SHIPPING REGISTER OF UKRAINE

RULES

FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS

Volume

3

Kyiv 2020

Shipping Register of Ukraine.

Rules for the Classification and Construction of Sea-Going Ships. Volume 3

This is an edition of the Rules for the Classification and Construction of Sea-Going Ships prepared on the basis of their third edition of 2011, taking into account the changes and additions included in the Bulletins of Amendments and Additions No.1(2014), No. 2 (2016), No. 3 (2017), No. 4 (2019) and taking into account changes in the applicable international conventions and codes adopted by the relevant resolutions of the International Maritime Organization (IMO), the unified requirements and recommendations of the International Association of Classification Societies (IACS) and changes in the applicable resolutions of the United Nations Economic Commission for Europe and European Parliament and Council directives, changes and additions adopted based on the analysis of the Rules of other classification societies, as well as from the experience of their application (for more details, see Introduction).

The third volume contains the following parts:

VI «Fire Protection»;
VII «Machinery Installations»;
VIII «Systems and Piping»;
IX «Machinery»;
X «Boilers, Heat Exchangers and Pressure Vessels»;
XII «Refrigerating Plants».

The Rules for the classification and construction of sea-going ships of the Shipping Register of Ukraine have been approved in accordance with the current regulation and come into force on 01.01.2020.

The rules are published in Ukrainian and English. In case of divergence between the Ukrainian and English texts and any doubt as to the interpretation of the Rules, the Ukrainian text shall prevail.

Official edition

of the Shipping Register of Ukraine

Registration of amendments and additions

Letter of change	Bulletin of amendments and additions / Circular letter	Date	Signature
1	2	3	4

Introduction

This edition of the Rules for the Classification and Construction of Sea-Going Ships 2020, compared to their 2011 edition as amended by bulletins, contains the following amendments and additions.

1. According to the text of the requirements in the parts of the reference to ISO and EN standards supplemented with references to the relevant DSTU standards (effective as of 01.09.2019).

2. In the text of the Rules the designations of fire-resistant constructions "type A", "type B" and "type C" have been replaced by "class A", "class B" and "class C".

3. In the text of the Rules, the definition of "Category of ice reinforcements" has been replaced by the definition - "Ice class ships".

4. Editorial amendments have been made.

PART VI. FIRE PROTECTION

1. Para **1.5.1** has been amended to comply with **4.6** Part VI «Machinery installations, machinery equipment and systems» Rules for the classification and construction of submersibles and ship diving complexes and passenger submersibles.

2. New paragraphs: «2.6 Fishing vessels of less than 500 gross tonnage»; «6.9 Ships continuosely operated at low temperatures»; «6.10 Ships operated in polar waters.

3. New paras: «**2.1.5.10** Special electrical spaces»; «**2.2.3.6** Interim Guidelines for minimizing the incidence and consiqences of fires in ro-ro spaces and special category spaces of ro-ro passenger ships» have been introduced.

4. Table 3.1.2.1 has been amended.

5. Para **3.6.1** has been amended subject to the requirements of **6.4.6**.

6. Table 5.1.2 has been amended subject to the requirements of IMO MSC.409(97).

7. Para **6.8.2.** has been amended subject to the requirements of IACS UI GF17 (Dec 2018).

8. Para **6.8.2.2-1** has been amended taking into account IMO MSC.458(101) has been introduced.

9. Para **7.1.2** has been amended subject to the requirements of IMO MSC.426(98).

10. Para **8.10.3.1** has been amended subject to the requirements of IACS № 99.

PART VII MACHINERY INSTALLATIONS

1. Para **1.1.1** with requirements in respect of machinery installations of polar class ships, Baltic ice class ships, ships equipped to ensure long-term operation at low temperatures.

2. New paras: «2.8 Machinery requirements for polar class ships»; «2.9 Requirements to baltic class ships machinery installations»; «2.11 Requirements for ship equipment to ensure long-term operation at low temperature» and Section «12 Requirements for boiler monitoring systems» have been introduced.

3. Paras: **2.1.16** and **2.1.17** concerning determining the minimum power of gas ICEs have been introduced.

4. Para **4.5.11** requirements have been specified.

5. Paragraph **4.7** «General requirements to the construction of ships equipped for using gases» has been transferred to Section **2** as paragraph «2.10 Requirements for ships equipped for using gases».

6. Formulas 6.2.1-2 and 6.2.1-3 the determining of the relative radius of design section has been specified.

7. Paras **7.2.3**, **7.2.5**, **7.2.7**, **7.2.14** have been completed with requirements according IACS UI SC242 (Corr.1August 2011р.).

8. Sequence number of Section 12 has been changed to number 13.

PART VIII. SYSTEMS AND PIPING

1. The name of Section 4 has been replaced by «4. Elements of the systems and piping».

2. New paras «5.9 Systems and piping to ensure long-term operation at low temperature»; «7.15 Bilge system of ships equipped for using gases or low-flashpoint fuels»; «8.9 Ballast system of ships equipped to ensure long-term operation at low temperature»; «9.17 Systems of tankers and combination carriers to ensure long-term operation at low temperature»; «13.17 Use of crude oil or other flammable liquids having a flashpoint of 60°c or less as fuel» have been introduced.

3.New para **«4.3.3** Sea inlets and cooling water systems on Polar and Baltic class ships**»** has been introduced**.**

4.Paras **5.1.2** and **7.1.3** have been amended subject to the requirements of IMO MSC.421(98).

6. Para **7.14.1** references have been specified.

7. Para **8.7.7** requirements have been specified.

8. Para **9.10.4** requirements have been specified.

9. Paras have been amended taking into account: **9.16.6.2** (IACS UI SC285 (July 2018) and SC286 (July 2018); **9.16.7.6.1** and **9.16.7.6.2** (IACS UI SC284 (July 2018)); **9.16.12.15** (IACS UI SC287 (July 2018)); **9.16.6.11, 9.16.7.2 (**IMO MSC.457(101)).

10. Para **10.4.9** requirement has been specified.

11. New para **12.1.22** has been introduced.

12. Paragraph «12.15 Inerting and atmosphere control for ships equipped for using gases or low-flashpoint fuels» has been transferred to Section **13** as paragraph **13.16**.

13. Para **13.7.8** has been amended taking into account IACS UI M76 (Apr 2016).

14. Para **13.8.1** has been amended taking into account IACS № 151 (July 2017).

15. Name and text of para **13.11** have been replaced by «Fuel system of ships, equipped for using gases or low-flashpoint fuels» taking into account IMO MSC.458(101) (refer to **13.11.4.12**).

16. Name and text of para **13.12** have been replaced by «Application of natural gas (methane) as fuel».

17. Paras **15.1.1.1** and **15.1.1.5** requirements have been specified.

18. Paragraph «17.4 Boiler and feed water quality monitoring system**»** has been transferred to Part VII «Machinery installations», Section «12. Boiler installations monitoring system**».**

19. Paragraph **21.4** has been changed in accordance with **8.10** Part 4 «Technical supervision of manufacture of products» of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

PART IX. MACHINERY

1. Table 1.2.3.1-2 has been amended;

2. В пунктах **1.2.4** and **1.6.1** requirements to machinery materials have been specified;

3.Table 1.2.3.1-3 has been introduced;

4. Para **1.3** requirements for hydraulic testing of ICEs parts taking into account IACS UR M72 (Rev.1 Mar 2016) have been specified.

5. Para **1.6.2** has been replaced in accordance with the provisions of the Annex **8**, Section **5** «Machinery», Part 4 «Technical supervision of manufacture of products» RTSM.

5. Para **2.4** has been amended taking into account IACS UR M53 (Rev.3 June 2017), requirements for the design of crankshafts made of cast iron have been specified;

6. Section **2** has been completed with Appendixes I and VI according to the requirements IACS UR M53 (Rev.3 June 2017).

7. Para **4.2** has been amended taking into account IACS UR M56 (Rev.3 Oct 2015).

8. Para **6.1.8** requirements for deck machinery of ships intended for long-term operation at low temperatures have been introduced;

9. Para **6.3** has been amended taking into account IACS UR A3 (June 2017);

10. Para **8.11** has been replaced by the new para «8.10 Natural gas fired turbines».

11. Para **9** has been replaced by the new para «9. Gas internal combustion engines» taking into account IMO MSC.458(101).

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1. Table 1.3.1.2 and para **1.4.1** have been amended concerning the division of pressure vessels and heat exchangers into classes and requirements for the inspection of materials for them.

2. Уточнені вимоги пунктів **3.3.3.6** and **3.3.3.9**.

3. The new para **4.4.5** has been introduced taking into account IACS UI SC283 (Aug 2017) has been introduced.

4. Paragraph «3.7 Requirements for boiler monitoring systems» has been transferred to Part VII «Machinery installations», as Section «12. Requirements for boiler monitoring systems**».**

PART XII. REFRIGERATING PLANTS

1. Requirements of para **8.2.3** have been specified.

CONTENTS

PART VII MACHINERY INSTALLATIONS

PART VIII. SYSTEMS AND PIPING

PART IX. MACHINERY

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

PART XII. REFRIGERATING PLANTS

Notes

Notes

PART VI. FIRE PROTECTION

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to ship's structural fire protection, fire extinguishing systems and fire detection and alarm systems, as well as fire-fighting equipment and outfit.

1.1.2 The fire protection requirements relating to the structural items of the ship hull, machinery and parts thereof, electrical equipment, pumping and piping, ship's arrangements, fuel oil and lubricating oil tanks, construction and location of boilers, refrigerating plants, ship's spaces, etc. are set out in the relevant parts of the Rules.

1.2 DEFINITIONS AND EXPLANATIONS

The definitions and explanations relating to the general terminology of the Rules are given in Part I "Classification" of the Rules for the classification and construction of ships[1].

The following definitions have been adopted in this Part of the Rules:

Atriums are public spaces within a single main vertical zone spanning three or more open decks.

Cabin balcony is an open deck space which is provided for exclusive use of the occupants of single cabin and has direct access from such a cabin.

Continuous "B" class ceilings or linings are those "B" class ceilings or linings which terminate at an "A" or "B" class division.

Adjacent compartments or spaces are those compartments or spaces which are separated from one another by a bulkhead, deck, platform, or any other fixed division without openings or with openings provided with means of closure.

Compartments or spaces continuous to one another at the corners only are not considered as adjacent.

Compartments and spaces separated from one another by removable divisions (i.e. those removable under normal service conditions) or having openings not fitted with means of closing, in the bulkhead or deck that separates them, are considered as one single space.

A standard fire test is a test in which the relevant specimens are exposed in a test furnace to temperatures corresponding approximately to the time-temperature curve in accordance with the test method specified in the FTP Code 2010.

Smothering is filling of a protected space with a medium not supporting combustion.

Surface extinction is cooling, wetting or restriction of oxygen access to burning surfaces.

Fire-fighting outfit is portable fire-fighting equipment (apparatus, appliances, consumable materials) intended for:

fire extinction; ensuring effective fire-fighting actions of the crew;

ensuring operation of fire extinguishing systems.

Water mist lance – means a tube with a piercing nozzle which is capable of penetrating a container wall and producing water mist inside a confined space (container, etc.) when connected to the fire main.

Structural fire protection is a complex of the passive means of structural fire protection intended for:

prevention of fire; containment of flame and smoke spreading throughout the ship;

creation of conditions for safe evacuation of people from the ship's spaces and from the ship, as well as for effective fire extinction.

Safe area perspective of habitability, any area(s) which is not flooded or which is outside the main vertical zone(s) in which a fire has occurred such that it can safely accommodate all persons on board to protect them from hazards to life or health and provide them with basic services.

Code on Alerts and Indicators means the Code on Alerts and Indicators, as adopted by IMO resolution A.1021(26).

IGC Code - The International Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk revised in accordance with IMO Resolution MSC.370 (93), as amended by Resolutions MSC.411 (97) and MSC.441 (99).

[1] Hereinafter referred to as Part I "Classification".

IGF Code - The International Code of Safety for Ships using gas or other low-flashpoint fuels (IGF Code) 2015, adopted by IMO Resolution MSC.391 (95), as amended, including by IMO Resolution MSC.458 (101).

IBC Code - International Bulk Chemical Code (IBC Code) The International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk 1994, as amended, including by IMO resolution MSC.460 (101).

Fire Safety Systems Code – means International Code for Fire Safety Systems, as adopted by the IMO Maritime Safety Committee by IMO resolution MSC.98(73) as amended by IMO resolution IMO MSC.457(101).

Fire Test Procedures Code means the International Code for Application of Fire Test Procedures, 2010 (2010 FTP Code), as adopted by the IMO Maritime Safety Committee by resolution IMO MSC.307(88) as amended by IMO resolution IMO MSC.437(99).

IMDG Code – International Maritime Dangerous Goods Code, adopted by IMO Resolution MS.406 (96), as amended, including by IMO Resolution MSC.442 (99).

IMSBC Code – International Maritime Solid Bulk Cargoes (IMSBC) Code, adopted by IMO Resolution MSC.268 (85), as amended, including by IMO Resolution MSC.462 (101).

MARPOL-73/78/97[2] – The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978, (MARPOL-73/78) as amended by the Protocol of 1997 (MARPOL-73/78/97).

SOLAS-74/78/88[3] – The International Convention for the Safety of Life at Sea 1974 as modified by the Protocols of 1978 and 1988 thereto, including applicable codes.

Nominal foam expansion ratio is the ratio of the volume of foam to the volume of foam solution from which it was made, under non-fire conditions, and at an ambient temperature of e.g. around 20ºC.

Independent pump drive is a pump drive from a separate electric, hydraulic or diesel engine, intended solely for the operation of the pump.

Lower flammable limit (LFL) is minimum concentration of oil gases and vapours in air capable of igniting from a source of ignition and propagating combustion in the mixture.

Fire-fighting equipment and systems are those active means of fire protection which are intended for fire extinction and containment of fire spreading throughout the ship.

Primary deck covering is the first layer of a floor construction, which is applied directly on top of the deck plating and is inclusive of any primary covering, corrosion-resistant compound or adhesive, which is necessary to provide protection or adhesion to the deck plating. Other layers of a floor construction, which are applied directly on top of the deck plating, constitute floor coverings.

Foam delivery ducts are supply ducts for introducing high expansion foam into the protected space from foam generators located outside the protected space.

POLAR Code[4] − The International Code for Ships Operating in Polar Waters 2014, adopted by IMO Resolutions MSC.385(94) and MEPC.264(68), having regard to the provisions of the amendments to the international SOLAS-74/78/88, adopted by Resolution MSC.386(94).

Casualty threshold in the context of a fire includes:

— loss of the space of origin up to the nearest “A” class boundaries, which may be a part of the space of origin, if the space of origin is protected by a fixed fire extinguishing system; or

— loss of the space of origin and adjacent spaces up to the nearest “A” class boundaries which are not part of the space of origin.

Fire control station is a control station where items of fire detection and fire alarm systems or control of fire extinguishing systems are centralized.

Protected space is a space equipped with one of the fire extinguishing systems or with an automatic fire detection system.

Rooms containing furniture and furnishings of restricted fire risk for the purpose of application on ships carrying more than 36 persons – are the rooms (whether cabins, public spaces, offices or other types of accommodation referred to in **1.5.2**) in which:

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[2] Hereinafter — MARPOL-73/78/97.

[3] Hereinafter — SOLAS Convebtion as ameneded.

[4] Hereinafter — POLAR Code.

all furniture, such as desks, wardrobes, dressing tables, bureaux, dressers, is constructed entirely of approved non-combustible materials, except that a combustible veneer not exceeding 2 mm in thickness may be used on the working surface of such articles;

all free-standing furniture, such as chairs, sofas, tables, is constructed with frames of non-combustible materials;

all draperies, curtains and other suspended textile materials have qualities of resistance to the flame spread not inferior to those of wool of mass 0,8 kg/m^2, this being determined in accordance with the FTP Code;

all floor coverings have low flame spread characteristics;

all exposed surfaces of bulkheads, linings and ceilings have low flame spread characteristics;

all upholstered furniture has qualities of resistance to ignition and flame spread, this being determined in accordance with the FTP Code;

all bedding components have qualities of resistance to ignition and flame spread, this being determined in accordance with the FTP Code.

Ray – a group of automatic and manual detectors identified in the alarm panel of the fire detection alarm system.

Fire damper, smoke damper is a device installed in a ventilation duct, which in the normal position is open and allows air flow in the middle of the duct.

In case of fire, the fire damper closes and prevents air from flowing inside the duct, thereby preventing from flame propagation through the ventilation duct.

Fire dampers may have the following definitions:

.1 automatic fire damper - a fire damper that closes automatically under the action of combustion products;

.2 manual fire damper – a fire damper that opens and closes using manual controls in place;

.3 remote control fire damper - a fire damper that is closed by means of controls located remotely from this damper.

The smoke damper closes in the event of a fire and prevents air from flowing inside the duct, thus preventing from the distribution of smoke and hot gases through the ventilation duct; it is not believed that the smoke damper will provide the integrity of the fire-resistant grillage through which the ventilation duct passes.

Smoke dampers may have the following definitions:

.1 automatic smoke damper – a smoke damper that closes automatically under the action of combustion products;

.2 manual smoke damper – a smoke damper that opens and closes using manual controls in place;

.3 remote control smoke damper – a smoke damper that is closed by means of controls located remotely from this damper.

Flammable liquids are liquids, or mixtures of liquids, or liquids containing solids in solution or suspension (e. g. paints, varnishes, lacquers, etc.) which give off flammable vapours at or below 60°C closed cup test.

Rated volume of a protected space is the gross volume of a space bounded by water-tight or gastight bulkheads and decks with the deduction for the volume occupied by main machinery reduction gear, auxiliaries, boilers, condensers, evaporators, tanks, ventilation and exhaust gas piping.

Sauna is a hot room with temperatures normally varying between (usually 80 to 120 °C) where the heat is provided by a hot surface (e. g., by electrically-heated oven). The hot room may also include the space where the oven is located and adjacent bathrooms.

Combustible medium is flammable liquids; flammable gases, compressed, liquefied or dissolved under pressure; solid combustible materials and substances, including cargoes, fuel, finishing materials, equipment, insulation, furniture.

Crude oil means any oil occurring naturally in the earth whether or not treated to render it suitable for transportation and includes crude oil from which certain distillate fractions may have been removed and crude oil to which certain distillate fractions may have been added.

Inside air foam system is a fixed high expansion foam fire extinguishing system with foam generators located inside the protected space and drawing air from that space.

Outside air foam system is a fixed high expansion foam system with foam generators installed outside the protected space that are directly supplied with fresh air.

High expansion foam fire extinguishing systems are fixed total flooding extinguishing systems that use either inside air or outside air for aeration of the foam solution. A high expansion foam system consists of both the foam generators and the dedicated foam concentrate approved during the fire testing specified in **3.7.3.1.1**.

Water-screen systems are systems which create a water barrier in the form of sufficiently thick curtain of water fed through spray nozzles. Such systems are fitted where the use of "A" class divisions is impracticable.

Water drenching systems are those systems which supply water onto vertical or horizontal ship's structures.

Fixed fire extinguishing systems are those systems which are intended to supply fire extinguishing medium to the protected spaces or directly therein and structurally fixed to the ship's hull.

A system equivalent to a deck foam system for cargo tanks is a system which shall be capable of extinguishing spill fires, precluding ignition of spilled oil not yet ignited and fire extinction in ruptured tanks.

Steel or other equivalent material means any non-combustible material, which by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure during a standard fire test (e. g., aluminium alloy with appropriate insulation).

Vehicle carrier means a cargo ship which only carries cargo in ro-ro spaces or vehicle spaces, and which is designed for the carriage of unoccupied motor vehicles without cargo, as cargo.

Flash point is the temperature in degrees Celsius (closed cup test), at which liquid will give off enough flammable vapours to be ignited as determined by an approved flash point apparatus.

Motor vehicle without fuel in its tanks is motor vehicle, motor bike, tractor, etc., powered with an internal combustion engine and having empty fuel system and fuel tanks, as well as both battery leads disconnected from the accumulator.

Fuel oil units refer to definition given in **1.2**, Part VII "Machinery Installations".

Safety centre is a control station dedicated to the management of emergency situations. Safety systems operation, control and/or monitoring are an integral part of the safety centre.

Central control station (CCS) control and indicator functions are centralized:

fixed fire detection and fire alarm systems;

automatic sprinkler system, fire detection and alarm systems, as well as remote starting controls of other fire extinguishing systems;

fire door indicator panels;

fire door closures;

watertight door indicator panels;

watertight door closures; ventilation fans;

general/fire alarms; ship communication systems including telephones; and

microphones for public address systems.

1.3 SCOPE OF SURVEYS

1.3.1 General regulations for the classification, survey of ships under construction and classification surveys, as well as the requirements for the documentation to be submitted to the Register for review are set out in General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.2 Subject to the Register survey during construction of a ship are: structural fire protection, materials used for the interior finishing of ship's spaces, as regards fire hazardous properties thereof, fire extinguishing, fire detection and alarm systems subject to the provisions of the present Part.

As regards fire-fighting outfit, it shall only be checked for correct location and for complete availability in accordance with the requirements of the present Part and availability of documents in accordabce with "The nomenclature of the objects of technical supervision of the Register" Part 1 of the Rules for the technical supervision of the construction of ships and the manufacture of materials and products.

