If nozzles with fusible elements are installed, supplying water components shall be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than 280 m^2. For application to a small ship with a total protected area of less than 280 m^2, the Society may specify the appropriate area sizing the alternative supply components.

m) The section valves and the alarms shall be fed by ship's electrical switchboards being the ship provided by at least two electrical switchboards which can not be put out of service at the same time by any event.

   The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards.

8.3 Automatic sprinkler, fire detection and alarm systems

8.3.1 Engineering specification

a) Type of sprinkler systems

   The automatic sprinkler systems shall be of the wet pipe type but small exposed sections may be of the dry pipe type where, in the opinion of the Society, this is a necessary precaution.

b) Equivalent fire-extinguishing automatic sprinkler systems

   Fire-extinguishing automatic sprinkler systems equivalent to those specified in [8.3.2] to [8.3.4] are to be approved by the Society based on IMO Resolution A.800(19) as amended.

8.3.2 Sources of power supply

There shall be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where the sources of power for the pump are electrical, these shall be a main generator and a secondary source of power. One supply for the pump shall be taken from the main switchboard, and one from the secondary switchboard by separate feeders reserved solely for that purpose. The feeders shall be so arranged as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk except in so far as it is necessary to reach the appropriate switchboards, and shall be run to an automatic changeover switch situated near the sprinkler pump. This switch shall permit the supply of power from the main switchboard so long as a supply is available therefrom, and be so designed that upon failure of that supply it will automatically change over to the supply from the secondary switchboard. The switches on the main switchboard and the secondary switchboard shall be clearly labelled and normally kept closed. No other switch shall be permitted in the feeders concerned. One of the sources of power supply for the alarm and detection system shall be a secondary source. Where one of the sources of power for the pump is an internal combustion engine it shall, in addition to complying with the provisions of item c) of [8.3.4], be so situated that a fire in any protected space will not affect the air supply to the machinery.

8.3.3 Component requirements

a) Sprinklers

   The sprinklers shall be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers shall come into operation within the temperature range from 68°C to 79°C. However, in locations where high ambient temperatures might be expected, such as drying rooms, the operating temperature may be increased by not more than 30°C above the maximum deckhead temperature of the considered space.

b) Pressure tanks

1) A pressure tank having a volume equal to at least twice that of the charge of water specified in this item shall be provided. This tank shall contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in item c) 2). Arrangements shall be provided for maintaining an air pressure in the tank such as to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. A glass gauge shall be provided to indicate the correct level of the water in the tank.

2) Means shall be provided to prevent the passage of sea water into the tank.

c) Sprinkler pumps

1) An independent power pump shall be provided solely for the purpose of continuing automatically the discharge of water from the sprinklers. The pump shall be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

2) The pump and the piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of 280 m^2 at the application rate specified in [8.3.5]. When deemed necessary by the Society, the piping hydraulic capacity shall be checked by examination of the hydraulic calculations and testing results of the system.

3) The pump shall have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe shall be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in item b) 1) above.

8.3.4 Installation requirements

a) General

Any parts of the system which may be subjected to temperatures in service equal or below 0°C shall be suitably protected against freezing.

b) Piping arrangements

1) Sprinklers shall be grouped into separate sections, each of which shall contain not more than 200 sprinklers. Any section of sprinklers shall not serve more than two decks and shall not be situated in more than one main vertical zone. However, the Society may permit such a section of sprinklers to serve more than two decks or be situated in more than one main vertical zone, if it is satisfied that the protection of the ship against fire will not thereby be reduced.

2) Each section of sprinklers shall be capable of being isolated by one stop valve only. The stop valves shall be readily accessible, outside their corresponding sections, or inside a box situated in stairway casings. The valves location shall be clearly and permanently indicated. Means shall be provided to prevent the operation of the stop valves by any unauthorized person.

3) A test valve shall be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section shall be situated near the stop valve for that section.

4) The sprinkler system shall have a connection from the ship's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

5) A gauge indicating the pressure in the system shall be provided at each section stop valve and at a central station.

6) The sea inlet to the pump shall, wherever possible, be in the space containing the pump. It shall be so arranged that when the ship is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

c) Location of systems

The sprinkler pump and tank shall be situated in a position reasonably remote from any machinery space of category A and shall not be situated in any space required to be protected by the sprinkler system.

8.3.5 System control requirements

a) Ready availability

1) Any required automatic sprinkler, fire detection and fire alarm system shall be capable of immediate operation at all times and no action by the crew shall be necessary to set it in operation.

2) The automatic sprinkler system shall be kept charged at the necessary pressure and shall have provision for a continuous supply of water as required in this Section.

b) Alarms and indication

1) Each section of sprinklers shall include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems shall be such as to indicate if any fault occurs in the system. Such units shall indicate in which section served by the system fire has occurred and shall be

centralized on the navigating bridge or the damage control station(s). More-over, they shall activate visible and audible alarms placed in a position other than on the above mentioned spaces, so as to ensure that the indication of fire is immediately received by the crew.