1.3.3 documents on fire tests run by competent bodies, confirming the efficiency of newly applied fire extinguishing medium with the recommended standards on composition and application rates, as well as information on storage life and conditions;

.2 reports of the recognized laboratories on the fire tests of "A" and "B" class fire-fighting divisions, closures of openings and passages (cutouts) in such divisions ("A" and "B" class doors included) (refer to **1.6**);

.3 drawings of fire-fighting divisions together with the protocols of the recognized laboratories on tests, which confirm their compliance with "A" and "B" class divisions;

.4 reports of the recognized laboratories on tests of the fire hazardous material features (refer to **1.6**);

.5 drawings for individual standard assemblies (equipment) of fire extinguishing systems and fire-fighting outfit;

.6 required calculations, which confirm the fulfillment of the requirements of the present Part.

1.3.4 After repair, revamping, and modification and associated changes in equipment, all ships shall at least comply with the requirements with which they complied before.

Such ships, if constructed before July 1, 2012, shall usually comply with requirements for ships constructed on and after this date, at least to the same extent as before the implementation of the repair, revamping, modification, or change in equipment.

After the repair, revamping, and modifications that significantly alter the size of the ship or accommodation spaces for passengers or significantly increase the life of ships as well as related changes in equipment, such ships shall comply with requirements for ships constructed on or after July 1, 2012 to the extent deemed appropriate and practicable by the Register.

1.3.5 Passenger ships that carry more than 36 passengers, except ships of a restricted navigation area **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS**, which were modified in accordance with **1.3.4** shall comply with the following requirements:

.1 all materials used in replacements for these ships must comply with requirements to materials used to build new ships; and

.2 all repairs, revamping, modifications, and changes in equipment that include the replacement of materials in the amount of 50 tons or more other than those required to upgrade the ship shall comply with requirements applicable to new ships.

1.4 FIRE PLANS

1.4.1 At the central control station, wheelhouse or in conspicuous positions in corridors and lobbies of any ship, there shall be exhibited general arrangement plans clearly showing the following for each deck:

.1 location of control stations;

.2 arrangement of fire-resisting and fire-retarding divisions;

.3 spaces protected by the fire detection and alarm system;

.4 spaces protected by fixed fire extinguishing systems with indication of the location of instruments and fittings for their control and also the disposition of fire hydrants;

.5 means of access to different compartments, decks, etc., with indication of escape routes, corridors and doors;

.6 ventilation system including the controls of fans and showing the disposition of dampers and the identification numbers of the fans serving the groups of spaces, fenced off by fire-resistant boundaries.

.7 arrangement of fire-fighting outfit;

.8 location of the documents referred to in **1.4.6**;

.9 location of emergency escape breathing devices specified in **5.1.23**.

1.4.2 In lieu of the plans, information specified in **1.4.1** may be set out in a booklet, a copy of which shall be supplied to each officer, and one copy at all times shall be available on board in an accessible position.

1.4.3 A duplicate set of the plans or the booklet protected against marine environment shall be permanently stowed outside the deck-house in a weather-tight enclosure painted red and marked as indicated in Fig. 1.4.3-1 in compliance with IMO MSC/Circ. 541.

The enclosure shall be capable of being easily opened, be readily available to the shore-side fire-fighting personnel, be located in a well-illuminated position, if possible including illumination from an emergency source.

In oil tankers, chemical tankers and gas carriers the enclosure of fire control plans shall not be located on exterior bulkheads of superstructures which face cargo area and the surfaces within 3 m from them along the side.

If the enclosure is not adjacent to the gangway, there shall be guide signs as indicated in Fig. 1.4.3-2 showing the way thereto.

The dimensions of the signs shall be not less than 300 x 400 mm.

1.4.4 Description in such plans and booklets shall be in the state language and in the English language. The symbols for items listed in 1.4.1 shall be in agreement with IMO resolution A.952(23) "Graphical Symbols for Fire Control Plans", as amended by IMO resolution A.1116(30) for ships constructed after 1 January 2019.

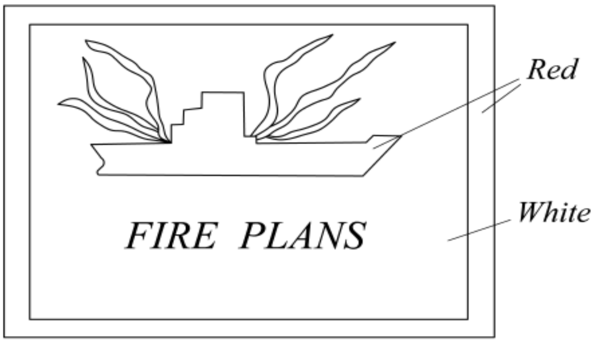
For ships not engaged on international voyages, translation into English is not required.

The graphical symbols shall be coloured.

1.4.5 All alterations in the fire protection of a ship shall be entered in the ship's documents stated in **1.4.1** and **1.4.2**.

1.4.6 To be kept in a separate file in an accessible position are technical instructions for maintenance and use of all ship's installations for extinction and containment of fire.

1.4.7 On passenger ships carrying more than 36 passengers, plans and booklets shall provide information regarding fire protection, fire detection and fire extinction in accordance with **1.4.1** and considering IMO resolution A.756(18).



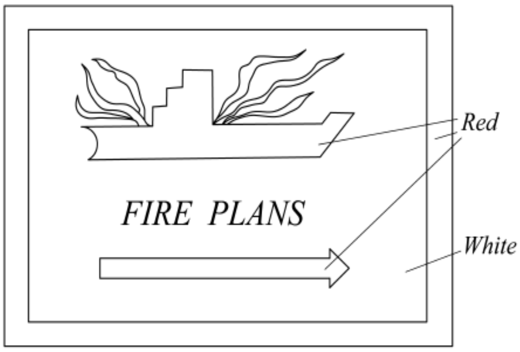


Fig. 1.4.3-1 Fig. 1.4.3-2

1.5 CATEGORIES OF SHIP'S SPACES

1.5.1 Control stations:

.1 spaces in which the ship's radio or main navigational equipment (in particular: steering stand, compass, radar and direction finding equipment), or the emergency power source, (including accumulator batteries regardless of their capacity, according to Part XI "Electrical Equipment"), or in which items of fire detection and fire alarm systems or control of fire extinguishing systems are centralized.

Steering gear room containing its emergency control is not considered as a control station.

If in the present Part there are no specific requirements for the centralization within a control station of major components of the fixed fire extinguishing systems, then such major components may be placed in spaces, which are not considered as control stations;

.2 control stations (refer to **1.5.1.1**), which may also be considered as machinery spaces, such as emergency diesel generators rooms;

.3 spaces containing equipment for the control of submersion, emersion and heeling;

.4 control stations for fire and rescue operations (refer to **6.6.2**);

.5 compression chamber control station and diving operation control station whose functions may be combined in one control station (refer to **4.6**, Part VI "Machinery Installations, Mechanical

Equipment and Systems" of the Rules for the Classification and Construction of Manned Submersibles and Ship's Diving Systems).

1.5.2 Accommodation spaces:

.1 spaces used as cabins, corridors, offices, medical rooms, cinema halls, games and entertainment halls, barbers shops, pantries which are not used for taking meals and do not contain equipment for cooking hot meals (however such pantries may have the following appliances: coffee machines, toasters, dish washing machines, microwave ovens, induction heaters and similar appliances each consuming not more than 5 kW; electric stoves and kitchen stoves for food heating consuming not more than 2 kW and having a surface temperature of not more than 150 °C), and other similar spaces;

.2 public spaces: the accommodation spaces used as halls, dining rooms, lounges and similar permanently enclosed spaces;

.3 sanitary spaces: the public spaces used as shower-rooms, bathrooms, toilets, small laundries, indoor swimming pools etc.

1.5.3 Service spaces:

.1 service spaces used as galleys (spaces containing electric stoves and kitchen stoves with a capacity of more than 5 kW), pantries containing equipment for cooking hot meals (such pantries may have the following appliances: toasters, microwave ovens and similar appliances each consuming not more than 5 kW; electric stoves and kitchen stoves for food heating consuming up to 5 kW), various workshops not forming part of machinery spaces and similar spaces as well as trunks leading to such spaces;

.2 service spaces used as storerooms:

.2.1 storerooms for explosives;

.2.2 storerooms for flammable materials and substances: paint lockers, spaces for flammable liquids, flammable liquefied and compressed gases, sheltered garages, fuel distribution systems, etc.;

.2.3 storerooms other than mentioned in **1.5.3.2.1** and **1.5.3.2.2**;

.2.4 working spaces defined in **1.5.8**;

.3 cargo control rooms (refer to definitions in **1.2**, Part VII “Machinery Installations”).

1.5.4 Cargo spaces:

.1 cargo tanks intended for the carriage of liquids in bulk, slop tanks included;

.2 spaces for dry cargoes other than ship stores: dry cargo and refrigerated cargo holds and ’tween-decks, including those intended also for carriage of containers and portable tanks, dangerous goods in packaged form or in bulk, motor vehicles without fuel in their tanks; storage spaces for ready produce, utilisable refuse, fishing equipment, packages, etc., as well as produce discharge trunks, cargo lifts and access trunks leading to such spaces;

.3 ro-ro cargo spaces not normally subdivided in any way and extending to either a substantial length or the entire length of the ship, spaces in which motor vehicles with fuel in their tanks for their own propulsion, and/or goods packaged (in tare or in bulk, on rail or road cars, vehicles (including road or rail tanks), trailers, containers, pallets, demountable tanks or similar enlarged units, or other tanks) are normally loaded and unloaded in a horizontal direction. Such spaces are divided into:

.3.1 closed ro-ro cargo spaces which are not spaces specified in **1.5.4.3.2** and **1.5.4.5**;

.3.2 open ro-ro cargo spaces either open at both ends, or open at one and provided with adequate natural ventilation effective over their entire length through permanent openings in the side plating or deck-head or from above while the total square of openings shall be at least 10% of the square of side plating of spaces;

.4 vehicle spaces intended for carriage of motor vehicles with fuel in their tanks for their own propulsion, which divide into:

.4.1 enclosed spaces, for vehicles which are not open spaces for vehicles neither weather decks;

.4.2 open vehicle spaces, open similar to **1.5.4.3.2**;

.5 weather deck is a deck fully open for environmental exposure from above and at least from two sides. **1.5.5 Machinery spaces** — refer to definition of 1.2, Part VII “Machinery Installations”.

1.5.6 Machinery spaces of category A – refer to definition given in 1.2, Part VII “Machinery Installations”.

1.5.7 Pump rooms on tankers and combination carriers:

.1 cargo pump rooms where cargo pumps are located as well as exits and trunks leading to such spaces; pump rooms adjacent to cargo tanks and bilge tanks (refer to **2.4.7**);

.2 pump rooms where pumps transporting water and liquid fuel are located.

1.5.8 Working spaces are spaces on special purpose ships, which are neither machinery spaces nor part of them such as workshops, laboratories and other similar spaces, as well as trunks leading to such spaces, where:

.1 fuel oil or flammable liquids are used or combustible materials are processed;

.2 neither flammable liquids are used, nor combustible materials are processed. Working spaces shall comply with the requirements of the present Part for service spaces if not specified otherwise.

1.5.9 Special category spaces are enclosed spaces located above or below the bulkhead deck into and out of which motor vehicles can be driven under their own propulsion and to which passengers have access. These spaces may be located on more than one deck if total overall clear height for the motor vehicles does not exceed 10 m.

1.5.10 Special electrical spaces — refer to 1.2, Part XI "Electrical Equipment.

1.6 SUBDIVISION AND TESTING OF MATERIALS AND PRODUCTS ACCORDING TO THE FIRE TEST PROCEDURES CODE 2010

1.6.1 The Fire Test Procedures Code is applied to materials and products subject to testing and assessment in accordance with the provisions of the Code and approved by the Register, as required by the Rules.

1.6.2 Where reference to the Fire Test Procedures Code is made in the text of any requirement of the present Rules, it means that the material or product shall be tested in compliance with an applicable fire test procedure or procedures, stipulated by the Code, except cases specified by the same Code.

1.6.3 In accordance with applicable parts of Annex 1 of the Fire Test Procedures Code materials and products shall be tested mentioned in the present Rules as:

.1 non-combustible materials (refer to **2.1.1.5**, **2.1.2**, **2.2.2.5** and **2.3.4**).

Non-combustible material is a material, which neither bums nor gives off flammable vapours in the amount sufficient for self-ignition when heated to 750°C approximately. Any other material is a combustible material. However, products made only of glass, concrete, ceramics, natural stone, masonry units, common metals and metal alloys are considered being noncombustible and may be installed without testing;

.2 not generating excessive quantities of smoke and toxic products (refer to **2.1.1.7** and **2.1.2.6**) or not hazardous as regards generation of toxic or explosive products at elevated temperatures (refer to **2.1.1.6**);

.3 "A" or "B" class divisions, such as: decks, bulkheads, doors, continuous ceilings and linings, windows, fire dampers, places of piping and cabling passage (refer to **2.1.2** and **2.1.3**);

.4 fire doors control systems capable of operating in case of fire (refer to **2.2.4.1.15**);

.5 low flame-spread surfaces (refer to **2.1.1.5**, **2.1.1.8**, **2.1.2.6**, and **2.1.2.8**). Low flame-spread means that the surface restricts the spread of flame to a sufficient extent;

.6 draperies, curtains and other vertically supported textile materials, which meet the requirements as regards flame spread resistance not inferior to those of wool having a mass of 0.8 kg/m^2 (refer to **2.1.1.9**);

.7 upholstered furniture meeting the requirements as regards ignition and flame-spread resistance (refer to **2.1.1.9**);

.8 bedding components (blankets, covers, pillows, mattresses), which meet the requirements as regards ignition and flame-spread resistance (refer to **2.1.1.9**).

1.6.4 When testing and approving the materials and products in accordance with the Fire Test Procedures Code additional requirements specified in the appropriate parts of Annex 1 of the Fire Test Procedures Code.

1.7 ALTERNATIVE DESIGN AND ARRANGEMENTS

1.7.1 General.

1.7.1.1 Fire safety design and arrangements may deviate from the requirements of the present Part, provided, that the design and arrangements meet the fire safety objectives and the functional requirements.

1.7.1.2 If the design and arrangements deviate from the prescriptive requirements of the present Part, engineering analysis, evaluation and approval of the alternative design and arrangements shall be carried out in accordance with the requirements of the present Chapter.

1.7.2 Engineering analysis.

1.7.2.1 The engineering analysis submitted to the Register shall be prepared based on the Guidelines on Alternative Design and Arrangements for Fire Safety[5], and shall include, as a minimum, the following elements:

.1 determination of the ship type and space(s) concerned;

.2 identification of prescriptive requirement(s) with which the ship or the space(s) will not comply;

.3 identification of the fire and explosion hazards of the ship or the space(s) concerned including:

.3.1 identification of the possible ignition sources;

.3.2 identification of the potential for the spread of fire of each space concerned;

.3.3 identification of the smoke and toxic products generation potential for each space concerned;

.3.4 identification of the potential for the spread of fire, smoke or of toxic products generation from the space(s) concerned to other spaces;

.4 determination of the required fire safety performance criteria for the ships or the space(s) concerned addressed by the prescriptive requirements, which shall:

.4.1 be based on the fire safety objectives and on the functional requirements of the present Part;

.4.2 provide a degree of fire safety not less than that achieved by using the prescriptive requirements;

.4.3 be quantifiable and measurable;

.5 detailed description of the alternative design and arrangements, including a list of the assumptions used in the design and any proposed operational restrictions or conditions;

.6 technical justification demonstrating that the alternative design and arrangements meet the required fire safety performance criteria.

1.7.3 Evaluation of the alternative design and arrangements.

1.7.3.1 The engineering analysis required in 1.7.2 shall be evaluated and approved by the Register taking into account the Guidelines for Alternative Design Solutions and Means for Fire Safety and Guidelines for Approval of Alternatives and Equivalents Approved by IMO Circular MSC.1/Circ.1455.

1.7.3.2 A copy of the documentation, as approved by the Register, indicating that the alternative design and arrangements comply with the requirements of the present Chapter shall be carried on board a ship.

1.7.4 Re-evaluation due to change of conditions.

1.7.4.1 If the assumptions and operational restrictions that were stipulated in the alternative design and arrangements are changed, the engineering analysis shall be carried out again under the changed condition and shall be approved by the Register.

2 STRUCTURAL FIRE PROTECTION

2.1 GENERAL

2.1.1 Requirements for materials.

2.1.1.1 The hull, superstructures, structural bulkheads decks and deckhouses shall be manufactured of steel or other equivalent material. For the purpose of using the definition of steel or other equivalent material, given in **1.2.1**, "applicable fire exposure" shall correspond to the standards of fire integrity and insulation, specified in the appropriate bulkheads and decks fire integrity tables. For example, if for such divisions as decks or side and end bulkheads of deckhouses fire integrity equal to "B-0" is allowed, then "applicable fire exposure" shall be equal to half an hour.

If aluminum alloys are used, the requirements of **2.1.1.3** shall be met.

2.1.1.2 Casings and crowns of machinery spaces of category A shall be of steel and insulated as required by Tables 2.3.3-1 and 2.4.2-1 as appropriate.

The floor plating of normal passageways in machinery spaces of category A shall be made of steel.

2.1.1.3 If any part of the division is manufactured of aluminum alloys, the following requirements shall be complied with:

.1 parts of "A" or "B" class divisions, made of aluminum alloy, except the divisions, which are not loadbearing, shall be insulated so, that the temperature of the structural core of the specimen does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure at the standard fire test;

[5] Refer to IMO MSC/Circ.1002 with Corr.1, Corr.2, Corr.3 and IMO MSC.1/Circ.1552.

.2 special attention shall be given to insulation of aluminum alloy components of columns, stanchions and other structural members required to support lifeboat and life raft stowage, launching and embarkation areas and "A" and "B" class divisions to ensure that:

2.1 such members required to support lifeboat and life raft stowage, launching and embarkation areas and "A" type divisions comply with the temperature rise limitation requirement, as specified in **2.1.1.3.1**, at the end of an hour;

2.2 such members required to support "B" class divisions comply with the temperature rise limitation requirement, as specified in **2.1.1.3**, at the end of half an hour.

2.1.1.4 In accommodation spaces, service spaces and control stations of all types of ships the total mass of combustible materials of each enclosed space shall be calculated based on the following formula:

$M_{rel} = M_t/S$ (2.1.1.4)

where M_{rel} - the total mass of combustible materials per unit area of the space, in kg/m^2;

M_t - the total mass of combustible materials of the space, in kg;

S - the floor area of the space, in m^2.

The following combustible materials shall be included to the calculations:

.1 construction materials as cables insulation, plastic pipes, veneers and combustible materials permitted to be used according to the present Part;

.2 outfitting, which may be installed during construction or provided by the shipowner or crew, including furniture, bedding components and electrical appliances.

Maximum values for the total mass of combustible materials per unit area *Mrel*, in kg/m2, shall not exceed the values specified in Table 2.1.1.4.2. Space categories shall correspond to the ones specified in **2.2.1.3**, **2.2.1.5**, **2.3.3** or **2.4.2**, depending on the ship type.

Table 2.1.1.4

Ship type	Space category		
	Passenger ship carrying more, than 36 passengers	Passenger ship carrying not more, than 36 passengers	Cargo ships
Stairways, corridors	5	5	5
Control stations	5	5	5
Accommodation spaces	15 - minor fire risk, 35 - moderate and greater fire risk	35	35
Service spaces surrounded by "A" class divisions	45	45	45

2.1.1.5 Insulation materials shall be non-combustible, except for use in cargo spaces, postal and baggage storerooms and refrigerated storerooms of service spaces. Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of piping fittings of cooling systems and piping of cooling water of the conditioning systems may be combustible, but they shall be kept to the minimum as far as practicable, while their exposed surfaces shall be low flame-spread.

Insulating materials shall not contain asbestos[6].

In the spaces where oily products may be present the insulation surface shall be oily vapours-impermeable, which may be provided by coating insulation with metallic film or glass cloth.

2.1.1.6 Primary deck coverings, if applied within accommodation and service spaces and control stations or on cabin balconies of passenger ships constructed on or after 1 July 2008 shall be of an approved material, which has low flame spread characteristics, this being determined in accordance with the FTP Code.

Where a floor covering is required to be low flame-spread; all layers shall comply with the requirement of 1.6.3.5. If the floor covering has a multilayer construction, the tests shall be conducted for each layer or combinations of some layers of such covering. At that, the Register approval is applicable to the tested combinations of layers.

Where primary deck covering is also the exposed surface (refer to **2.1.1.8**), it shall comply with the requirements of **1.6.3.5**

Primer or similar thin film of paint on deck plating need not comply with the requirements of **1.6.3.5**.

On passenger ships constructed on or after 1 July 2008, primary deck coverings on cabin balconies shall not give rise to smoke, toxic or explosive hazards at elevated temperatures, this being determined in accordance with the FTP Code.

2.1.1.7 Paints, varnishes and other finishings used on exposed surfaces inside service and accommodation spaces, control stations and stairways enclosures shall not generate excessive quantity of smoke and toxic vapours, this being determined in accordance with the FTP Code.

This requirement applies to the finish materials of bulkheads, decks, floor coverings, linings and ceilings, but is not applicable to cables insulation, plastic piping and furniture.

Finish materials and primary deck coverings (refer to **2.1.1.6**) with total thermal emission of not more than 0,2 MJ and maximum value of thermal emission factor not more than 1,0 kW (both values are determined in accordance with Part 5 of the FTP Code and are considered as complying with the requirements of **1.6.3.2** without tests.

On board oil tankers, chemical tankers and oil recovery ships the use of aluminium coatings containing greater than 10 % aluminium by weight in the dry film is prohibited in cargo tanks, cargo tank deck area, pump rooms, cofferdams or any other area where cargo vapour may accumulate.

On passenger ships constructed on or after 1 July 2008, paints, varnishes and other finishes used on exposed surfaces of cabin balconies, excluding natural hard wood decking systems, shall not be capable of producing excessive quantities of smoke and toxic products, this being determined in accordance with the FTP Code.

2.1.1.8 In accordance with the FTP Code the following surface shall have low flame spread characteristics:

.1 on passenger ships:

.1.1 exposed surfaces in corridors and stairway enclosures, as well as bulkheads and plating, ceiling linings in accommodation and service spaces (except saunas) and control stations;

.1.2 surfaces and grounds in concealed and inaccessible spaces in accommodation and service spaces and control stations;

.2 on fishing vessels of 24 m in length and over and on cargo ships of 500 gross tonnage and upwards:

.2.1 exposed surfaces in corridors and stairway enclosures and of ceilings in accommodation and service spaces (except saunas) and control stations;

.2.2 surfaces and grounds in concealed and inaccessible spaces in accommodation and service spaces and control stations;

.3 glues and sealants used in the "A" and "B" class divisions;

.4 exposed surfaces of cabin balconies, except for natural hard wood decking systems;

.5 primary deck coverings.

The above requirements apply to finish materials of bulkheads, decks, floor coverings, linings and ceilings, but is not applicable to plastic piping, electrical cables and furniture.

2.1.1.9 On passenger ships carrying more than 36 passengers in accommodation spaces, the furniture and furnishings of which constitute restricted fire risk, upholstered furniture, bedding components, draperies and curtains and other vertically supported textile materials shall be satisfactorily tested in compliance with the FTP Code (refer to **1.6.3.6 - 16.3.8**). For other types of ships, the said requirements are recommended only.

2.1.1.10 On passenger ships, "A", "B" and "C" class divisions in accommodation and service spaces and cabin balconies, which are faced with combustible materials, facings, mouldings, decorations and veneers shall comply with the requirements of the present paragraph and **2.1.1.6 - 2.1.1.8**. However, traditional wooden benches and wooden linings of bulkheads and ceilings are allowed in saunas and such materials may not be taken into calculation required by the paragraph.

On cargo ships, non-combustible bulkheads, ceilings and linings fitted in accommodation and service spaces may be faced with combustible materials, facings, mouldings, decorations and veneers provided such spaces are bounded by non-combustible bulkheads, ceilings and linings in accordance with the requirements of the present paragraph and **2.1.1.6 - 2.1.1.8.**

Combustible materials used on the surfaces and linings shall have calorific value not exceeding 45 MJ/m2 taking into consideration their thickness. Requirements of this article are not applicable to the surfaces of furniture fixed to linings or bulkheads.

Calorific value Q, in MJ/m^2, taking into consideration the thickness of covering material, is determined by the formula

$$Q = Q_g p s \qquad (2.1.1.10)$$

where Q_g - the maximum specific heat of combustion determined oil in accordance with ISO 1716 "Construction Materials. Determination of the Calorific Potential", in MJ/kg;

p - the density of material, in kg/m3;

s - the thickness of material, in m.

Where combustible materials are used in accordance with the present paragraph, they shall comply with the following requirements:

.1 the total volume of combustible facings, mouldings, decorations and veneers in any accommodation or service spaces shall not exceed a volume equivalent to 2,5 mm veneer of the combined area of the walls and ceiling linings. The furniture fixed to linings, bulkheads or decks may be not included into the calculation of the total volume of combustible materials;

.2 in case of ships fitted with an automatic sprinkler system complying with the provisions of the FSS Code, the above volume may include some combustible materials used for erection of "C" class divisions.

On non-self-propelled ships without regard of their gross tonnage it is permissible to fit non-combustible bulkheads, linings and ceilings with combustible covering less than 2 mm thick except corridors, stairway enclosures as well as control stations where thickness of covering shall not exceed 1,5 mm.

The furnishings specified in **2.1.1.10.1** and **2.1.1.10.2** and applied on cabin balconies may not be taken into calculation required by the paragraph.

2.1.1.11 All waste receptacles shall be constructed of non-combustible materials with no openings in the sides and bottom.

Containers constructed of combustible materials may be used in galleys, pantries, bars, garbage handling or storage spaces and incinerator rooms provided they are intended purely for the carriage of wet waste, glass bottles or metal cans and are suitably marked.

2.1.1.12 If the ship's structures are made of glass-reinforced plastic in accordance with Part XVI "HULL STRUCTURE AND STRENGTH OF GLASS-REINFORCED PLASTIC SHIPS AND BOATS", the fire-retardant properties and fire resistance of such structures shall be tested according to the procedure set out in the Fire Test Procedures Code.

2.1.2.1 "A" class divisions are those divisions which are formed by bulkheads or decks complying with the following requirements:

.1 they shall be constructed of steel or other equivalent material;

.2 they shall have respective stiffening elements;

.3 they shall be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the 60-min standard fire test;

.4 they shall be so insulated with approved non-combustible material that the average temperature of the unexposed side will not rise more than 140 8C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 8C above the originaltemperature.

Depending on the time during which the above-indicated temperature rise is ensured in the course of the standard fire test, the following symbols are given to divisions: "A-60" - during 60 min; "A-30" - during 30 min; "A-15" - during 15 min; "A-0" - during 0 min.

2.1.2.2 When approving the structural fire protection the danger of heat transfer through joints and ends of insulation shall be taken into account. Insulation of steel and aluminium decks and bulkheads shall extend for at least 450 mm beyond boundaries of structures forming the given space.

If a space is divided by the "A" class deck or bulkhead with an insulation of different size, then an insulation of greater size shall extend over the deck and bulkhead for at least 450 mm from the less insulated structure.

Measures taken to prevent heat transfer through joints and ends of insulation of decks and bulkheads are shown in Figs. 2.1.2.2-1 and 2.1.2.2-2. The Register may approve some other variants of such measures, provided the efficacy of the proposed structure is verified by the results of tests conducted in accordance with the FTP Code.

Where the lower part of insulation is cut off to provide drainage, the structure shall comply with Fig. 2.1.2.2-3.

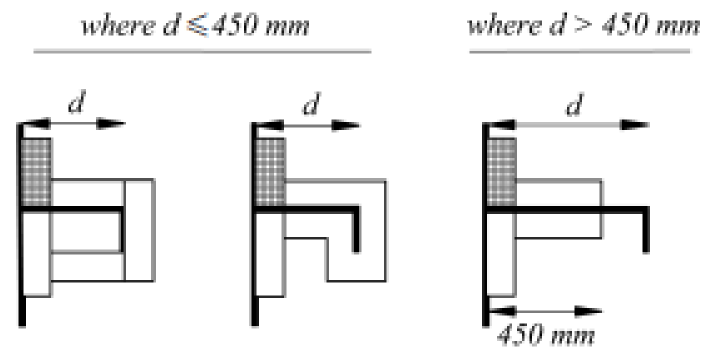


Fig. 2.1.2.2-1

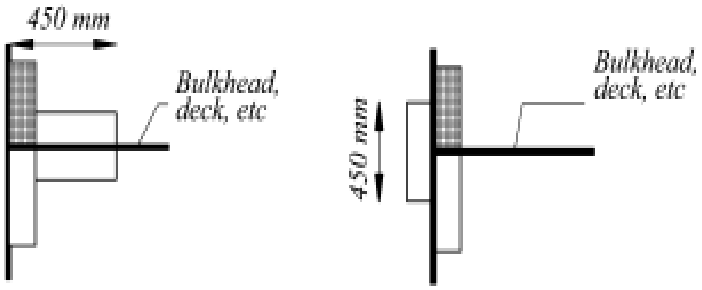


Fig. 2.1.2.2-2

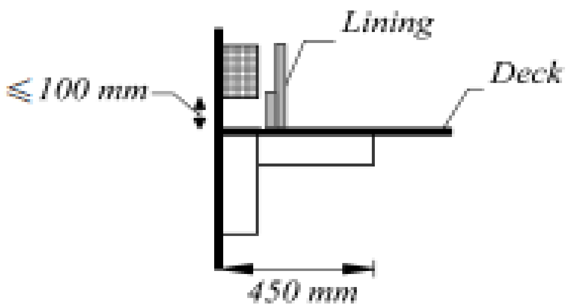


Fig. 2.1.2.2-3

N o t e . *d* - height of the stiffener at the longitudinal member.

-structural insulation

-insulation in accordance with **2.1.2.2**.

2.1.2.3 Lightweight (honeycomb and other) structures made of steel or other equivalent material may be used as internal divisions of "A" class in the accommodation and service spaces, provided they are not load-bearing structures and successfully passed prescribed tests in accordance with the FTP Code. Such lightweight structures shall not be used as the components of the main fire protection zones and stairways enclosures in passenger ships.

2.1.2.4 The following elements may be fitted without tests:

.1 "A-0" class bulkheads, if made of steel and having the dimensions not less than the following:

plate thickness - 4 mm;

stiffeners 60x60x5 mm located at a distance of 600 mm from each other or having similar construction;

.2 "A-0" class decks if made of steel and having the dimensions not less than the following:

plate thickness - 4 mm;

stiffeners 95x65x7 mm located at a distance of 600 mm from each other or having similar construction.

2.1.2.5 "B" class divisions are those divisions which are formed by bulkheads, decks, ceilings or linings which comply with the following requirements:

.1 they are made of approved non-combustible materials.

Use of combustible veneer is permitted (refer to **2.1.1.8** and **2.1.1.10**);

.2 divisions shall be so constructed as to remain capable of preventing the passage of flame up to the end of the 30-minute standard fire test;

.3 divisions shall have an insulation value such that the average temperature on the unexposed side during the fire test 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 when either side is exposed to the fire test.

According to the time during which the above-mentioned temperature rise is ensured in the course of the standard fire test, the following symbols are given to divisions: "B-30" - during 30 min; "B-15" - during 15 min.; "B-0" - during 0 min.

2.1.2.6 Materials used in the "A" and "B" class divisions, which according to the present Part shall have particular characteristics (be non-combustible, low flame-spread or not generating excessive quantities of smoke and toxic agents), shall comply with the requirements of the FTP Code (refer to **1.6.3.1**, **1.6.3.2** and **1.6.3.5**).

2.1.2.7 Continuous "B" class ceilings and linings with the relevant decks or bulkheads may be considered as fully or partially ensuring insulation and fire integrity of structures, as required by the respective fire integrity tables.

2.1.2.8 "C" class divisions are the divisions made of approved non-combustible materials. They do not need meet any requirements relative to the passage of smoke and flame or the limiting of temperature rise. It is not required that gluing materials in these structures be non-combustible, however, these materials shall be low flame-spread.

2.1.2.9 Divisions consisting of non-combustible core and combustible veneers may be accepted as "B" or "C" class divisions, provided that the non-combustible core is tested and complies with the requirements of **1.6.3.1**, and the "B" class division is tested and complies with the requirements of **2.1.2.4**, and the veneers, if applicable, are tested and comply with the requirements of **1.6.3.2** and **1.6.3.5**.

2.1.3 Closures of openings in fire-fighting divisions.

2.1.3.1 Fire integrity of doors shall be equal to fire integrity of the divisions where they are installed, which is determined in accordance with the FTP Code and applicable provisions of IMO circular MSC.1/Circ.1319 for large fire doors. Doors and doorframes in "A" class divisions shall be made of steel or other equivalent material. Doors in "B" class divisions shall be non-combustible.

2.1.3.2 The doors designed in compliance with the requirements of **7.5.2** and **7.12**, Part III "Equipment, Arrangements and Outfit" and fitted according to **7.12** of the above mentioned Part, and, in certain cases (e.g., for providing gastightness), if specially agreed with the Register, may be fitted in "A" classbulkheads. As doors fitted in watertight bulkheads of cargo and passenger ships and subject to fire integrity and water tightness requirements, watertight doors may serve but not need to be fire-tested notwithstanding the fire integrity of the division in which they are fitted.

However, such doors fitted above the bulkhead deck on passenger ships shall be tested to the FTP Code in accordance with the fire integrity of the division they are fitted.

If it is not practical to ensure self-closing for the said doors which shall be self-closing, means of indication on the bridge showing whether these doors are open or closed and a notice "TO BE KEPT CLOSED AT SEA" can be alternative of the self-closing.

Where a watertight door is located adjacent to a fire door, both doors shall be capable of independent operation, remotely if required by **7.12**, Part III "Equipment, Arrangements and Outfit" and from both sides of each door.

2.1.3.3 If the "A" class divisions are penetrated, then such penetrations (cutouts) shall be tested in accordance with the FTP Code, considering the provisions of **2.2.1.4**. The requirements of **12.1.12** and **12.1.23**, Part VIII "Systems and Piping" are applied to ventilation ducts. Tests may not be conducted if the pipes penetrations are made of steel or other equivalent material with a thickness of 3 mm or greater and a length of not less than 900 mm (preferably 450 mm at each side of the division) and do not have any openings. Such penetrations shall be insulated similar to the division itself.

In case where pipe penetrations and cable transits are constructed without structural sockets and consist of removable sleeves welded or bolted to the division and/or of soft or intumescent filling material, these sleeves shall be of minimum 3 mm thickness and of minimum 60 mm length and filling material shall be adequately secured by bonded materials or mechanical means in order to prevent damage or fall out. Such penetrations shall not impair fire integrity and structural strength of the divisions.

2.1.3.4 If "B" class divisions are penetrated for the passage of electric cables, pipes, ducts, trunks, etc., or for the fitting of the ventilation terminals, lighting fixtures and similar devices, arrangements shall be provided to ensure fire integrity of a division. Ventilation ducts shall comply with the requirements of **12.1.13**, Part VIII "Systems and Piping". Pipes other than steel or copper that penetrate "B" class divisions shall be protected by the following:

.1 fire tested penetration device, adequate to the fire integrity of the division penetrated and the type of pipes used; or

.2 steel sleeve, having a thickness of not less than 1,8 mm and a length of not less than 900 mm for pipe diameters of 150 mm or greater and not less than 600 mm for pipe diameters of less than 150 mm (preferably equally divided at each side of the division). Pipes shall be connected to the ends of the sleeve by flanges or

couplings; or the clearance between the sleeve and the pipe shall not exceed 2,5 mm; or any clearance between the pipe and the sleeve shall be made tight by means of non-combustible or other suitable material.

2.1.3.5 Uninsulated metallic pipes penetrating "A" or "B" class divisions shall be made of materials having a melting temperature exceeding 950°C for "A-0" class divisions and 850 8C for "B-0" class divisions.

2.1.3.6 In ships other than passenger ships carrying more than 36 passengers external boundaries, which shall be made of steel or other equivalent material, may be penetrated for the fitting of windows and side scuttles, provided there is no requirement in the present Part for such boundaries to be of "A" class.

In such boundaries, which are not required to be of "A" class, doors on agreement with the Register may be made of materials the ventilation ducts than the ones of the boundary.

2.1.3.7 Balancing openings or ducts between two enclosed spaces are prohibited except for the openings permitted by **2.2.4.3** and **2.3.8**.

2.1.4 Measures for prevention of spread of fire and smoke.

2.1.4.1 For machinery spaces provision shall be made to control the opening and closing of skylights, arrangements for closing openings in funnels, which normally ensure exhaust ventilation as well as closing of ventilation flaps.

The controls shall be located outside the serviced space where they would not be isolated in case of fire in the space.

2.1.4.2 For the protection of openings in the boundaries of A category machinery spaces the following measures shall be taken:

.1 the number of skylights, doors, ventilation openings, openings in funnels to permit exhaust ventilation and other openings shall be reduced to a minimum required for ventilation, as well as proper and safe operation of ship;

.2 skylights shall be made of steel and shall have no glass panels;

.3 provision shall be made to control the closing of power operated doors or actuating release mechanism of doors other than watertight power operated doors. The controls shall be located outside the serviced space where they would not be isolated in case of fire in the space;

.4 windows shall not be fitted in machinery spaces boundaries. However, this does not preclude the use of glass in control stations within the machinery spaces;

.5 in passenger ships the requirements of **2.2.4.1** shall be met additionally.

Skylights of cargo pump rooms, specified in **1.5.7.1**, shall be made of steel and shall be closed from a position located outside the pump room.

2.1.4.3 In accommodation and service spaces, as well as in control stations stairways and lift trunks shall be protected in the following way:

.1 in cargo ships stairways which penetrate only a single deck shall be protected at least at one level by at least "B-0" class divisions and self-closing doors. Lifts which penetrate only a single deck shall be surrounded by "A-0" class divisions with steel doors at both levels. Stairways and lift trunks which penetrate more than a single deck shall be surrounded by at least "A-0" class divisions and protected by self-closing doors at all levels. Stairway enclosures may be arranged so as to allow to go from one stair to a superimposed stair within such enclosure (Fig. 2.1.4.3.1-1), or to enclose the stairs only with doors at each end of the stair (Fig. 2.1.4.3.1-2), or to enclose the stairs only in combination with fully closed steel stairs and doors fitted at the end of each stair (Fig. 2.1.4.3.1-3);

.2 on ships having accommodation for 12 persons or less, where stairways penetrate more than a single deck and where there are at least two escapes direct to the open deck at every accommodation level, stairways and lift trunks may be protected by "B-0" class divisions;

.3 in passenger ships the stairways and lift trunks shall be protected in compliance with **2.2.2.4**;

.4 the construction of stairways shall comply with the requirements of **8.5.4**, Part III "Equipment, Arrangements and Outfit".

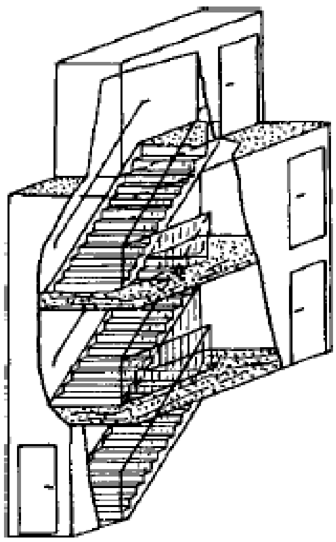


Fig. 2.1.4.3.1-1

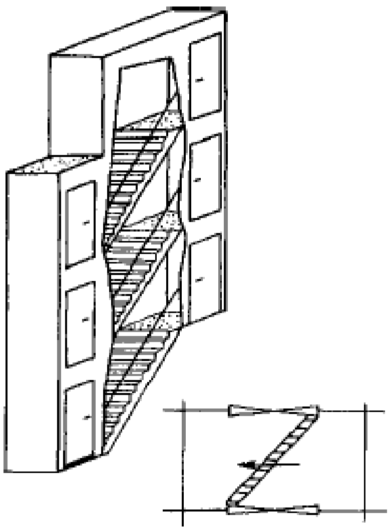


Fig. 2.1.4.3.1-2

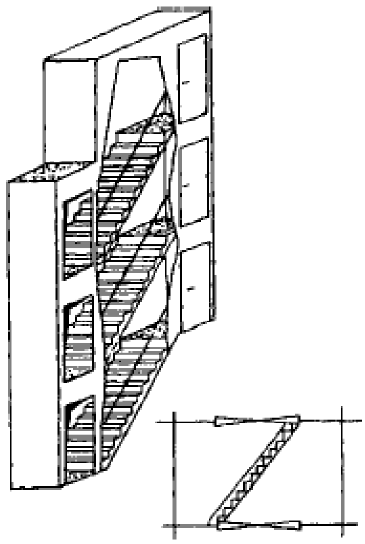


Fig. 2.1.4.3.1-3

2.1.4.4 Air spaces enclosed behind ceilings, panellings, or linings shall be divided by close-fitting draught stops spaced not more than 14 m apart.

In the vertical direction, such air spaces, including those behind linings or stairways, trunks, etc. shall be closed at each deck.

2.1.4.5 In machinery spaces from which two stairways are provided in accordance with **4.5**, Part VII "Machinery Installations" one of them shall be protected by enclosure along its whole length meeting requirement **2.2.1.3** category (**2**) or requirements **2.2.1.5** category (**4**), **2.3.3** or **2.4.2**, as appropriate. Self-closing fire doors of the same type of fire integrity shall be fitted in the enclosure.

Stairways shall be arranged to avoid transfer of heat to the enclosure through uninsulated fixing points.

2.1.4.6 In addition to watertight door separating the machinery space of category A from the shaft tunnel, from the side of the latter a light steel fire-screen door shall be fitted to be operated from each side.

2.1.4.7 Permanent openings in the side shell, ends and ceiling of enclosed spaces for the carriage of vehicles, enclosed ro-ro spaces, as well as special category spaces shall be so situated that a fire in these spaces does not endanger stowage areas and embarkation stations for lifeboats and liferafts, accommodation spaces, service spaces and control stations in superstructures and deckhouses above the mentioned spaces.