2) Switches shall be provided at one of the indicating positions referred to in the previous item 1) which will enable the alarm and the indicators for each section of sprinklers to be tested.

3) Sprinklers shall be placed in an overhead position and spaced in a suitable pattern to maintain an aver-age application rate of not less than 5 l/m^2 per minute over the area covered by the sprinklers. However, the Society may permit the use of sprinklers providing such an alternative amount of water suitably distributed as has been shown, to the satisfaction of the Society, to be no less effective.

4) A list or plan shall be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance shall be available.

c) Testing

Means shall be provided for testing the automatic operation of the pump on reduction of pressure in the system.

9 Fixed fire detection and fire alarm systems

9.1 Engineering specifications

9.1.1 General requirements

a) Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

b) The fire detection system shall not be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel in the continuously manned damage control station.

Note 1: The ventilation fans and the fire dampers serving a machinery room equipped with internal combustion engines taking their combustion air directly inside the room are not to be automatically stopped or closed in case of fire detection, in order to prevent depressurization of the room.

c) The system and equipment shall be suitably designed to withstand supply voltage variation and transients, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.

d) Fire detection systems with a zone address identification capability shall be so arranged that:

1) means are provided to ensure that any fault (e.g. power break, short-circuit, earth) occurring in the loop will not render the whole loop ineffective

Note 2: Loop means an electrical circuit linking detectors of various sections in a sequence and connected (input and output) to the indicating unit(s).

2) all arrangements are made to enable the initial configuration of the system to be restored in the event of failure (electrical, electronic, informatic)

3) the first initiated fire alarm will not prevent any other detector from initiating further fire alarms

4) no loop will pass through a space twice. When this is not practical (e.g. for large public spaces), the part of the loop which by necessity passes through the space for a second time shall be so installed at the maximum possible distance from other parts of the loop.

9.1.2 Sources of power supply

There shall be not less than two sources of power supply for the electrical equipment used in the operation of the fire detection and fire alarm system, one of which shall be an emergency source which may be a second main switchboard where both feeding switchboards can not be put out of service at the same time in any event. Furthermore the feeders shall feed the control panel through buffer battery. The supply shall be provided by separate feeders reserved solely for that purpose. Such feeders shall run to an automatic change-over switch situated in or adjacent to the control panel for the fire detection system.

The main (respective emergency) feeder shall run from the main (respective emergency) switchboard to the change-over switch without passing through any other distributing switchboard.

9.1.3 Component requirements

a) Detectors

1) Detectors shall be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered by the Society provided that they are no less sensitive than such detectors. Flame detectors shall only be used in addition to smoke or heat detectors.

2) Smoke detectors required in all stairways, corridors and escape routes within accommodation spaces shall be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds 2 per cent obscuration per metre. Smoke detectors to be installed in other spaces shall operate within sensitivity limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

3) Heat detectors shall be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector shall operate within temperature limits to the satisfaction of the Society having regard to the avoidance of detector insensitivity or oversensitivity.

Note 1: For heat detection inside ammunition spaces, different temperatures of operations and sensitivity requirements may be specified by the Naval Authority.

4) At the discretion of the Society, the permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

5) All detectors shall be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

9.1.4 Installation requirements

a) Sections

1) Detectors as well as manually operated call points shall be grouped into separate sections.

Note 1: Section means group of fire detectors or manually operated call points as shown in the indicating unit(s) required in item a)3) of [9.1.5].

2) A section of fire detectors which covers a control station, a service space or an accommodation space shall not include a machinery space of category A or ammunition spaces.

For fire detection systems with remotely and individually identifiable fire detectors the requirement set out in this item 2) is considered to be met when a loop covering an accommodation space, a service space and a control station does not include machinery spaces of category A or ammunition spaces.

3) If the ship is divided in safety zones, there shall be one control panel per safety zone. Associated loops of detectors should not extend outside the safety zone in which its control panel is fitted.

Each control panel is to be provided with an indicating unit in each other damage control stations.

Cable between the fire control panel and the indicating unit is to be either of a fire resistant type or to be duplicated and to follow different routes which are to be as far apart as practicable, separated both vertically and horizontally.

Note 2: The indicating unit is to ensure that the fire detection and alarm systems from one damage control station are also available in the other damage control station.

Note 3: An indicating unit is a dedicated fire repeater alarm panel.

4) If there is no fire detection system capable of remotely and individually identifying each detector, a section of detectors shall not serve spaces on both sides of the ship nor on more than one deck and neither shall it be situated in more than one main vertical zone except that the Society if it is satisfied that the protection of the ship against fire will not thereby be reduced, may permit such a section of detectors to serve both sides of the ship and more than one deck. In ships fitted with individually identifiable fire detectors, a section may serve spaces on both sides of the ship and on several decks but may not be situated in more than one main vertical zone.

b) Positioning of detectors

1) Detectors shall be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely shall be avoided. In general, detectors which are located on the overhead shall be a minimum distance of 0,5 m away from bulkheads.