2.1.5 Additional requirements to spaces of separate categories.

In addition to the requirements of Section 2, the following requirements to structural fire protection shall be complied with.

2.1.5.1 Saunas shall comply with the following requirements:

.1 the perimeter of the sauna shall be of "A-60" class boundaries except spaces inside of the perimeter and spaces of categories (***5***), (***9***) and (***10***) as specified in **2.2.1.3**, or spaces of categories (***5***), (***7***) and (***10***) as specified in **2.2.1.5.1**, **2.3.3**, **2.4.2**, **2.5.3** or **2.6.3**, depending on the purpose of ship;

.2 saunas may include changing rooms, showers and toilets. Bathrooms with direct access to saunas may be considered as part of them. In such cases, the door between sauna and the bathroom need not comply with fire safety requirements;

.3 the traditional wooden lining on the bulkheads and ceiling are permitted in the sauna. The ceiling above the oven shall be lined with non-combustible plate with an air gap of at least 30 mm. The distance from the hot surfaces to combustible materials shall be at least 500 mm or the combustible materials shall be protected (e.g., by a non-combustible plate with an air gap of at least 30 mm);

.4 the traditional wooden benches are permitted in saunas;

.5 the sauna door shall have no locks and open outwards by pushing;

.6 electrically heated ovens shall be provided with a timer and meet the requirements of Section **15**, Part XI "Electrical Equipment", while cables and wires shall meet the requirements of **16.8** of the same Part.

2.1.5.2 Galleys shall comply with the following requirements:

.1 galleys utilizing sources of power other than electricity shall not be adjacent to storerooms for flammable materials and substances or to fuel oil and lubricating oil tanks;

.2 galley decks shall be covered with ceramic tiles or similar non-combustible covering;

.3 exhaust ventilation ducts from galley ranges shall meet the requirements of **12.2.4**, **12.2.7** or **12.3.6**, Part VIII "Systems and Piping".

2.1.5.3 Storerooms for flammable materials and substances shall comply with the following requirements:

.1 storerooms for flammable materials shall not be generally situated in common with accommodation spaces in superstructure or deckhouse. Access to the storerooms shall be provided from the open deck directly or through a corridor and/or a stairway leading only to these storerooms;

.2 all electrical equipment of the storeroom shall be explosion proof in compliance with **2.9**, Part XI "Electrical Equipment".

2.1.5.4 Spaces for electric and gas welding operations shall comply with the following requirements:

.1 the spaces shall be separated from adjacent spaces by "A-60" class divisions;

.2 spaces shall have direct access from the open deck; the doors shall open outwards and be fitted with locks;

.3 location and arrangement of such spaces in oil tankers shall meet the requirements of **2.1.5.4.1**, **2.1.5.4.2** and as follows:

.3.1 spaces shall be positioned aft of cargo and slop tanks as well as protecting cofferdams;

.3.2 spaces shall be provided with mechanical ventilation, which shall ensure at least twenty air changes per hour;

.3.3 the possibility of welding operations shall be excluded with the access door opened and with inactive mechanical ventilation;

.3.4 the warning plates:

«DO NOT ENTER! WELDING!» shall be provided on the room doors;

.4 oxygen and acetylene cylinders for electric and gas welding operations shall be kept in separate storerooms, complying with the following requirements:

.4.1 acetylene cylinders storeroom shall be independent of the oxygen cylinder storeroom;

.4.2 storerooms shall be located on or above the uppermost continuous deck and shall not be adjacent to accommodation spaces, control stations, galleys, storerooms for flammable materials, as well as to fuel oil and lubricating oil tanks;

.4.3 divisions separating the storerooms from adjacent spaces shall be of "A-60" class;

.4.4 such spaces shall have direct access from the open deck, the doors shall open outwards and be fitted with locks providing their reliable closure to prevent unauthorized access;

.4.5 the warning plates:

"DANGER OF EXPLOSION!" and **"NO SMOKING!"** shall be provided on the storerooms doors.

2.1.5.5 Cargo spaces specified in **1.5.4.3**, **1.5.4.4** and **1.5.9**, in which motor vehicles with fuel in their tanks are carried, shall comply with the following requirements:

.1 entrances to the cargo spaces from accommodation, machinery and special electrical spaces shall be equipped with self-closing permanently closed doors. The coamings height of these doors shall not be less than 450 mm;

.2 warning plates prohibiting smoking shall be provided near the entrances to the cargo spaces;

.3 the cargo spaces shall comply with the requirements of **12.6**, Part VIII "Systems and Piping" and **19.3**, Part XI "Electrical Equipment".

2.1.5.6 A portion of open deck recessed into a deck structure, machinery casing, deck house, etc, used for the exclusive storage of gas bottles shall comply with the following requirements:

.1 such a recess shall have an unobstructed opening, except for small appurtenant structures, such as opening corner radii, small sills, pillars, etc. The opening may be provided with grating walls and doors;

.2 the depth of such a recess shall not be greater than 1 m;

.3 a portion of the open deck complying with the requirements of **2.1.5.6.1** and **2.1.5.6.2**, is considered as open deck in applying Tables 2.2.1.3-1, 2.2.1.3-2, 2.2.1.5-1, 2.2.1.5-2, 2.3.3-1, 2.3.3-2, 2.4.2-1, 2.4.2-2.

2.1.5.7 Fan rooms serving engine rooms shall meet the following requirements:

.1 a fan room solely serving the engine room or multiple spaces containing an engine room may be treated as machinery space having little or no fire risk, in this case boundaries between the fan room and engine room casing shall be of "A-0" fire integrity;

.2 a fan room solely serving the engine room may be considered as part of the engine room, in this case the requirements for fire integrity of the horizontal boundary between fan room and engine room need not apply;

.3 for both of the cases described above, for any space(s) adjacent to the fan room superstructure, the fire integrity of the separating bulkhead(s) shall meet the applicable fire integrity requirements contained in the present Rules.

2.1.5.8 Independent back-up dynamic positioning control system shall be arranged in a special space separated by "A-60" class bulkhead from the main control station in accordance with **8.9.3**, Part XV "Automation".

2.1.5.9 Incinerators and waste stowage spaces.

2.1.5.9.1 As regards structure, equipment and insulation, the incinerator rooms shall be considered as category "A" machinery spaces; waste stowage spaces, garbage grinding and compacting spaces - as service spaces.

Structural fire protection shall be performed in accordance with **2.2.1.3 (12)**, **2.2.1.5 (6)**, **(9)**, **2.3.3 (6)**, **(9)**, **2.4.2 (6)**, **(9)** (refer to Table 1).2.2.1.3-1, 2.2.1.3-2; 2.2.1.5-1, 2.2.1.5-2; 2.3.3-1, 2.3.3-2; 2.4.2-1, 2.4.2-2) as appropriate.

2.1.5.9.1 Requirements for structural fire protection in compliance with 2.2.1.3, 2.2.1.5, 2.3.3, 2.4.2 may not be applied, if the spaces are arranged aft as far as practicable; at least 3 m from entrances, air inlets or openings to accommodations, service spaces and control stations, not less than 5 m measured horizontally from the nearest hazardous area or vent outlet from a hazardous area; not less than 2 m shall separate the incinerator and the waste material stowage area, unless physically separated by a structural fire barrier in accordance with **2.1.5.9.1**.

The spaces are located on weather deck shall be accessible with two means of fire extinguishment; either fire hoses or fire extinguishers in compliance with para **5**, Table 5.1.2; fire monitors, or fixedf fire-extinguishing system.

2.1.5.10 Special electrical spaces.

2.1.5.10.1 The minimum fire resistance of bulkheads and decks that restrict special electrical spaces (refer **to 1.5.10**) or separate such adjacent spaces depends on the purpose of the vessel.

Structural fire protection shall be performed in accordance with the requirements of Tables 2.2.1.3-1, 2.2.1.3-2; 2.2.1.5-1, 2.2.1.5-2; 2.3.3-1, 2.3.3-2; 2.4.2-1, 2.4.2-2 appropriate to the ship's purpose.

2.1.5.10.2 Special purpose passenger ships.

.1 spaces of deck area less than $4m^2$ - structural fire protection according to **2.2.1.3*(7)*** або **2.2.1.5*(5)*** asappropriate;

.2 1 spaces of deck area $4m^2$ and over:

.2.1 with sectional electrical switchboards and electrical equipment, including those having oil transformers with a capacity not exceeding 10kVA or other electrical equipment that holds fire hazardous liquids – **2.2.1.3*(10)***;

.2.2 with sectional electrical switchboards and electrical equipment with a capacity over 10kVA, including those having oil transformers with a capacity over 10 or other electrical equipment that holds fire hazardous liquids – **2.2.1.3*(11)*** або **2.2.1.5*(5)*** as appropriate;

.3 spaces of electrical equipment (automatic telephone exchanges, air conditioning systems, etc.) – **2.2.1.5*(7)***.

Note: Special purpose ships carrying: up to 240 shall comply with the requirements of Tables 2.2.1.3-1 and 2.2.1.3-2; over 240 persons shall comply with the requirements of Tables 2.2.1.5-1, 2.2.1.5-2.

2.1.5.10.3 Cargo ships, oil tankers and combined carriers with a gross tonnage of 500 and over and fishing vessels with a gross tonnage of 500 and over and / or with a length of 45 m and over.

.1 spaces of deck area less than 4m^2 - structural fire protection according to **2.3.3*(5)*** or **2.4.2*(5)*** or **2.5.3(*5)*** appropriate to the ship's purpose;

.1 spaces of deck area 4m^2 and over:

.2.1 with sectional electrical switchboards and electrical equipment, including those having oil transformers with a capacity not exceeding 10kVA or other electrical equipment that holds fire hazardous liquids – **2.3.3*(5)*** or **2.4.2*(5)*** or **2.5.3(*5)*** appropriate to the ship's purpose;

.2.2 with sectional electrical switchboards and electrical equipment with a capacity over 10kVA, including those having oil transformers with a capacity over 10 or other electrical equipment that holds fire hazardous liquids – **2.3.3*(9)*** or **2.4.2*(9)*** or **2.5.3(*9)*** appropriate to the ship's purpose;

.3 spaces of electrical equipment (automatic telephone exchanges, air conditioning systems, etc.) – **2.3.3(*7*)** or **2.4.2(*7*)** or **2.5.3*(7)*** appropriate to the ship's purpose.

2.2 PASSENGER SHIPS

2.2.1 General.

2.2.1.1 The requirements of this Chapter are additional to those set out in 2.1as well as changes and additions made in accordance with Directive 2009/45 / EC as amended (latest Directive (EU) 7017/2108 of 15.11.2017) on the Rules and Standards for the Safety of Passenger Ships.

2.2.1.2 For ships carrying more than 36 passengers, the hull, superstructure and deckhouses shall be divided into main vertical zones by "A-60" class divisions. Steps and recesses shall be kept to a minimum, but where they are necessary they shall also be "A-60" class divisions. Where a class **2.2.1.3** (**5**), **2.2.1.3** (**9**) or **2.2.1.3** (**10**) space is on one side of the division the class may be reduced to "A-0".

For ships carrying not more than 36 passengers, the hull, superstructure and deckhouses in way of accommodation and service spaces shall be divided into main vertical zones by "A" class divisions. These divisions shall have insulation values in accordance with Tables 2.2.1.5-1 and 2.2.1.5-2

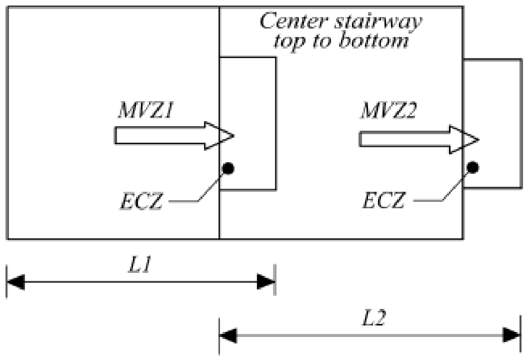


Fig. 2.2.1.2-1

ECS serves one MVZ

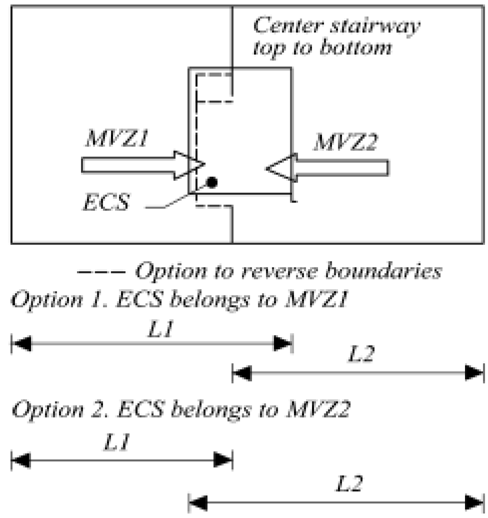


Fig. 2.2.1.2-2

ECS serves two MVZ

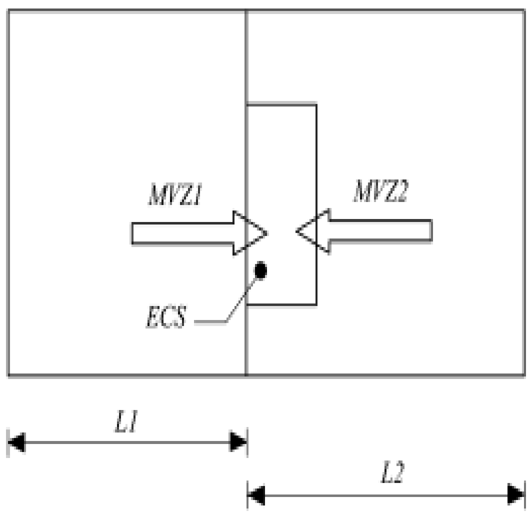


Fig. 2.2.1.2-3

ECS serves two MVZ (ECS belongs to MVZ2)

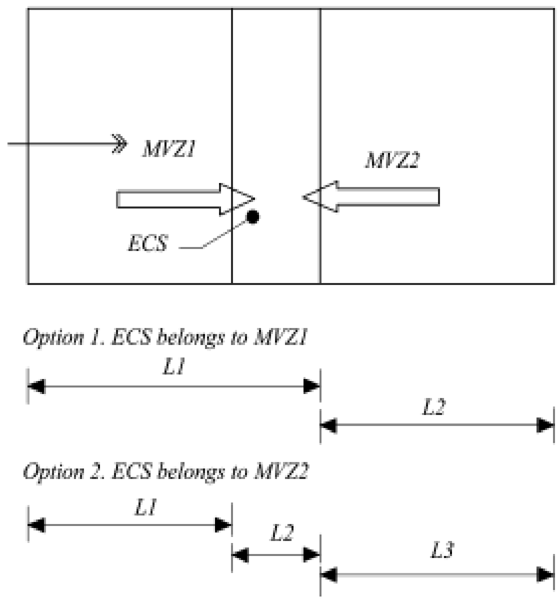


Fig. 2.2.1.2-4

ECS serves two MVZ

N o t e s to Figs. 2.2.1.2-1 - 2.2.1.2-4:
MVZ: Main vertical zone
ECS: Escape stairway
 : Direction of escape.

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 main vertical zones may be extended to a maximum of 48 m in order to bring the ends of main vertical zones to coincide with subdivision watertight bulkheads or in order to accommodate a large public space extending for the whole length of the main vertical zone provided that the total area of the main vertical zone is not greater than 1600 m2 on any deck.

If a stairway serves two main vertical zones, then maximum length of one main vertical zone shall be measured from the far side of the main vertical zone stairway enclosure. In this case, all boundaries of the stairway enclosure are to be insulated as main vertical zone bulkheads and access doors leading to the stairway are to be provided from these zones (refer to Figs. 2.2.1.2-1 to 2.2.1.2-4). However, the stairway is not to be included in calculating size of the main vertical zone if it is treated as its own main vertical zone.

Bulkheads forming the boundaries of main vertical zones shall extend from deck to deck and to the shell or other boundaries.

Where the main vertical zone is divided by horizontal "A" class divisions into horizontal zones for the purpose of providing an appropriate barrier between sprinklered and non-sprinklered zones of the ship, the divisions shall extend between adjacent main vertical zone bulkheads and to the shell or exterior boundaries of the ship and shall be insulated in accordance with the fire insulation classes given in Table 2.2.1.5-2.

On ships designed for special purposes, such as automobile or railroad car ferries, where the provision of main vertical zone bulkheads would defeat the purpose for which the ship is intended, equivalent means for controlling and limiting a fire, such as water screens complying with the requirements of **3.5**, shall be provided.

Service spaces and storerooms if they are not protected in compliance with the applicable requirements shall not be located on decks of ships specified in **1.5.4.3**.

2.2.1.2.1 Protection of atriums:

.1 atriums shall be within enclosures formed of "A" class divisions having a fire rating determined in accordance with Tables 2.2.1.3-2 and 2.2.1.5-1, as applicable;

.2 decks separating spaces within atriums shall have a fire rating determined in accordance with Tables 2.2.1.3-2 and 2.2.1.5-1, as applicable.

2.2.1.3 The minimum fire integrity of all bulkheads and decks separating adjacent spaces in ships carrying 36 passengers and more shall be as prescribed in Tables 2.2.1.3-1 and 2.2.1.3-2.

For the purpose of determining the class of structures between adjacent spaces, such spaces are classified according to their fire risk as follows.

(1) *Control stations* - spaces accommodating emergency sources of electrical power and lighting; wheelhouse and navigation room;

spaces accommodating ship radio equipment; fire stations; main machinery control room if it is located outside the space accommodating such machinery;

spaces accommodating centralized fire alarm system;

spaces accommodating central control stations and emergency loud speaking system equipment.

(2) *Stairways*: interior stairways, lifts, fully enclosed trunks for evacuation and escalators for passengers and crew (except those, which are fully located in machinery spaces) and their enclosures.

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.

(3) *Corridors*: corridors and lobbies for passengers and crew.

(4) Evacuation stations and external escape routes;

survival craft stowage area;

open deck spaces and enclosed promenades forming lifeboat and liferaft embarkation and launching stations;

muster stations, internal and external;

external stairs and open decks used for escape routes;

the ship's side to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferaft's and evacuation slide's embarkation areas.

(5) *Open deck spaces*: open deck spaces and enclosed promenades clear of lifeboat and liferaft embarkation and launching stations. To be considered in this category, enclosed promenades shall have no fire risk. This means that furnishings shall be restricted to deck furniture. In addition, such places shall be naturally ventilated by permanent openings; air spaces (spaces outside superstructures and deckhouses).

(6) *Accommodation spaces of minor fire risk*: cabins, offices, dispensaries and public spaces containing furniture and furnishings of restricted fire risk and having a deck area of less than 50 m^2 (refer to **1.2**).

(7) *Accommodation spaces of moderate fire risk*: accomodation spaces as in category (6) containing furniture and furnishings other than of restricted fire risk;

public spaces containing furniture and furnishings of restricted fire risk and having a deck area of 50 m^2 and greater;

isolated lockers and small storerooms in accommodation spaces having areas less than 4 m^2 (in which flammable liquids are not stowed);

cleaning gear lockers, laboratories (in which flammable liquids are not stowed);

drying rooms (having

a deck area of 4 m2 or less); diet kitchens (containing no open flame);

specie rooms;

motion picture projection rooms and film rooms;

drug-stores;

operating rooms;

spaces accommodating electrical distribution boards with an area less, than 4 m^2.

(8) Accommodation spaces of greater fire risk: public spaces containing furniture and furnishings of other than restricted fire risk and having a deck area of 50 m^2 and greater, sale shops;

barber shops, beauty parlours and saunas.

Table 2.2.1.3-1 **Bulkheads not bounding either main vertical zones or horizontal zones**

Spaces		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*
Control stations	*(1)*	B-0[1]	A-0	A-0	A-0	A-0	A-60	A-60	A-60	A-0	A-0	A-60	A-60	A-60	A-60
Stairways	*(2)*		A-0[1]	A-0	A-0	A-0	A-0	A-15	A-15	A-0[2]	A-0	A-15	A-30	A-15	A-30
Corridors	*(3)*			B-15	A-60	A-0	B-15	B-15	B-15	B-15	A-0	A-15	A-30	A-0	A-30
Evacuation stations and external escape routes	*(4)*					A-0	A-60[3]	A-60[3]	A-60[3]	A-0	A-0	A-60[3]	A-60[3]	A-60[3]	A-60[3]
Open deck spaces	*(5)*					—	A-0[4]	A-0[4]	A-0[4]	A-0[4]	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of minor fire risk	*(6)*						B-0	B-0	B-0	C	A-0	A-0	A-30	A-0	A-30
Accommodation spaces of moderate fire risk	*(7)*							B-0	B-0	C	A-0	A-15	A-60	A-15	A-60
Accommodation spaces of greater fire risk	*(8)*								B-0	C	A-0	A-30	A-60	A-15	A-60
Sanitary and similar spaces	*(9)*									C	A-0	A-0	A-0	A-0	A-0
Tanks, voids and auxiliary machinery spaces having minor or no fire risk	*(10)*										A-0[1]	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, special category spaces,[5] cargo and other oil tanks and other similar spaces of moderate fire risk	*(11)*											A-0[1]	A-0	A-0	A-15
Machinery spaces and main galleys	*(12)*												A-0[1]	A-0	A-60
Storerooms, workshops, pantries, etc.	*(13)*													A-0[1]	A-0
Other spaces in which flammable liquids are stored	*(14)*														A-30

[1]If adjacent spaces marked with footnote 1 have the same fire integrity, it is not nessary to divide such spaces with a bulkhead or deck. For instance for spaces of category *(12)* it is not necessary to divide a galley and buffets which are part thereof with bulkheads provided the bulkheads and buffet decks have the same fire resistance equal to that of structures bordering the galley. However, it is necessary to erect a bulkhead between the galley and machinery space although both spaces have the same category *(12)*.

[2]Where public toilets are installed completely within the stairway enclosure, the public toilet bulkhead within the stairway enclosure can be of "B" class fire integrity.

[3]The ship's side, to the waterline in the lightest seagoing condition, superstructure and deckhouse sides situated below and adjacent to the liferafts and evacuation slides may be reduced to "A-30" class.

[4]Where spaces of categories *(6)*, *(7)*, *(8)* and *(9)* are located completely within the outer perimeter of the muster station, the bulkheads of these spaces are allowed to be of "B-0" class fire integrity. Control positions for audio, video and light installations may be considered as part of the muster station.

[5]Where fuel oil tanks are located under a special category space, the fire integrity of the separating deck may be reduced to "A-0" class.

N o t e s : 1. The need to apply the requirements of Table 2.2.3-1 for the spaces of category *(5)* in respect of the bounded superstructurers and deckhouses, as well as requirements of Table 2.2.1.3-2 for the spaces of category *(5)* in respect of the spaces bounded by the upper deck shall be determined by the ship designer and agreed with the Register.

2. Where the contents and use of a space are such that there is a doubt as to its classification, it shall be treated as a space within the relevant category having the most stringent boundary requirements.

3. Notwithstanding the provisions of 2.2.2 there are no special requirements for material or fire integrity of boundaries where only a dash appears in the tables.

4. Small enclosed spaces inside the room are treated as separate spaces if square of doorways to adjacent spaces is less than 30 % of openings (doorways). Fire integrity of bulkheads and decks surrounding such spaces shall comply with the requirements set forth in tables of the paragraph of the Rules.

(9) Sanitary and similar spaces:

communal sanitary facilities, showers, baths, water closets, etc.;

small laundry rooms;

indoor swimming pool area;

isolated serving pantries containing no cooking appliances in accommodation spaces.

Individual sanitary spaces shall be considered a portion of the spaces 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;

spaces accommodating stabilizer equipment;

electrical propulsion motor room;

rooms containing section switchboards and purely electrical equipment, except oil transformers (with capacity over 10 kVA); shaft alleys and pipe tunnels;

spaces for pumps and refrigeration machinery (not handling or using flammable liquids);

closed trunks serving the spaces listed above;

other closed trunks such as pipe and cable trunks.

(11) *Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks and other similar spaces of moderate fire risk*:

cargo oil tanks;

cargo holds, trunkways and hatchways;

refrigerated chambers;

fuel oil 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;

fuel oil filling stations;

spaces containing turbine and reciprocating steam engine driven auxiliary generators and small internal combustion engines up to 110 kW driving generators, sprinkler, drencher or fire pumps, bilge pumps, etc.;

closed trunks serving the spaces listed above;

spaces accommodating oil transformers (with capacity over 10 kVA).

(12) *Machinery spaces and main galleys*:

engine and boiler rooms (other than electric propulsion motor rooms);

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;

trunks and casings to the spaces listed above;

incinerator and combined incinerator/waste stowage spaces, and the flue uptakes from such spaces (refer to **2.1.5.9**).

(13) *Storerooms, workshops, pantries, etc.*:

main pantries, not annexed to galleys;

main laundry;

large drying rooms (having a deck area of more than 4 m^2);

miscellaneous stores;

mail and baggage rooms;

garbage rooms and garbage chutes connected thereto;

workshops (not part of machinery spaces, galleys, etc.);

lockers and storerooms having areas of more than 4 m^2 and not having provisions for the storage of flammable liquids.

(14) Other spaces in which flammable liquids are stowed:

paint rooms;

storerooms containing flammable liquids (including dyes, medicines, etc.);

laboratories (in which flammable liquids are stowed).

Table 2.2.1.3-1 **Table Decks not forming steps in main vertical zones nor bounding horizontal zones**

Spaces below		Spaces above													
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Control stations	(1)	A-30	A-30	A-15	A-0	A-0	A-0	A-15	A-30	A-0	A-0	A-0	A-60	A-0	A-60
Stairways	(2)	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-30	A-0	A-30
Corridors	(3)	A-15	A-0	A-0[1]	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-30	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
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
Accommodation spaces of minor fire risk	(6)	A-60	A-15	A-0	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of moderate fire risk	(7)	A-60	A-15	A-15	A-60	A-0	A-0	A-15	A-15	A-0	A-0	A-0	A-0	A-0	A-0
Accommodation spaces of greater fire risk	(8)	A-60	A-15	A-15	A-60	A-0	A-15	A-15	A-30	A-0	A-0	A-0	A-0	A-0	A-0
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
Tanks, voids and auxiliary machinery spaces having minor 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[1]	A-0	A-0	A-0	A-0
Auxiliary machinery spaces, cargo spaces, special category spaces, cargo and other oil tanks and other similar spaces of moderate fire risk	(11)	A-60	A-60	A-60	A-60	A-0	A-0	A-15	A-30	A-0	A-0	A-0[1]	A-0	A-0	A-30
Machinery spaces and main galleys	(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[1]	A-0	A-60
Storerooms, workshops, pantries, etc.	(13)	A-60	A-30	A-15	A-60	A-0	A-15	A-30	A-30	A-0	A-0	A-0	A-0	A-0	A-0
Other spaces in which flammable liquids are stored	(14)	A-60	A-60	A-60	A-60	A-0	A-30	A-60	A-60	A-0	A-0	A-0	A-0	A-0	A-0

[1]Refer to Footnote 1 to Table 2.2.1.3-1.
N o t e. Refer to notes to Table 2.2.1.3-1.

2.2.1.4 On ships carrying not more than 36 passengers, where a space is protected by an automatic sprinkler system or fitted with a continuous "B" class ceiling, openings in decks not forming steps in main vertical zones nor bounding horizontal zones shall be closed reasonably tight and such decks shall meet the "A" class requirements.

2.2.1.5 The minimum fire integrity of all bulkheads and decks separating adjacent spaces in ships carrying not more than 36 passengers shall be as prescribed in Tables 2.2.1.5-1 and 2.2.1.5-2 with regard to the following:

.1 for determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified according to their fire risk as shown in categories (1) - (11) below:

(1) control stations: spaces accommodating emergency sources of electrical power and lighting;

wheelhouse and navigation room; spaces accommodating ship radio equipment;

fire stations;

main machinery control room if it is located outside machinery spaces; spaces accommodating centralized fire alarm system;

(2) corridors and lobbies;

(3) accommodation spaces as defined in 1.5.2, except corridors;

(4) stairways:

interior stairways, lifts, totally enclosed emergency escape exits trunks and escalators (other than those wholly contained within machinery spaces) and enclosures thereto.

In this connexion, a stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door;

Table 2.2.1.5-1 **Fire integrity of bulkheads separating adjacent spaces**

Spaces												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Control stations	*1)*	A-0[1]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors and lobbies	*2)*		C[2]	B-0[2]	A-0[3] B-0[2]	B-0[2]	A-60	A-0[8]	A-0[9]	A-15 A-0[4]	*	A-30[6]
Accommodation spaces	*3)*			C[2]	A-0[3] B-0[2]	B-0[2]	A-60	A-0	A-0	A-15 A-0[4]	*	A-30 A-0[4]
Stairways	*4)*				A-0[3] B-0[2]	A-0[3] B-0[2]	A-60	A-0	A-0	A-15 A-0[4]	*	A-30[6]
Service spaces (low risk)	*5)*					C[2]	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	*6)*						*	A-0	A-0	A-60	*	A-60
Other machinery spaces	*7)*							A-0[5]	A-0	A-0	*	A-0
Cargo spaces	*8)*								*	A-0	*	A-0
Service spaces (high risk)	*9)*									A-0[5]	*	A-30
Open decks	*10)*										*	A-0
Special category spaces	*11)*										*	A-30[6]

Table 2.2.1.5-2 Fire integrity of decks separating adjacent spaces

Spaces												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Control stations	*1)*	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60[6]
Corridors and lobbies	*2)*	A-0	*	*	A-0	*	A-60	A-0[8]	A-0[9]	A-0	*	A-30[6]
Accommodation spaces	*3)*	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30 A-0[4]
Stairways	*4)*	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30[6]
Service spaces (low risk)	*5)*	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	*6)*	A-60	A-60	A-60	A-60	A-60	*	A-60[7]	A-30	A-60	*	A-60
Other machinery spaces	*7)*	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	*8)*	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0
Service spaces (high risk)	*9)*	A-60	A-30 A-0[4]	A-30 A-0[4]	A-30 A-0[4]	A-30[6]	A-60	A-0	A-0	A-0	*	A-30
Open decks	*10)*	*	*	*	*	*	*	*	*	*	*	*
Special category spaces	*11)*	A-60	A-30[6]	A-30 A-0[4]	A-30[6]	A-30[6]	A-60[6]	A-0	A-0	A-30	A-0	A-30[6]

Footnotes to Tables. 2.2.1.5-1 and 2.2.1.5-2:

[1] Bulkheads separating the wheelhouse and chartroom from each other may be "B-0" class. No fire rating is required for those partitions separating the navigation bridge and the safety centre when the latter is within the navigation bridge..

[2] "B-0" or "C" class bulkheads, where appearing in the table as main fire-fighting bulkheads required by **2.2.1.2** shall be read as "A-0" class.

[3] For clarification of the applicable fire integrity standard, refer to **2.2.2.1**, **2.2.2.2** and **2.2.2.4**.

[4] Where each of the adjacent spaces is protected by an automatic sprinkler system, the lower of the two values given in the tables may be used.

[5] Where the spaces are used for the same purpose, no divisions may be fitted between them..

[6] Ships constructed before 1 July 2014 shallmeet at least the previous requirements applicable during the cship construction..

[7] Where other machinery spaces of category (7) are the spaces of low fire risk, i.e. they do not contain machinery operating in fuel oil or having a pressure lubrication systems, "A-0" class divisions are permitted (refer to Table 2.2.1.5-2).

8 On ships built on or after January 1, 2018, class A-15 divisions shall be installed.

9 On ships built on or after January 1, 2018, class A-60 divisions shall be installed.

Notes to Tables. 2.2.1.5-1 *and* 2.2.1.5-2:

1 Where an asterisk appears in the tables the division shall be of steel or equivalent material, but is not required to be of "A" class.

However, if in the deck except for the decks in a space of category (*10*), there are penetrations for electric cables, piping and ventilation ducts, such penetrations shall be flame and smoke tight.

Divisions between control stations (emergency generators) and open decks may have air intake openings without closing appliances, except cases when fixed gas fire-fighting system is installed.

Where the requirements of **2.2.1.2** are applicable, an asterisk means "A-0" class, except categories (8) and (10).

2. If, due to the content and purpose of the space, doubts arise regarding the determination of its category, then it shall be considered as a space of the category to which higher requirements are set with respect to the fire integrity of divisions

3. Small enclosed spaces indoors, having the area of openings in bounding structures, connected to the space, less than 30%, are considered as separate spaces.

Fire integrity of divisions and decks bounding such small spaces shall comply with the Tables of this paragraph of the Rules.

(5) *service spaces (low risk)*:

lockers and storerooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2, drying rooms and laundries, spaces accommodating electrical distribution boards with an area less than 4 m^2;

(6) *machinery spaces of category A*:

spaces as defined in 1.2, Part VII "Machinery Installations";

incinerator and combined incinerator/ waste stowage spaces, and the flue uptakes from such spaces (refer to **2.1.5.9**).

(7) *other machinery spaces*:

machinery spaces excluding spaces referred to in (6) and spaces accommodating electrical equipment (automatic telephone stations, spaces for air conditioning ducts);

(8) *cargo spaces*: all spaces, which are not special category spaces used for the carriage of cargo (including cargo tanks for oily products), as well as ventilation and hatch trunks servicing such spaces;

(9) *service spaces (high risk)*: galleys, pantries containing appliances for hot food preparation, paint rooms, lockers and storerooms with an area of 4 m2 and over, spaces for storage of flammable liquids, saunas, workshops and similar spaces, which are not part of machinery spaces;

waste stowage spaces and garbage chutes connected thereto.

(10) *open decks*:

open deck spaces and enclosed promenades having no fire risk. To be considered in this category, enclosed promenades shall have no fire risk. This means that furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by means of permanent openings;

air spaces (spaces outside superstructures and deckhouses).

(11) special category spaces as defined in **1.5.9** and ro-ro spaces in compliance with **1.5.4.3**;

.2 the doors from the cabins to individual sanitary spaces may be of combustible materials.

2.2.2 Accommodation and service spaces within a main vertical zone.

2.2.2.1 For ships carrying more than 36 passengers all bulkheads which are not required to be "A" class divisions shall be "B" class or "C" class divisions as prescribed in Table 2.2.1.3-1.

For ships carrying not more than 36 passengers all bulkheads within accommodation and service spaces which are not required to be "A" class divisions shall be "B" class or "C" class divisions asprescribed in Table 2.2.1.5-1.

All such divisions may be faced with combustible materials in accordance with the provisions of **2.1.1.10**.

2.2.2.2 For ships carrying not more than 36 passengers all corridor bulkheads where not required to be "A" class divisions shall be "B" class divisions which shall extend from deck to deck except:

.1 when continuous "B" class ceilings or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining shall be of material which, in thickness and composition, is acceptable in the construction of "B" class divisions but which shall be required to meet "B" class integrity standards only in so far as is reasonable and practicable in the opinion of the Register;

.2 on ships equipped with an automatic sprinkler system complying with the provisions of the FSS Code, corridor bulkheads may end by the corridor ceilings provided that such bulkheads and ceilings are of "B" class in accordance with **2.2.1.5**. All doors and door frames in such bulkheads shall be made of non-combustible materials and they shall have the same fire integrity as the bulkhead in which they are fitted.

2.2.2.3 Bulkheads required to be "B" class divisions, except corridor bulkheads required by **2.2.2.2**, shall extend from deck to deck and to the shell or other boundaries unless the continuous "B" class ceilings or linings, having at least the same fire integrity as the adjacent bulkhead, are fitted on both sides of it, in which case the bulkhead may terminate at the continuous ceiling or lining.

If an air gap between the cabins results in an opening in the continuous "B-15" class ceiling, the bulkheads on both sides of the air gap shall be of "B-15" class.

2.2.2.4 Stairways in accommodation and service spaces shall be protected as follows:

Stairways and lifts shall be protected in the following way:

.1 stairways shall be enclosed by "A" class divisions with positive closing appliances of all openings, except that a stairway connecting only two decks need not be enclosed, provided the integrity of the deck is ensures by proper bulkheads or self-closing doors. When a stairway is enclosed in 'tween deck, then this enclosure shall be protected in compliance with Tables 2.2.1.3-2 or 2.2.1.5-2;

.2 stairways in public spaces may not have enclosures, provided they are located wholly within the public space;

.3 lift trunks shall be so fitted as to prevent the penetration of smoke and flame from one 'tween-deck compartment to another and shall be provided with closing appliances to prevent draught and smoke penetration. Lifts machinery located within stairways enclosure shall be arranged in a separate space, surrounded by steel boundaries, except that small passages for lift cables are permitted. Lifts, which open into spaces other, than corridors, public spaces, special category spaces, stairways and external spaces shallnot open (stop) into stairways serving as the means of escape;

.4 stairway enclosures shall have direct communications with the corridors and be of sufficient area to comply with **8.5.4.2**, Part III "Equipment, Arrangements and Outfit". Within the perimeter of such stairway, enclosures, only public toilets, lockers of non-combustible material providing storage for safety equipment and open information counters are permitted. Only corridors, public toilets, special category spaces, other escape stairways required by Part III "Equipment, Arrangements and Outfit" and external areas are permitted to have direct access to these stairway enclosures. Public spaces may also have direct access to stairway enclosures except for the backstage of a theatre;

.5 one of the means of escape from a watertight compartment or a main fire vertical zone as required in **8.5.2.1**, Part III "Equipment, Arrangements and Outfit" shall consist of enclosed stairways which provide a continuous shelter according to the requirements of **2.2.1.3** or **2.2.1.5**;

.6 protection of escape routes from the stairways enclosures to the life boats and life rafts embarkation stations shall be provided either directly, or by protected interior passageways, having fire integrity and insulation values for the stairways enclosures as specified by Tables 2.2.1.3-1, 2.2.1.3-2, 2.2.1.5-1, 2.2.1.5-2, as applicable;

.7 on passenger ships constructed on or after 1 July 2008, non-load bearing partial bulkheads which separate adjacent cabin balconies shall be capable of being opened by the crew from each side for the purpose of fighting fires.

.8 on ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS**, spaces other than those specified in this paragraph may be located, within such stairway enclosures, which must be: empty, permanently closed and disconnected from the power supply; separated from stairway enclosures by means of class A divisions according to the requirements of Table 2.2.1.5-1. Such spaces can have direct access to stairway enclosures by means of class A doors according to the requirements of Table 2.2.1.5-1, these spaces shall also be fitted with a sprinkler fire-fighting system.

On such ships, category (10) spaces, as defined in 2.2.1.3, and auxiliary spaces (offices) located behind open information offices may have access directly to stairway enclosures, provided that they are protected by smoke alarms, and these auxiliary spaces contain only furniture with a limited fire hazard.

2.2.2.5 In all spaces, except for refrigerated provision storerooms, cargo spaces, mail baggage cabins and saunas, the ceilings, bulkheads, linings, draught stops and grounds shall be made of non-combustible materials.

2.2.2.5.1 Partial bulkheads and decks on passenger ships:

.1 partial bulkheads or decks used to subdivide a space for utility or artistic treatment shall be of non-combustible materials;

.2 linings, ceilings and partial bulkheads or decks used to screen or to separate adjacent cabin balconies shall be of non-combustible materials.

2.2.2.6 In the case of ships fitted with an automatic sprinkler system, combustible materials used for erection of "C" class divisions may be added to the total volume of combustible materials mentioned in **2.1.1.10**.

2.2.2.7 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, except where there is no risk of fire originating in such places.

2.2.2.8 The furniture in stairway enclosures shall consist of seats only. It shall be fixed to six seats on each deck in each stairway enclosure, be of restricted fire risk determined in accordance with the FTP Code and shall not create obstacles for passengers at the routes of escape.

The Register may permit additional seating in the main reception area within the stairway enclosure if it is fixed, non-combustible and do not create obstacles for passengers at the routes of escape.

The furniture shall not be permitted in passenger and crew corridors forming escape routes in cabin areas.

In addition to the above lockers of non-combustible material, providing storage for fire-fighting equipment and life-saving appliances required by the present Rules may be permitted.

Drinking water automation devices and ice cube machines may be permitted in corridors provided they are properly fixed and do not restrict the width of the escape routes. This applies as well to decorative flower or plant arrangements, statues or other objects of art such as painting and tapestries in corridors and stairways enclosures.

2.2.2.9 Linings, ceilings and partial bulkheads used to screen or to separate adjacent cabin balconies shall be of non-combustible materials. Cabin balconies on passenger ships constructed before 1 July 2008 shall comply with the requirements of this paragraph by the first survey after 1 July 2008.

2.2.2.10 Furniture and furnishings on cabin balconies shall comply with the requirements for rooms containing furniture and furnishings of restricted fire risk (refer to definitions in **1.2**) unless such balconies are protected by a fixed pressure water-spraying and fixed fire detection and fire alarm systems complying with the requirements of **3.4.1** and **4.2.1.1.5**.

2.2.3 Motor vehicles spaces, ro-ro spaces, special category spaces.

2.2.3.1 When the special category spaces cannot be protected by main vertical fire zones, their protection shall be ensured by subdivision into horizontal zones. These zones may cover more than one deck, but their overall height calculated as a sum of distances between adjacent decks without regard of framing height shall not exceed 10 m.

Fire doors and passages (cutouts) in decks and bulkheads of "A" class, forming boundaries, which separate horizontal areas from each other as well as the remain part of the ship shall meet the requirements applicable to fire doors and penetrations (cutouts) in horizontal areas (refer to **2.2.4**).

2.2.3.2 In ships carrying more than 36 passengers the boundary bulkheads and decks of special category spaces shall be "A-60" class. However, where category **2.2.1.3 (5)**, **2.2.1.3 (9)** or **2.2.1.3 (10)** space is on one side of the division the class may be reduced to "A-0". If fuel oil tanks are located under special category spaces, the fire integrity of decks between such spaces may be of "A-0" class.

In ships carrying not more than 36 passengers the boundary bulkheads of special category spaces shall be as required for category (11) spaces in 2.2.1.5-1 and the horizontal boundaries as required for category (*11*) spaces in Table 2.2.1.5-2.

In passenger ships carrying not more than 36 passengers, the bulkheads and decks forming boundaries of enclosed and open ro-ro spaces shall have fire integrity required for spaces of category (*8*) according to 2.2.1.5-1, while the horizontal boundaries shall have fire integrity required for spaces of category (*8*) according to 2.2.1.5-2.