2) The maximum spacing of detectors shall be in accordance with Tab 3. The Society may require or permit other spacings based upon test data which demonstrate the characteristics of the detectors.

3) Flame detectors shall be positioned at the edge of the room, pointing directly at the center of the area to be protected. If the detector doesn't have the complete area to be protected in its field of vision, one or more additional detectors may be required according to the distance from the anticipated flame and the angle of view of detector. The arrangement of the flame detector shall take into account that the smoke created by fire may render the detection ineffective.

c) Arrangement of electric wiring

1) Electrical wiring which forms part of the system shall be so arranged as to avoid galleys, machinery spaces of category A, and other enclosed spaces of high fire risk except where it is necessary to provide for fire detection or fire alarm in such spaces or to connect to the appropriate power supply.

2) A loop of fire detection systems with a zone address identification capability shall be capable to operate even if the loop is damaged in one point by the fire.

9.1.5 System control requirements

a) Visual and audible fire signals

1) The activation of any detector or manually operated call point shall initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm shall be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of category A. This alarm sounder system need not be an integral part of the detection system.

2) The control panel shall be located at the continuously manned damage control station.

3) Indicating units shall, as a minimum, denote the section in which a detector is activated or a manually operated call point has operated. At least one unit shall be so located that it is easily accessible to responsible members of the crew at all times. One indicating unit shall be located on the damage control stations.

4) Clear information shall be displayed on or adjacent to each indicating unit about the space covered and the location of the sections.

5) Power supplies and electric circuits necessary for the operation of the system shall be monitored for loss of power or fault conditions as appropriate. Occurrence of a fault condition shall initiate a visual and audible fault signal at the control panel which shall be distinct from a fire signal.

Table 3 : Maximum spacing of detectors

Type of detector	Maximum floor area per detector	Maximum distance apart between centres	Maximum distance away from bulkheads
Heat	37 m^2	9 m	4,5 m
Smoke	60 m^2	10 m	5,0 m
Note 1: For spaces of categories (8) (11) (12) (13) or (14), as defined in Ch 4, Sec 5, [1.2.3] item b), the maximum floor area per smoke detector is not to exceed 24 m^2.			

10 Fire protection system for flight decks

10.1 General

10.1.1 The water capacity, the foam forming liquid capacity and the areas to be protected by the fire protection systems for flight decks given in this article should not restrict the technical solutions for fire-fighting issued by the risk analysis proceeded by the Naval Authority.

10.1.2 The fire protection of flight decks should consist on the other means of fire-fighting as required in [10.2.3] and one of the following fixed fire-extinguishing systems or a combination of them:

- a flight deck thick water system complying with the requirements of [10.2.1] below; and/or
- an arrangement of foam monitors complying with the requirements of [10.2.2] below.

10.2 Flight decks fire-extinguishing systems

10.2.1 Fixed fire-extinguishing thick water system for flight decks

The thick water flow rate of the system shall be at least:

a) 5 l/min/m^2 on the areas of the flight decks identified as high fire risk.

b) 5 l/min/m^2 on the exterior bulkheads of the superstructures facing the flight decks extending up to a height of 5 m above the level of the flight deck.

c) 3 l/min/m^2 on the areas of the flight decks identified as moderate fire risk.

The system shall be capable of remote control from a damage control station and from an aircraft control station.

The thick water nozzles used for the system shall be of a type approved by the Society.

The foam forming liquid shall be of a type approved by the Society.

The mixing ratio of foam forming liquid with sea water shall be at least 3%. Other mixing ratios shall be to the satisfaction of the Society.

10.2.2 Arrangement of foam monitors for flight decks

The foam monitors shall be of a type approved by the Society

The monitors shall be capable of local and remote control from a damage control station and from an aircraft control station.

The foam expansion ratio of the foam delivered by the foam monitors shall be from 5 to 12.

The throw length of the foam monitor in still air conditions shall be at least 1,3 times the maximum distance between the monitor and the area to be protected.

The flow rate of the monitors shall be at least 1200 l/min.

The monitors shall be capable of delivering foam to each part of the flight deck required to be protected by the system. Each of the protected areas shall be covered by the throw emanating from at least two monitors.

The foam forming liquid shall be of a type approved by the Society.

10.2.3 Other means of fire-fighting

Hydrants capable of dual jet/spray purpose and capable of delivering foam at a flow rate of at least 200 l/min and shall be provided throughout the fly decks. Their number and location shall be such as two jets of foam not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the fly decks. The length of the fire hose shall be limited to 20 m but may extend up to 25 m if the maximum breath of the ship exceed 30 m.

A fire-fighter vehicle VLIP capable of delivering foam and powder and having the necessary means for rapidly and safely extracting the pilot from an helicopter or an airplane shall be available on flight decks during the aircraft operations.

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