2.2.3.3 Indicators shall be provided on the navigating bridge which shall indicate when any fire door of special category spaces is closed.

2.2.3.4 Special category spaces shall have means of escape leading to the lifeboat and liferaft embarkation places complying with the requirements of **8.5.1**, **8.5.2.3**, Part III "Equipment, Arrangements and Outfit" as well as the requirements of **2.1.4.7** and **2.2.2.4.1** of this Part.

One of escape routes from machinery spaces where the crew is normally engaged shall not have a direct access to the special category spaces.

2.2.3.5 Special category spaces shall be fitted with an approved water spraying system that complies with the applicable provisions of **3.4**.

2.2.3.6 Interim Guidelines for minimizing the incidence and consiqences of fires in ro-ro spaces and special category spaces of ro-ro passenger ships[7].

2.2.3.6.1 Strengthening of the requirement for elimination of sources of ignition:

.1 a fire-fighting plan that, in particular, identifies any risks specific to alternatively powered vehicles, including battery powered vehicles, and outlines the most appropriate fire-fighting techniques for such vehicles shall be developed. Good access to any specialized fire-fighting equipment for alternatively powered vehicles shall be ensured.

.2 where vehicles powered by compressed natural gases or hydrogen are carried, the hazards associated with accumulation of flammable gases and gases lighter than air under ceilings need to be addressed.

.3 pipes with combustible hydraulic oil should be protected from damage. Hydraulic oil from a damaged pipeline in contact with a source of ignition, for example, a refrigerating unit of a truck working during the voyage, can cause a fire.

2.2.3.6.2 Fire detection and methods/measures to ensure fire safety:

.1 addressable fixed fire detection and alarm systems;

.1.2 if a fixed water-based deluge system is used for ro-ro spaces and special category spaces then a fire detection and alarm system addressable to the same sections of the deluge systems should be arranged;

.1.3 in the design of the fire detection alarm system (refer to **4.2.1.1**) it should be designed with a system interface which provides logical and unambiguous presentation of the information, to allow a quick and correct understanding and decision-making. In particular, the alarm system section numbering should coincide with the sections of other systems, such as fixed water-based fire-extinguishing system or television surveillance system, if available;

.2 video monitoring;

.2.1 television surveillance systems can be effective for rapid confirmation of a fire after activation of fire alarms, as well as rapid execution of related actions after the confirmation of fire. This supports the activation of the correct deluge section, as well as manual fire-fighting;

.2.2 effective television surveillance systems should be provided in ro-ro and special category spaces for continuous video monitoring of these spaces and be provided with immediate playback capability to allow for quick identification of fire location, as far as practicable. Continuous monitoring of the video image by the crew needs not be ensured;

.3 fire detection in open ro-ro spaces.

in open ro-ro spaces on all ro-ro passenger ships, if smoke detectors are installed (refer to **4.2.1.6**), they should be supplemented with other effective means of detection e.g. flame detectors, heat detectors;

.4 fire detection on weather decks.

A fixed fire detection and fire alarm system should be provided for weather decks intended for the carriage of vehicles. The fixed fire detection system should be capable of rapidly detecting the onset of fire on the weather deck.

The type of detectors, spacing, and location should be to the satisfaction of the Register taking into account the effects of weather, cargo obstruction and other relevant factors. Different settings may be used for specific operation sequences, such as during loading or unloading and during voyage, in order to reduce the false alarms;

.5 alarm system design and integration.

Alarm notifications should follow a consistent alarm presentation scheme (wording, vocabulary, colour, and position) and that alarms are immediately recognizable on the bridge and not compromised by noise or poor placing. The interface should provide alarm addressability to allow the crew to identify the alarm history, the most recent alarm, and the means to suppress alarms while ensuring the alarms with ongoing trigger conditions are still clearly visible.

.6 signage and markings for effective identification and localization.

For closed vehicle, ro-ro spaces, and special category spaces where fixed pressure water-spraying systems are fitted, they should be provided with suitable signage and marking on deck and vertical boundaries to easily identify the sections of the fixed fire-extinguishing system. Signage and markings should be adapted to typical patterns of crew movement and should not be obstructed by fixed installations. Section number signs should be of photoluminescent material complying with ISO 15370. The section numbering indicated inside the space should be the same as the section valve identification and section identification at the safety centre or continuously manned control station.

2.2.3.6.3 Extinguishment.

.1 Additional fire-fighting equipment for ro-ro passenger ships.

.1.1 ro-ro passenger ships shall be equipped with fire-fighting systems in accordance with **3.1.6;**

.1.2 fire-fighting equipment and outfit shall be available for rapid firefighting in all ro-ro and special category spaces.

.2 Positioning of sprinklers and nozzles

MSC.1/Circ.1430/Rev.1 on Revised guidelines for the design and approval of fixed water-based fire-fighting systems for ro-ro spaces and special category spaces should be referred to with regard to functional requirements for positioning of sprinklers and nozzles to provide satisfactory performance with respect to both activation time and water distribution.

Fixed water-based fire-fighting system shall comply with the requirements of **3.4**.

.3 Fixed fire-extinguishing measures on weather decks.

Additional fire-extinguishing measures such as fire monitors and drainage systems may be considered on weather decks. Remotely controlled fire monitors may allow for safe operation of the monitors, but where suitable, manually operated fire monitors may also be used.

2.2.3.6.4 Structural fire protection.

.1 Fire integrity of ro-ro decks and decks in special category spaces.

The fire integrity of ro-ro decks separating ro-ro spaces should be at least A-30 (refer also to **2.2.3.2**).
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.2 Types of ro-ro spaces.

Vehicles spaces and ro-ro spaces should be either closed ro-ro spaces or weather decks.

2.2.3.6.5 Integrity of life-saving appliances and evacuation.

.1 Ro-ro passenger ships shall be equipped with life-saving appliances and embarkation stations in accordance with the requirements of 5.4, Part II "Life-saving appliances" of the Rules for the equipment of sea-going ships.

.2 The following safety distances (measured horizontally) are recommended to avoid jeopardizing life-saving appliances and embarkation stations in case of fire in ro-ro and special category spaces):

.2.1 survival craft and marine evacuation systems stowed and in a position to be deployed:

.2.1.1 more than 6 m from a cargo space side opening; and

.2.1.2 more than 8 m from cargo on weather deck;

.2.2 survival craft embarkation stations and muster stations located:

.2.2.1 more than 6 m away from a cargo space side opening; and

.2.2.2 more than 13 m from cargo on weather deck.

.3 Equivalent arrangements to the satisfaction of the Register, providing at least the same level of protection, could be considered.

2.2.4 Doors, windows and sidescuttles.

2.2.4.1 Except hatches between the cargo spaces, special category spaces, storerooms and baggage rooms, as well as between such spaces and open decks, all openings shall be provided with permanent closing appliances, having at least such fire integrity as the divisions, in which they are fitted.

Construction of doors and doorframes in the bulkheads of "A" class with locking devices shall provide the same fire integrity and smoke and flame tightness as the bulkheads, in which those doors are fitted as determined in compliance with the FTP Code. Doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, 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. Each door fitted in "A" class division shall be capable of being opened and closed manually from both sides of the bulkhead by one person only.

Fire doors in main vertical bulkheads, galley boundaries and stairway enclosures other than power-operated watertight doors and those which are normally locked, shall satisfy the following requirements:

.1 the doors shall be self-closing and be capable of closing with an angle of inclination of

up to 3,5° opposing closure;

.2 the approximate time of closure for hinged fire doors shall be no more than 40 s and no less than 10 s from the beginning of their movement with the ship in the upright position.

The approximate uniform rate of closure for sliding fire doors shall be no more than 0,2 m/s and no less than 0,1 m/s from the beginning of their movement with the ship in the upright position;

.3 the doors shall be capable of remote release from the continuously manned central control station, either simultaneously or in groups and shall be capable of release also individually from a position at both sides of the door. Release switches shall have an on-off function to prevent automatic resetting of the system;

.4 hold-back hooks not subject to central control station release are prohibited;

.5 a door closed remotely from the central control station shall be capable of being re-opened at both sides of the door by local control. After such local opening, the door shall automatically close again;

.6 indication shall be provided at the fire door indicator panel in the continuously manned central control station whether each of the remote-released doors is closed;

.7 the release mechanism shall be so designed that the door will automatically close in case of disruption of the control system or main source of power;

.8 local power accumulators for power-operated doors shall be provided in the immediate vicinity of the doors to enable the doors to be operated after disruption of the control system or main source of electrical power at least ten times (fully opened and closed) using the local controls;

.9 disruption of the control system or main source of electrical power of one door shall not impair the safe functioning of other doors;

.10 remote-released sliding or power-operated doors shall be equipped with an alarm that sounds for at least 5 s but no more than 10 s after the door is released from the central control station and before the door begins to move and continues sounding until the door is completely closed;

.11 a door designed to re-open upon contacting an object in its path shall re-open not more than 1 m far from the point of contact;

.12 double-leaf doors equipped with a latch necessary to their fire integrity shall have a latch that is automatically activated by the operation of the doors when released by the control system;

.13 doors giving direct access to special category spaces which are power-operated and automatically closed need not be equipped with the alarms and remote-release mechanisms required in **2.2.4.1.3** and **2.2.4.1.10**;

.14 the components of the local control system shall be accessible for maintenance and adjusting; and

.15 power-operated doors shall be provided with a control system of an approved type which shall be able to operate in case of fire, this being determined in accordance with the FTP Code. This system shall satisfy the following requirements:

the control system shall be able to operate the door at the temperature of at least 200°C for at least 60 min, served by the power supply;

the power supply for all other doors not subject to fire shall not be impaired;

at temperatures exceeding 200°C the control system shall be automatically isolated from the power supply and shall be capable of keeping the door closed up to at least 945°C.

2.2.4.2 Except watertight doors, weathertight doors (semi watertight doors), doors leading to the open decks, and doors required to be adequately gastight, all "A" class doors located in stairways, public spaces and main vertical zone bulkheads in escape routes shall be equipped with a self-closing hose port of material, construction and fire integrity which is equivalent to the door into which it is fitted, and shall be 1506150 mm square 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, nearest the opening.

2.2.4.3 Doors and doorframes in "B" class divisions and their locking devices shall ensure the same fire integrity as the divisions where they are installed in accordance with the FTP Code, except that ventilation openings may be permitted in the lower portion of such doors. If such ventilation openings are located in the door or under it, their total net area shall not exceed 0,05 m^2. Alternatively, pressurebalancing ventilation duct made of non-combustible material is allowed to be arranged between the cabin and the corridor, and located below sanitary room if an area of its cross section does not exceed 0,05 m^2.

All such openings shall be fitted with grills made of non-combustible material. Doors shall be noncombustible.

Doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 25 mm. Cabin doors in "B" class divisions shall be of the self-closing type and shall have no hold-backs.

2.2.4.4 For ships carrying not more than 36 passengers, windows facing survival craft and escape slide, embarkation areas and windows situated below such areas shall have fire integrity at least equal to "A-0" class.

For ships carrying more than 36 passengers, windows facing survival craft and life-saving appliances, embarkation and assembly stations, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have fire integrity as required in Table 2.2.1.3-1.

Where automatic dedicated sprinkler heads are provided for windows, "A-0" windows may be accepted as equivalent. Dedicated sprinkler heads shall be located above windows in addition to the conventional ceiling sprinklers or these shall be conventional ceiling sprinkler heads arranged in such a manner that a window is protected by an average application rate of at least 5 l/min per 1 m^2, and the square of a window shall be included into calculation of the area of coverage or these may be water-mist nozzles complying with the requirements of IMO resolutionIMO A.800(19) as amended by MSC.265(84) and MSC.284(86).

Windows located in the ship's side below the lifeboat embarkation areas shall have the fire integrity at least equal to "A-0" class.

All windows and side scuttles in bulkheads within accommodation and service spaces, and control stations, except those subject to provisions of **2.2.4.5** and **2.2.4.8**, shall be fitted so as to ensure that fire integrity of the bulkheads they are fitted in is not impaired, which is determined in accordance with the FTP Code. Despite the requirements of Tables 2.2.1.3-1, 2.2.1.3-2, 2.2.1.5-1 and 2.2.1.5-2, windows and side scuttles in the outer bulkheads of accommodation spaces, service spaces and control stations shall have frames made of steel or other equivalent material and meet the requirements of **7.2.2.4**, Part III "Equipment, Arrangements and Outfit".

2.2.4.5 The requirements for "A" class fire integrity of ship external boundaries do not apply to glassed bulkheads, windows and side scuttles, provided that **2.2.4.4** does not contain the requirement that such boundaries shall be of "A" class. The requirements for "A" class fire integrity of the outer boundaries of a ship shall not apply to exterior doors, except for those in superstructures and deckhouses facing life-saving appliances, embarkation and external muster station areas, external stairs and open decks used for escape routes. Stairway enclosure doors need not meet this requirement.

2.2.4.6 In passenger ships carrying not more than 36 passengers, it is allowed to use combustible materials for manufacture of doors separating cabins from internal individual sanitary spaces such as showers.

2.2.4.7 Doors to machinery spaces of category A, other than power-operated watertight doors shall be arranged to ensure their positive closing by power operated closings arrangements or by fitting self-closing doors capable of being closed with an angle of inclination of up to 3,58 opposite to the door closure and equipped with locking device and remotely controlled release mechanism. Doors for the emergency escape trunks may not to be equipped with locking devices and remotely controlled release mechanisms.

Doors closure controls, required by **2.1.4.2.3**, shall be located in one place or centralized at possibly less number of places. These places shall have free access from the open deck.

2.2.4.8 The requirements for "B" class fire integrity of ship external boundaries do not apply to glassed bulkheads, windows and side scuttles. Such requirements for "B" class fire integrity do not apply to exterior doors in superstructures and deckhouses.

2.2.4.9 Notwithstanding the requirements of 2.2.4.4, requirements of 2.2.4.9 - 2.2.4.11 apply to ships contracted for the construction on or after January 1, 2020.

2.2.4.10 For ships carrying more than 36 passengers, windows facing survival craft and life-saving appliances, embarkation and assembly stations, external stairs and open decks used for escape routes, and windows situated below liferaft and escape slide embarkation areas shall have fire integrity as required in Table 2.2.1.3-1.

Where automatic dedicated sprinkler heads are provided for windows, "A-0" windows may be accepted as equivalent. Dedicated sprinkler heads shall be located above windows in addition to the conventional ceiling sprinklers or these shall be conventional ceiling sprinkler heads arranged in such a manner that a window is protected by an average application rate of at least 5 l/min per 1 m^2, and the square of a window shall be included into calculation of the area of coverage or these may be water-mist nozzles complying with the requirements of IMO resolutionIMO A.800(19) as amended by MSC.265(84) and MSC.284(86).

Windows located in the ship's side below the lifeboat embarkation areas shall have the fire integrity at least equal to "A-0" class.

2.2.4.11 For ships carrying not more than 36 passengers, windows facing survival craft and escape slide, embarkation areas and windows situated below such areas shall have fire integrity at least equal to "A-0" class.

2.2.5 External areas on passenger ships.

2.2.5.1 Fire risk of external areas on passenger ships is evaluated in accordance with the provisions of IMO circular MSC.1/Circ.1274.

2.2.6 Casualty threshold, safe return to port and safe areas.

2.2.6.1 Passenger ships having length, as defined in **1.2.1** of Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones, shall comply with the requirements of **2.2.6** in order to meet functional requirements and performance standards for safe areas in case of casualty that does not exceed the casualty threshold.

2.2.6.2 When fire damage does not exceed the casualty threshold, the ship shall be capable of returning to port while providing a safe area as defined in **1.2**. To be deemed capable of returning to port the fixed fire extinguishing systems, including the fire main system, and the fire detection and fire alarm system shall remain operational in the remaining part of the ship not affected by fire.

2.2.6.3 The fire main system shall remain operational in all main vertical zones not directly affected by the casualty. Water feed for fire-fighting purposes shall be available to all areas of the ship.

2.2.6.4 The automatic sprinkler system or any other fixed fire extinguishing system designed to protect an entire space shall be operational in all spaces not directly affected by the casualty.

2.2.6.5 The fire detection and fire alarm system, including smoke detection system, shall be operational in all spaces not directly affected by the casualty.

2.2.6.6 Means of access to life-saving appliances shall be provided from each safe area, taking into account that a main vertical zone may not be available for internal transit.

2.2.6.7 In addition to the requirements of **2.2.6.2**, the following systems, machinery and equipment shall remain operational in the remaining part of the ship not affected by fire:

.1 propulsion and essential auxiliary machinery;

.2 steering systems and steering-control systems;

.3 power-operated watertight doors;

.4 fuel oil systems for propulsion and essential auxiliary machinery;

.5 ballast and bilge systems;

.6 internal communication between the bridge, engineering spaces, safety centre, fire-fighting and damage control teams, and as required for passenger and crew notification and mustering; internal communication shall be provided by effective fixed or portable means;

.7 flooding detection systems;

.8 navigation lights in accordance with the requirements of International Regulations for Preventing Collisions at Sea;

.9 GMDSS radio equipment (radio communication by GMDSS radio equipment shall be provided or, if the main GMDSS radio equipment is out of service due to casualty, the distress alert initiating shall be provided on the VHF frequencies including two-way VHF radiotelephone apparatus for communications with aircrafts);

.10 navigational equipment essential for navigation, indicating the ship location and collision risk assessment.

2.2.6.8 The systems, machinery and equipment specified in **2.2.6.2** and **2.2.6.7** shall remain operational in case of flooding of any watertight compartment.

2.2.6.9 If systems are needed to fight with fire and flooding which are not specified in **2.2.6.2** and **2.2.6.7** they shall comply with the requirement of **2.2.6.7**.

2.2.6.10 Ventilation of safe area(-s) shall comply with the requirements of **2.2.6.7** and **2.2.6.8**.

Ventilation design shall reduce the risk that smoke and hot gases could affect the use of the safe area(s).

2.2.6.11 Power supply of electrical equipment specified in **2.2.6.7** and **2.2.6.13** shall be provided to ensure their simultaneous operation.

2.2.6.12 The safe area(s) shall generally be internal space(s); however, the use of an external space as a safe area may be allowed taking into account any restriction due to the area of operation and relevant expected environmental conditions.

2.2.6.13 The safe area(s) shall provide all occupants with the following basic services to ensure that the health of passengers and crew is maintained:

.1 sanitation;

.2 fresh water;

.3 food;

.4 alternate space for medical care;

.5 shelter from the weather;

.6 means of preventing heat stress and hypothermia;

.7 light;

.8 ventilation.

2.2.7 Systems to remain operational after a fire casualty.

2.2.7.1 Passenger ships having length, as defined in **1.2.1** of Load Line Rules for Sea-Going Ships, of 120 m or more, or having three or more main vertical zones shall comply with the requirements of **2.2.7** to provide the systems operability if the casualty threshold is exceeded.

2.2.7.2 In case any one main vertical zone is unserviceable due to fire, the fire main system shall be so arranged and segregated as to remain operational for at least 3 h based on the assumption of no damage outside the unserviceable main vertical zone. In particular, the fire main system shall remain operational in all main vertical zones not directly affected by the casualty. The fire main system is not required to remain operational within the unserviceable main vertical zones.

2.2.7.3 Cabling and piping within a trunk constructed to an "A-60" class shall remain intact and serviceable while passing through the unserviceable main vertical zone. An equivalent degree of protection for cabling and piping may be approved by the Register.

2.2.7.4 In addition to **2.2.7.2** the following systems, machinery and equipment shall be so arranged and segregated as to remain operational for at least 3 h based on the assumption of no damage outside the unserviceable main vertical zone:

.1 bilge systems for removal of fire-fighting water;

.2 lighting along escape routes, at assembly stations and at embarkation stations of life-saving appliances;

.3 low location lighting of escape routes with electrical power supply;

.4 internal communications (in support of fire-fighting as required for passenger and crew notification and evacuation); internal communication shall be provided by effective fixed or portable means;

.5 GMDSS radio equipment (radio communication by GMDSS radio equipment shall be provided or, if the main GMDSS radio equipment is out of service due to casualty, the distress alert initiating shall be provided on the VHF frequencies including two-way VHF radiotelephone apparatus for communications with aircrafts).

2.2.7.5 The systems, machinery and equipment specified in **2.2.7.4** are not required to remain operational within the unserviceable main vertical zones.

2.2.7.6 Power supply of electrical equipment for evacuation from ship including life-saving appliances, as well as of systems, machinery and equipment specified in **2.2.7.4** shall be provided to ensure their simultaneous operation.

2.2.8 Safety centre on passenger ships (refer also to IMO circular MSC.1/Circ.1368).

2.2.8.1 Passenger ships shall have on board a safety centre, as defined in 1.2, complying with the requirements of **2.2.8**.

2.2.8.2 The safety centre shall either be a part of the navigation bridge or be located in a separate room adjacent to and having direct access to the navigation bridge.

2.2.8.3 Means of communication between the safety centre, the storage room(s) for fire extinguishing system(s) and fire equipment lockers shall be provided.

2.2.8.4 According to MSC.1/Circ.1368 the functionality, i.e. activation, control, monitoring or combination thereof, of the following safety systems shall be available from the safety centre: fire detection and fire alarm system, sprinkler and equivalent systems, water-based systems for machinery spaces, fixed local application fire extinguishing systems as well as fire pumps and emergency fire pumps.

2.2.8.5 In addition to **2.2.8.3** means of communication between the safety centre, the central control station, the navigation bridge, the engine control room shall be provided.

2.2.8.6 According to IMO circular MSC.1/Circ.1368 in addition to 2.2.8.4 the functionality, i.e. activation, control, monitoring or combination thereof, of the safety systems listed below shall be available from the safety centre:

.1 all powered ventilation systems;

.2 atrium smoke extraction system;

.3 indication of closing watertight and fire doors;

.4 general emergency alarm system;

.5 public address system;

.6 low location lighting of escape routes with electrical power supply;

.7 indicators for shell doors, loading doors and other closing appliances;

.8 flooding detection system.

2.3 CARGO SHIPS

2.3.1 The requirements of this Chapter are additional to those set out in **2.1** and apply to cargo ships of 500 gross tonnage and upwards.

2.3.2 In way of accommodation and service spaces and control stations one of the following methods of protection shall be adopted:

Method IC: construction of internal subdivision bulkheads of non-combustible "B" or "C" class divisions, generally without installation in the accommodation and service spaces of the automatic sprinkler fire extinguishing system and fire detection and fire alarm system;

Method IIC: the fitting of an automatic sprinkler system and fire detection and fire alarm system in all spaces in which fire might be expected to originate, generally with no restriction on the type of internal bulkheads; or

Method IIIC: the fitting of a fixed fire detection and fire alarm system of approved type complying with requirements of **4.1** and **4.2** in spaces where fire might develop, generally with no restriction on the class of internal subdivision bulkheads, except that in no case shall the area of any accommodation space bounded by "A" or "B" class division exceeds 50 m^2. Consideration may be given by the Register to increasing this area for public spaces.

The requirements on using non-combustible materials for the construction and insulation of bulkheads bounding machinery spaces, control stations, service spaces, etc. as well as protection of above mentioned trunks and stairways enclosures are common for all three methods described above.

2.3.3 The minimum fire integrity of the bulkheads and decks separating adjacent spaces shall be as prescribed in Tables 2.3.3-1 and 2.3.3-2.

For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, the spaces are classified according to their fire risk as follows:

(1) control stations: spaces accommodating emergency sources of electrical power and lighting; wheelhouse and navigation room; spaces accommodating ship radio equipment; fire stations; main machinery control room if it is located outside machinery space; spaces accommodating centralized fire alarm system;

(2) corridors and lobbies;

(3) accommodation spaces in accordance with **1.5.2**, except corridors;

(4) stairways:

interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

A stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door;

(5) service spaces (low risk):

storerooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2,

drying rooms, laundries and refrigerated provision storerooms insulated with non-combustible materials;

spaces accomodating electrical distribution boards having an area of less than 4 m^2;

(6) machinery spaces of category A:

spaces as defined in **1.2**, Part VII "Machinery Installations";

incinerator and combined incinerator/waste stowage spaces, and the flue uptakes from such spaces (refer to **2.1.5.9**).

(7) other machinery spaces:

machinery spaces excluding those specified in (6) and spaces accommodating electrical equipment (automatic telephone stations, spaces for air conditioning ducts);

(8) cargo spaces:

all spaces used for carriage of cargoes (including cargo tanks for oily products) as well as trunkways and hatchways to such spaces;

(9) service spaces (greater fire risk): galleys and pantries containing appliances for hot food preparation, saunas, paint lockers and storerooms with an area of 4 m^2 and over, spaces for storage of flammable liquids, workshops and similar spaces, which are not part of machinery spaces;

refrigerated provision storerooms insulated with combustible materials;

waste stowage spaces and garbage chutes connected thereto;

(10) open decks:

open deck spaces and enclosed promenades having no fire risk. This means that their furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings:

air spaces (spaces outside superstructures and deckhouses);

(11) ro-ro cargo spaces and motor vehicles spaces as defined in **1.5.4.3** and **1.5.4.4**.

Table 2.3.3-1 **Fire integrity of bulkheads separating adjacent spaces**

Spaces												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Control stations	*1)*	A-0[1]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*	A-60
Corridors and lobbies	*2)*		C	B-0	A-0[2] B-0	B-0	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	*3)*			C[3,4]	A-0[2] B-0	B-0[2]	A-60	A-0	A-0	A-0	*	A-30
Stairways	*4)*				A-0[2] B-0	A-0[2] B-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	*5)*					C	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	*6)*						*	A-0	A-0[5]	A-60	*	A-60[6]
Other machinery spaces	*7)*							A-0[7]	A-0	A-0	*	A-0
Cargo spaces	*8)*								*	A-0	*	A-0
Service spaces (high risk)	*9)*									A-0[7]	*	A-30
Open decks	*10)*										*	A-0
Special category spaces	*11)*										*	A-30[8]

Table 2.3.3-2 **Fire integrity of decks separating adjacent spaces**

Spaces												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Control stations	*1)*	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*	A-60
Corridors and lobbies	*2)*	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Accommodation spaces	*3)*	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*	A-30
Stairways	*4)*	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*	A-30
Service spaces (low risk)	*5)*	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*	A-0
Machinery spaces of category A	*6)*	A-60	A-60	A-60	A-60	A-60	*	A-60[9]	A-30	A-60	*	A-60
Other machinery spaces	*7)*	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*	A-0
Cargo spaces	*8)*	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	A-0
Service spaces (high risk)	*9)*	A-60	A-30	A-30	A-30	A-30	A-60	A-0	A-0	A-0[7]	*	A-30
Open decks	*10)*	*	*	*	*	*	*	*	*	*	-	A-0[8]
Special category spaces	*11)*	A-60	A-30	A-30	A-30	A-30	A-60	A-0	A-0	A-30	A-0[8]	A-30[8]

Footnotes to Tables*. 2.3.3-1*, *2.3.3-2*.

[1] Bulkheads separating the wheelhouse, chartroom and radio room from each other may be "B-0" class..

[2] For clarification as to which applies, refer to 2.1.4.3.

[3] Doors separating cabins from individual sanitary accommodation may be constructed of combustible materials in *method IC* fire protection. No special requirements are imposed upon bulkheads in *methods IIC* and *IIIC*.

[4] In case of *method IIIC* bulkheads of "B-0" class shall be provided between spaces or groups of spaces of 50 m^2 and over in area.

[5] For cargo spaces intended for carriage of dangerous goods refer to **7.2.12**.

[6] "A-0" class may be used if no dangerous goods are intended to be carried.

[7] Where spaces are used for the same purpose, divisions between them need not be fitted.

[8] Ships built before 1 July 2014 shall meet at least the preliminary requirements applicable during the construction of the ship

[9] Where other machinery spaces of category (7) are the spaces of low fire risk, i.e. they do not contain machinery operating on fuel oil or having a pressure lubrication systems, "A-0" class divisions are permitted (refer to Table 2.3.3-2).

1Where an asterisk appears in the tables the division shall be of steel or equivalent but is not required to be of "A" class. However, if in the deck except for the decks in a space of category (*10*), there are penetrations for electric cables, piping and ventilation ducts, such penetrations shall be flame and smoke tight. Divisions between control stations (emergency generators) and open decks may have air intake openings without closing appliances, except cases when fixed gas fire-fighting system is installed.

2. Small enclosed spaces indoors, having the area of openings in bounding structures, connected to the space, less than 30%, are considered as separate spaces.

Fire integrity of divisions and decks bounding such small spaces shall comply with the Tables of this paragraph of the Rules.

2.3.4 Linings, ceilings, draught stops and their associated grounds shall be made of non-combustible materials:

in accomodation and service spaces, and in control stations, if protection *method IC* is used;

in corridors and stairway enclosures serving accomodation and service spaces, and control stations, if protection *methods IIC* and *IIIC* are used.

2.3.5 Within accommodation spaces, bulkheads not required to be "A" or "B" class divisions shall be:

.1 at least "C" class division in *method IC* fire protection;

.2 not subject to any restrictions, except in cases where "C" class bulkheads are required in accordance with Table 2.3.3-1 in *method IIC* fire protection;

.3 not subject to any restrictions except that in no case shall the area of any accommodation space or spaces bounded by "A" or "B" class divisions exceed 50 m^2 (except in cases where "C" class bulkheads are required in accordance with Table 2.3.3-1), in *method IIIC* fire protection.

Consideration may be given by the Register to increasing this area for public spaces.

If the *IC method* of protection has been used while ship construction, application of combustible materials may be allowed for doors separating cabins from internal sanitary spaces such as showers.

2.3.6 The doors installed in the bulkheads bounding machinery spaces of category A shall be self-closing and adequately gastight. "A" class doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 12 mm, and a non-combustible sill shall be installed under the door such that floor coverings do not extend beneath the closed door.

"B" class doors approved without the sill being part of the frame, which are installed on or after 1 July 2010, shall be installed such that the gap under the door does not exceed 25 mm.

2.3.7 The doors required to be self-closing shall not be equipped with locking devices. However, locking devices may be used equipped with remotely controlled release mechanisms.

2.3.8 In the corridor bulkheads ventilation openings may be permitted in and under the doors of cabins and public spaces. Ventilation openings are also permitted in "B" class doors leading to sanitary rooms, studies, pantries, lockers and storerooms. Except for the permitted below, openings shall be provided in the lower portion of such doors only. If such ventilation opening is located in or under the door, the total net area of such opening shall not exceed 0,05 m^2. Alternatively, balancing duct made of non-combustible material and located below sanitary room is allowed to be arranged between the cabin and the corridor if an area of its cross section does not exceed 0,05 m2. Ventilation openings except the ones located under the door shall be fitted with grills made of non-combustible material.

2.3.9 All bulkheads required to be "B" class divisions within accommodation spaces, shall extend from deck to deck and to the hull shell or other boundaries. However, if the continuous "B" class ceilings or linings are fitted on both sides of the bulkhead the bulkhead may terminate at the continuous ceiling or lining.

2.3.10 For the purpose of application of the requirements of **2.1.1.7**, **2.1.1.8** and **2.1.1.10** it is necessary to follow Fig. 2.3.10 and Table 2.3.10 subgroup 1 for the *method IC*, subgroup 2 for the *methods IIC* and *IIIC*.

Table 2.3.10

Nos.	Requirements to materials Structural member	Non-combustibility (refer to **2.3.4**)	Non-combustibility (refer to **2.1.1.5**)	Low Flame-spread (refer to **2.1.1.8**)	Total volume of combustible materials (refer to **2.1.1.10.1**)	Calorific value (refer to **2.1.1.10**	Smoke and toxic vapors generation (refer to **2.1.1.7**)	Hardened combustibility (refer to **2.1.1.6**)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
				IC				
1.1	Moldings				x			
1.2	Panels	x						
1.3	Painted surfaces, linings, textiles, films			x	x	x	x	
1.4	Painted surfaces, linings, textiles, films			x	x	x	x	
1.5	Decorations				x		x[2]	
1.6	Painted surfaces, linings, textiles, films				x	x	x[2]	
1.7	Plinth				x			
1.8	Insulation		x[1]					

1.9	Surfaces and paints in concealed and inaccessible places			x				
1.10	Draught prevention seals	x						
1.11	Furring	x		x				
1.12	Linings	x						
1.13	Primary deck covering						x	x
1.14	Floor covering			x[3]			x[3]	
1.15	Scuttle frame	x						
1.16	Scuttle frame surface			x[3]	x	x	x[3]	
1.17	Scuttle frame surface in concealed and inaccessible places			x				
1.18	Ceiling panel	x						
IIC and IIIC								
2.1	Moldings				x			
2.2	Panels	x[4]						
2.3	Painted surfaces, linings, textiles, films			x	x	x	x	
2.4	Painted surfaces, linings, textiles, films			x	x[6]	x[5]	x	
2.5	Decorations				x[6]		x[2]	
2.6	Painted surfaces, linings, textiles, films				x[6]	x[5]	x[2]	
2.7	Plinth				x[6]			
2.8	Insulation		x[1]					
2.9	Surfaces and paints in concealed and							
2.10	inaccessible places	x[4]		x[2]				
2.11	Draught prevention seals	x[4]		x				
2.12	Furring	x[4]						
2.13	Linings						x	x
2.14	Primary deck covering			x[3]			x[4]	
2.15	Floor covering	x[4]						
2.16	Scuttle frame			x[6]	x[6]	x[5]	x[4]	
2.17	Scuttle frame surface			x				
2.18	Scuttle frame surface in concealed and	x[4]						

[1] Vapor barriers used for coating of the cooling systems piping (refer to **2.1.15**) may be combustible, provided they are low flame-spread.
[2] Applied to paints, varnishes and other coatings.
[3] In corridors and stairways enclosures.
[4] Only in corridors and stairways enclosures servicing accommodation and service spaces and control stations.
[5] When combustible materials are fitted on non-combustible bulkheads, ceilings and linings in accommodation and service spaces.
[6] Applied to such accommodation and service spaces, which are bounded by non-combustible bulkheads, ceilings and linings.
[7] Non-combustible - a characteristic applicable to deck plating (primary or plating in general, if they are used in acommodation and service spaces and control stations or on the balconies of passenger ships cabins), which shall be made of an approved material that is not flammable or non-hazardous regarding the release of toxic or explosive substances at elevated temperatures, as determined by the FTP Code 2010.

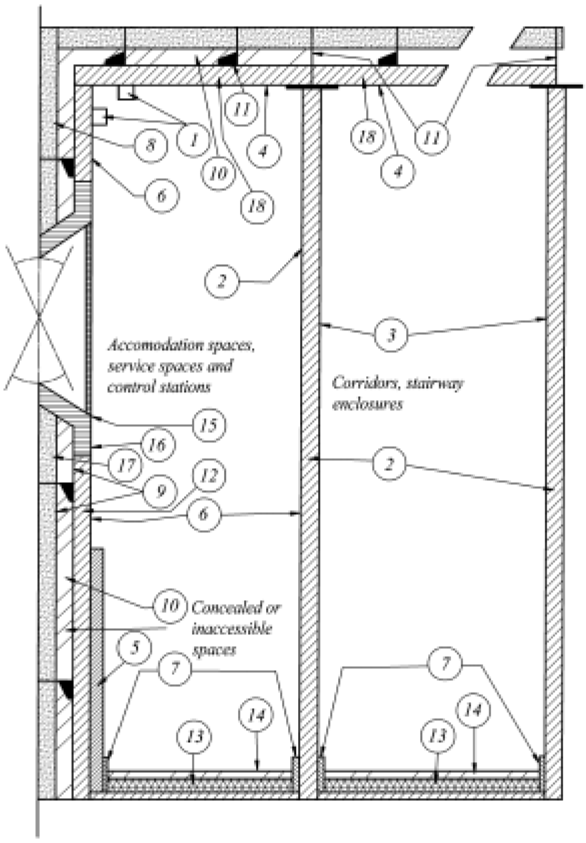

Fig. 2.3.10 Structural members

1. Moldings; 2. Panels; 3. Painted surfaces, linings, textiles, films; 4. Painted surfaces, linings, textiles, films; 5. Decorations; 6. Painted surfaces, linings, textiles, films; 7. Plinth; 8. Insulation; 9. Surfaces and paints in concealed and inaccessible places; 10. Draught prevention seals; 11. Furring; 12. Linings; 13. Primary deck covering; 14. Floor covering. 15. Scuttle frame; 16. Scuttle frame surface; 17. Scuttle frame surface in concealed and inaccessible places; 18. Ceiling panel.

2.4 OIL TANKERS

2.4.1 The requirements of this Chapter are additional to those set out in 2.1 and 2.3 (except for 2.3.3) when only *method IC* fire protection is adopted and apply to oil tankers and combination carriers of 500 gross tonnage and upwards.

2.4.2 The minimum fire integrity of bulkheads and decks separating adjacent spaces shall be as prescribed in Tables 2.4.2-1 and 2.4.2-2 with regard to the following.

For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, the spaces are classified according to their fire risk as follows:

(1) control stations: spaces accommodating emergency sources of electrical power and lighting;

wheelhouse and navigation room;

spaces accommodating ship radio equipment;

fire stations;

main machinery control room if it is located outside machinery space;

spaces accommodating centralized fire alarm system;

(2) corridors and lobbies;

(3) accommodation spaces as defined in **1.5.2**, except corridors;

(4) stairways:

interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.

A stairway which is enclosed only at one level shall be regarded as part of the space from which it is separated by a fire door;

(5) service spaces (low risk):

storerooms having areas less than 4 m^2 and not having provisions for the storage of flammable liquids, drying rooms, laundries and refrigerated provision storerooms insulated with non-combustible materials;

spaces accomodating electrical distribution boards having an area of less than 4 m^2;

(6) machinery spaces of category A:

spaces as defined in **1.2**, Part VII "Machinery Installations";

incinerator and combined incinerator/ waste stowage spaces, and the flue uptakes from such spaces (refer to **2.1.5.9**);

(7) other machinery spaces:

machinery spaces excluding spaces referred to in (6) and spaces accommodating electrical equipment (automatic telephone stations, spaces for air conditioning ducts);

(8) cargo pump rooms as defined in **1.5.7.1**;

(9) service spaces (greater fire risk): galleys and pantries containing appliances for hot food preparation, saunas, paint lockers and storerooms with an area of 4 m^2 and over, spaces for storage of flammable liquids, workshops and similar spaces, which are not part of machinery spaces;

refrigerated provision storerooms insulated with combustible materials;

waste stowage spaces and garbage chutes connected thereto;

(10) open decks:

open deck spaces and enclosed promenades having no fire risk. This means that their furnishings shall be restricted to deck furniture. In addition, such spaces shall be naturally ventilated by permanent openings.

air spaces (spaces outside superstructures and deckhouses);

Table 2.4.2-1 **Fire integrity of bulkheads separating adjacent spaces**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0[1]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors and lobbies	*2)*		C	B-0	A-0 B-0[2]	B-0	A-60	A-0	A-0	A-0	*
Accommodation spaces	*3)*			C	A-0 B-0[2]	B-0	A-60	A-0	A-0	A-0	*
Stairways	*4)*				A-0 B-0[2]	A-0 B-0[2]	A-60	A-0	A-0	A-0	*
Service spaces (low risk)	*5)*					C	A-60	A-0	A-0	A-0	*
Machinery spaces of category A	*6)*						*	A-0	A-0[3]	A-60	*
Other machinery spaces	*7)*							A-0[4]	A-0	A-0	*
Pump rooms	*8)*								*	A-0	*
Service spaces (high risk)	*9)*									A-0[4]	*
Open decks	*10)*										*

Table 2.4.2-2 **Fire integrity of decks separating adjacent spaces**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0	A-0	A-0	A-0	A-0	A-60	A-0	-	A-0	*
Corridors and lobbies	*2)*	A-0	*	*	A-0	*	A-60	A-0	-	A-0	*
Accommodation spaces	*3)*	A-60	A-0	*	A-0	*	A-60	A-0	-	A-0	*
Stairways	*4)*	A-0	A-0	A-0	*	A-0	A-60	A-0	-	A-0	*
Service spaces (low risk)	*5)*	A-15	A-0	A-0	A-0	*	A-60	A-0	-	A-0	*
Machinery spaces of category A	*6)*	A-60	A-60	A-60	A-60	A-60	*	A-60[5]	A-30	A-60	*
Other machinery spaces	*7)*	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Pump rooms	*8)*	-	-	-	-	-	A-0[3]	A-0	*	-	A-0
Service spaces (high risk)	*9)*	A-60	A-0	A-0	A-0	A-0	A-60	A-0	-	A-0[4]	*
Open decks	*10)*	*	*	*	*	*	*	*	*	*	*

Footnotes to Tables. *2.3.4-1*, *2.3.4-2*.
[1] Bulkheads separating the wheelhouse, chartroom and radio room from each other may be "B-0" class.
[2] For clarification as to which applies, refer to 2.1.4.3.
[3] Where bulkheads and decks are penetrated by cargo pump shafts, electric cables, etc. refer to 2.4.8

[4] Where spaces are used for the same purpose, divisions between them need not be fitted
[5] 1Where other machinery spaces of category (7) are the spaces of low fire risk, i.e. they do not contain machinery operating on fuel oil or having a pressure lubrication systems, "A-0" class divisions are permitted (refer to Table 2.4.2-2)
1Where an asterisk appears in the tables the division shall be of steel or equivalent but is not required to be of "A" class. However, if in the deck except for the decks in a space of category (*10*), there are penetrations for electric cables, piping and ventilation ducts, such penetrations shall be flame and smoke tight. Divisions between control stations (emergency generators) and open decks may have air intake openings without closing appliances, except cases when fixed gas fire-fighting system is installed.
2. Small enclosed spaces indoors, having the area of openings in bounding structures, connected to the space, less than 30%, are considered as separate spaces.
Fire integrity of divisions and decks bounding such small spaces shall comply with the Tables of this paragraph of the Rules.

2.4.3 Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks which support such accommodation, shall be constructed of steel and be "A-60" class for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area.

The distance of 3 m shall be measured horizontally and parallel to the centreline of the ship from the boundary facing the cargo area at the each deck level. The insulation above shall be provided up to the underside of navigation bridge deck.

Lower part of the navigation bridge facing the cargo area shall be "A-60" class.

2.4.4 Arrangement of openings shall meet the requirements of **2.4.4.1 - 2.4.4.3**.

2.4.4.1 Except as permitted in **2.4.4.2**, access doors, air inlets and openings to accommodation spaces, service spaces, control stations and machinery spaces shall not face the cargo area. They shall be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at the distance of at least 4 % of the ship length but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. However, this distance need not exceed 5 m.

Access to forecastle spaces containing sources of ignition may be permitted through doors facing cargo area provided the doors are located outside hazardous areas (refer to **19.2**, Part XI "Electrical Equipment").

2.4.4.2 The Register may permit access doors in superstructures or deckhouses on transverse bulkheads facing the cargo area or on side bulkheads within 5 m limits specified in **2.4.4.1**, to cargo control rooms and to such service spaces used as provision rooms, storerooms and lockers, provided they do not give access directly or indirectly to any other space containing or providing for accommodation, control stations or service spaces such as galleys, pantries or workshops or similar spaces containing sources of vapour ignition. Boundaries of such a space shall be of "A-60" class except for the boundary facing the cargo area. Bolted plates for the removal of machinery may be fitted within the limits specified in **2.4.4.1**.

Wheelhouse doors and windows may be located within the limits specified in **2.4.4.1** so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gastight and vapourtight.

2.4.4.3 The Register may permit access to a deck foam system room where foam tanks and control station are located within the distances specified in **2.4.4.1** provided the requirements of **2.4.4.2** are fulfilled and the door is located flush with a bulkhead.

2.4.5 Windows and sidescuttles facing the cargo area and located on the sides of superstructures and deckhouses within the limits specified in **2.4.4.1** shall be of the fixed (non-opening) type. Such windows and sidescuttles, except wheelhouse window, shall be of "A-60" class.

Except that "A-0" class standard is acceptable for windows and sidescuttles outside the limit specified in **2.4.4.1**.

2.4.6 The Register may permit a navigation position to be fitted above the cargo area where this is for navigation purposes only, and it shall be separated from the cargo tank deck by means of an open space with a height of at least 2 m. The fire protection of such a navigation position shall be as required for control stations in **2.4.2** and other provisions, as applicable, of this Part.

2.4.7 Machinery spaces shall be positioned aft of cargo tanks and slop tanks; they shall also be situated aft of pump rooms and cofferdams, but not necessarily aft of the fuel oil tanks. Any machinery space shall be isolated from cargo tanks and slop tanks by cofferdams, pump rooms, fuel oil tanks, or ballast tanks.

Pump rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks, and pumps for fuel oil transfer may be used for isolation of machinery spaces from cargo tanks and slop tanks provided that such pump rooms have the same safety standard as that required for cargo pump rooms. The lower portion of the pump room bulkhead may be recessed into machinery spaces of category A to accommodate pumps. The deck head of the recess may be not more than one third of the moulded depth above the keel. In ships of not more than 25000 t deadweight, for reasons of access and satisfactory piping arrangements and on agreement with the Register, the deck head of the recess may be at a level of up to one half of the moulded depth above the keel.

A cargo tank or a slop tank adjoining machinery spaces by a corner shall be isolated therefrom by a corner cofferdam. The design and dimensions of cofferdams shall comply with the requirements of **2.7.5.2**, Part II "Hull".

Corner cofferdams inaccessible for inspection shall be fitted with suitable media.

No cargoes or wastes shall be stowed in cofferdams.

Void space or ballast water tank protecting fuel oil tank as shown in Fig. 2.4.7, need not be considered as a cargo area even though they have a cruciform contact with the cargo oil tank or slop tank. The void space protecting fuel oil tank is not considered as a cofferdam required above. Void spaces may be located as shown in Fig. 2.4.7 even though they have a cruciform contact with the slop tank.

2.4.8 Pump rooms shall be closed in by gastight bulkheads.

Permanent approved gastight lighting enclosures may be installed in bulkheads and decks separating pump rooms from other spaces. These enclosures are intended for lighting of pump rooms provided that they are sufficiently durable and that fire integrity and gas-tightness of the bulkhead or deck is preserved.

2.4.9 Control stations, cargo control stations, accommodation and service spaces (except for isolated cargo handling gear lockers) shall be positioned aft of all cargo tanks, slop tanks and spaces isolating cargo or slop tanks from machinery spaces, but not necessarily aft of the fuel oil tanks and ballast tanks, and shall be arranged in such a way that a single failure to a deck or bulkhead shall not permit the entry of gas or fumes from the cargo tanks into any of the above spaces. The recess provided in accordance with **2.4.7** may be disregarded when determining the location of the said spaces.

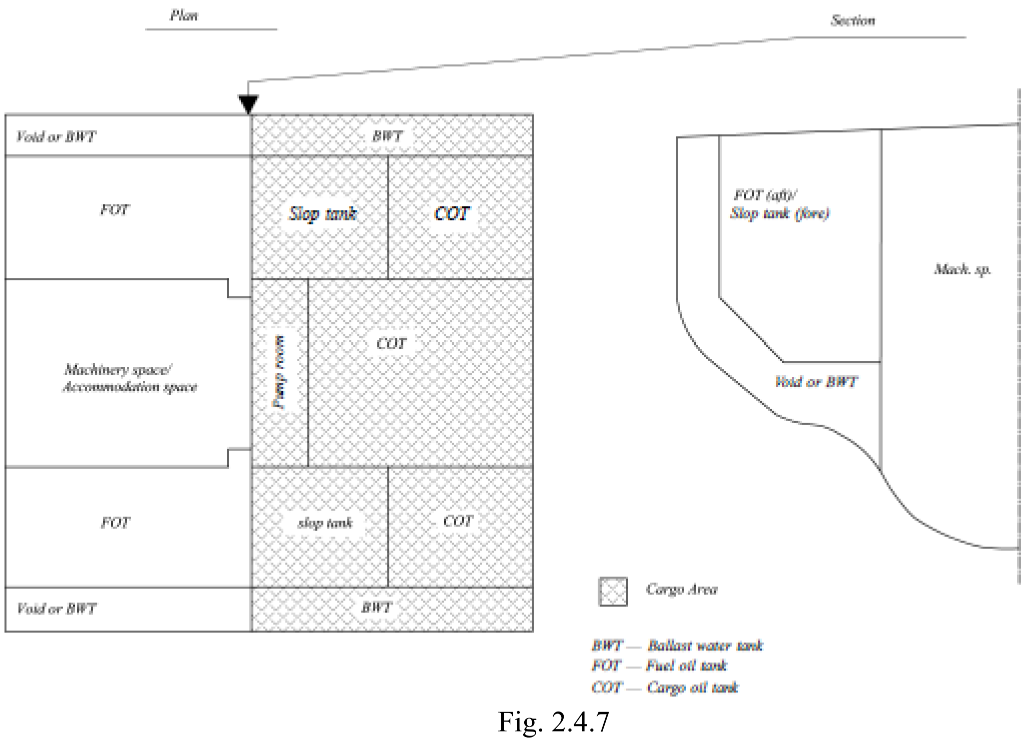

Fig. 2.4.7

Enclosed smoking rooms shall be provided within the accommodation area. These spaces shall be formed by "B-15" class divisions, and facings shall be made of materials having low flame spread characteristics.

2.4.10 Where deemed necessary and on agreement with the Register, control stations, cargo control rooms, accommodation and service spaces may be positioned forward of the cargo tanks, slop tanks and spaces which isolate cargo tanks and slop tanks from machinery spaces but not necessarily forward of fuel oil tanks or ballast tanks. Machinery spaces other than category A may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, pump rooms, fuel oil tanks or ballast tanks.

All of the above-mentioned spaces shall be subject to an equivalent standard of safety and appropriate availability of fire extinguishing appliances. Control stations, cargo control rooms, accommodation and service spaces shall be arranged in such a way that a single failure of a deck or a bulkhead shall not permit the entry of gas or fumes from the cargo tanks into such spaces. In addition, where deemed necessary for the safety of navigation of the ship, machinery spaces containing internal combustion engines not being main propulsion machinery having output greater than 375 kW may be located forward of the cargo area.

Paint lockers, regardless of their use shall not be positioned above the tanks and spaces as determined in **2.4.9**.

2.4.11 No access holes to fuel oil tanks located in the double bottom below cargo tanks are permitted in cargo tanks and in the machinery space.

2.4.12 Means shall be provided to keep deck spills away from the accommodation and service spaces.

This may be accomplished by provision of a permanent continuous coaming of a height at least 300 mm from side to side. Similar measures and arrangements shall be provided for stern loading.

2.4.13 Manholes, openings for cleaning cargo tanks and other openings shall not be arranged in completely enclosed or in semi-enclosed spaces.

2.4.14 The following requirements shall be also met in combination carriers:

.1 the slop tanks shall be surrounded by cofferdams, except where the boundaries of the slop tanks are the hull, main cargo deck, cargo pump room bulkhead or fuel oil bunker tank. These cofferdams shall not be open to a double bottom, pipe tunnel, pump room or other enclosed space, as well as they shall not be used for carriage of cargo or ballast and they need not be connected with cargo or ballast systems.

Means shall be provided for filling the cofferdams with water and draining them.

Where the boundary of the slop tank is the cargo pump room bulkhead, the pump room shall not be open to the double bottom, pipe tunnel or other enclosed space. However, openings provided with gastight bolted covers may be permitted;

.2 hatches and tank cleaning openings to slop tanks shall be only permitted on the open deck;

they shall be fitted with closing arrangements, except where they consist of bolted plates with bolts at watertight spacing. Closing arrangements shall be fitted with securing devices controlled by responsible person out of ship officers;

.3 arrangement of openings for cargo handling operations in decks and bulkheads separating the spaces for the carriage of oil and oil products from the spaces not intended or fitted for their carriage is permitted only provided equivalent tightness for oil products and their vapours is ensured;

.4 detailed instructions shall be exhibited on board, covering safety measures to be taken during loading or unloading of the ship and when dry cargoes are carried with oil product residues in the slop tanks.

2.4.15 Where the electrochemical protection is fitted on the ship it shall comply with the following requirements:

.1 where the electrochemical protection of structures or their elements is fitted, anodes can be made of zinc, magnesium or aluminium alloys;

.2 impressed current systems are not permitted in oil cargo tanks either are permitted magnesium or magnesium alloy anodes in cargo tanks or tanks adjacent to cargo tanks;

.3 aluminium alloy anodes are only permitted in cargo tanks and tanks adjacent to cargo tanks of ships carrying oil products in locations where the potential energy does not exceed 275 J. The height of the anode shall be measured from the bottom of the tank to the centre of the anode, and its weight shall be taken as the weight of the anode as fitted, including the fitting devices and inserts.

However, where aluminium alloy anodes are located on horizontal surfaces such as bulkhead girders and stringers not less than 1 m wide and fitted with an upstanding flange or face flat projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured from the surface.

Aluminium alloy anodes shall not be located under tank hatches or openings (in order to avoid any metal parts falling on the fitted anodes), unless protected by adjacent structure;

.4 the anodes shall have steel covers and these shall be sufficiently rigid to avoid resonance in the anode support and be designed so that they retain the anode even when it is wasted. Anodes shall be fitted with delimiters from sides and bottom made of the material which does not spark while contact with the anode. The steel inserts shall be attached to the structure by means of a continuous weld of adequate section, the weld elements shall be free of stress concentrations. Alternatively they may be attached to separate supports by bolting, provided a minimum of two bolts with locknuts are used.

However, other mechanical means of clamping approved by the Register may be accepted.

The supports at each end of an anode shall not be attached to separate items which are likely to move independently.

2.4.16 The fenders shall be made of or securely faced with non-sparking materials, and shall not be bolted to the shell plating.

2.5 FISHING VESSELS

2.5.1 The requirements of this Chapter are additional to those set out in **2.1** and apply to fishing vessels of 500 gross tonnage and upwards and/or 45 m and more in length, the definition of which is given in **1.2.1**, Part I "Classification" of the Rules for the Classification and Construction of Small Sea Fishing Vessels.

2.5.2 In way of accommodation and service spaces and control stations one of three methods of protection shall be adopted in compliance with **2.3.2**.

2.5.3 The minimum fire integrity of the bulkheads and decks separating adjacent spaces shall be as prescribed in Tables 2.5.3-1 and 2.5.3-2.

Table 2.5.3-1 **Fire integrity of bulkheads separating adjacent spaces**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0[1]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors and lobbies	*2)*		C	B-0	B-0 A-0[2]	B-0	A-60	A-0	A-0	A-0	*
Accommodation spaces	*3)*			C[3,4]	B-0 A-0[2]	B-0	A-60	A-0	A-0	A-0	*
Stairways	*4)*				B-0 A-0[2]	B-0 A-0[2]	A-60	A-0	A-0	A-0	*
Service spaces (low risk)	*5)*					C	A-60	A-0	A-0	A-0	*
Machinery spaces of category A	*6)*						*	A-0	A-0[5]	A-60	*
Other machinery spaces	*7)*							A-0[6]	A-0	A-0	*
Cargo spaces	*8)*								*	A-0	*
Service spaces (high risk)	*9)*									A-0[6]	*
Open decks	*10)*										*

Footnotes to Table *2.5.3-1*

[1] Bulkheads separating the wheelhouse, chartroom and radio room from each other may be "B-0" class..

[2] For clarification as to which applies, refer to 2.1.4.3.

[3] Doors separating cabins from individual sanitary accommodation may be constructed of combustible materials in *method IC* fire protection. No special requirements are imposed upon bulkheads in *methods IIC* and *IIIC*.

[4] In case of *method IIIC* bulkheads of "B-0" class shall be provided between spaces or groups of spaces of 50 m^2 and over in area.

[5] "A-0" class may be used if no dangerous goods are intended to be carried. For cargo spaces intended for carriage of dangerous goods refer to **7.2.12**.

[6] Where spaces are used for the same purpose, divisions between them need not be fitted.

N o t e s : 1Where an asterisk appears in the tables the division shall be of steel or equivalent but is not required to be of "A" class. However, if in the deck except for the decks in a space of category (*10*), there are penetrations for electric cables, piping and ventilation ducts, such penetrations shall be flame and smoke tight. Divisions between control stations (emergency generators) and open decks may have air intake openings without closing appliances, except cases when fixed gas fire-fighting system is installed.

2 Refer to Note 4 to Table **2.2.1.3-1**.

Table 2.5.3-2 **Fire integrity of decks separating adjacent spaces in ships**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*
Corridors and lobbies	*2)*	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*
Accommodation spaces	*3)*	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*
Stairways	*4)*	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*
Service spaces (low risk)	*5)*	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*
Machinery spaces of category A	*6)*	A-60	A-60	A-60	A-60	A-60	*	A-60[1]	A-30	A-60	*
Other machinery spaces	*7)*	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Cargo spaces	*8)*	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*
Service spaces (high risk)	*9)*	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0[2]	*
Open decks	*10)*	*	*	*	*	*	*	*	*	*	-

Footnotes to Table *2.5.3-2*.

[1] Where other machinery spaces of category (7) are the spaces of low fire risk, i.e. they do not contain machinery operating on fuel oil or having a pressure lubrication systems, "A-0" class divisions are permitted.

[2]Refer to Footnote 6 to Table 2.5.3-1.
N o t e s : 1. Refer to Note 1 to Table 2.5.3-1.
2. Refer to Note 4 to Table 2.2.1.3-1.

For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, the spaces are classified according to their fire risk as follows:

(1) control stations: spaces accommodating emergency sources of electrical power and lighting;

wheelhouse and navigation room;

spaces accommodating ship radio equipment;

fire stations; main machinery control room if it is located outside machinery space;

spaces accommodating centralized fire alarm system;

(2) corridors and lobbies;

(3) accommodation spaces in accordance with 1.5.2, except corridors;

(4) stairways:

interior stairways, lifts, totally enclosed emergency escape trunks and escalators (other than those wholly contained within the machinery spaces) and enclosures.

A stairway which is enclosed only at one level shall be regarded as part of the space from which it is not separated by a fire door;

(5) service spaces (low risk):

storerooms not having provisions for the storage of flammable liquids and having areas less than 4 m^2;

drying rooms and laundries;

refrigerated provision storerooms insulated with non-combustible materials;

spaces accommodating electrical distribution boards having an area of less than 4 m^2;

(6) machinery spaces of category A:

spaces as defined in 1.2, Part VII "Machinery Installations";

incinerator rooms and combined incinerator/waste stowage spaces and the flue uptakes from such spaces (refer to 2.1.5.9);

(7) other machinery spaces:

machinery spaces excluding those specified in *(6)*;

spaces for fish meal plants;

spaces accommodating electrical equipment (automatic telephone stations, spaces for air conditioning ducts);

(8) cargo spaces:

all spaces used for carriage of cargoes (including bulk cargo tanks) as well as trunkways and hatchways to such spaces;

(9) service spaces (greater fire risk): galleys and pantries containing appliances for hot food preparation, saunas;

storerooms with an area of 4 m^2 and over;

paint lockers and lamp lockers;

spaces for storage of flammable liquids;

workshops and similar spaces, which are not part of machinery spaces;

waste stowage spaces and garbage chutes connected thereto;

(10) open decks:

open deck spaces and enclosed rest areas having no fire risk (this means that their furnishings shall be restricted to deck furniture; in addition, such spaces shall be naturally ventilated by permanent openings:

raw fish-filleting areas, fish washing rooms and similar spaces with no fire risk;

air spaces (spaces outside superstructures and deckhouses).

2.5.4 Linings, ceilings, draught stops and their associated grounds shall be made of non-combustible materials:

in accommodation and service spaces, and in control stations, if protection *method IC* is used;

in corridors and stairway enclosures serving accommodation and service spaces, and control stations, if protection *methods IIC* and *IIIC* are used.

2.5.5 Provisions of **2.3.5** shall apply to bulkheads within accommodation and service spaces not required to be "A" or "B" class divisions.

Within accommodation spaces, bulkheads required to be "B" class divisions shall extend from deck to deck and to the shell or other boundaries. However, if the continuous "B" class ceilings or linings are fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

2.5.6 Provisions of **2.3.5.3**, **2.3.6**, **2.3.7** and **2.3.8** shall apply to fire doors.

2.5.7 For the purpose of application of the requirements of **2.1.1.7**, **2.1.1.8** and **2.1.1.10** it is necessary to follow Fig. 2.3.10 and Table 2.3.10 subgroup 1 for the *method IC*, subgroup 2 for the *methods IIC* and *IIIC*.

2.5.8 As a lining material for specially equipped fish-processing shops (for raw fish filleting and washing, refrigerating, canning shops) moisture-resistant plywood with low flame-spread characteristics may be used as specified in the FTP Code 2010. For plastic laminated moisture-resistant plywood, both composing materials (plywood and laminate) shall have low flame-spread characteristics.

2.6 FISHING VESSELS OF LESS THAN 500 GROSS TONNAGE

2.6.1 Unless otherwise stated, the requirements of this Chapter are additional to those set out in **2.1** and apply to fishing vessels of less than 500 gross tonnage and 24 m in length and over but less than 45 m, the definition of which is given in 1.2.1, Part I "Classification" of the Rules for the Classification and Construction of Small Sea Fishing Vessels.

2.6.2 In way of accommodation and service spaces and control stations *method IC* fire protection shall be adopted in compliance with **2.3.2**.

2.6.3 The minimum fire integrity of the bulkheads and decks separating adjacent spaces shall be as prescribed in Tables 2.6.3-1 and 2.6.3-2.

For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, the spaces are classified according to their fire risk according to **2.5.3**.

2.6.4 In accommodation and service spaces, in control stations as well as in corridors and stairway enclosures serving accommodation and service spaces and control stations, linings, ceilings, draught stops and their associated grounds shall be made of non-combustible materials.

2.6.5 Within accommodation spaces, bulkheads required to be "B" class divisions shall extend from deck to deck and to the shell or other boundaries. However, if the continuous "B" class ceilings or linings are fitted on both sides of the bulkhead, the bulkhead may terminate at the continuous ceiling or lining.

Within accommodation spaces, bulkheads not required to be "A" or "B" class divisions, shall be at least "C" class division.

Application of combustible materials may be allowed for doors separating cabins from internal sanitary spaces.

Table 2.6.3-1 **Fire integrity of bulkheads separating adjacent spaces**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0[1]	A-0	A-60	A-0	A-15	A-60	A-15	A-60	A-60	*
Corridors and lobbies	*2)*		C	B-0	B-0	B-0	A-60	A-0	A-0	A-0[2] B-15	*
Accommodation spaces	*3)*			C[3]	B-0	B-0	A-60	A-0	A-0	A-0[2] B-15	*
Stairways	*4)*				B-0	B-0	A-60	A-0	A-0	A-0[2] B-15	*
Service spaces (low risk)	*5)*					C	A-60	A-0	A-0	A-0[2] B-15	*
Machinery spaces of category A	*6)*						*	A-0	A-0[4]	A-60	*
Other machinery spaces	*7)*							A-0[5]	A-0	A-0	*
Cargo spaces	*8)*								*	A-0	*
Service spaces (high risk)	*9)*									A-0[2,5] B-15[5]	*
Open decks	*10)*										-

Footnotes to Table *2.6.3-1*

[1]Bulkheads separating the wheelhouse, chartroom and radio room from each other may be of "B-0" class.

[2]Bulkheads separating galley from spaces of categories (*2*) — (*5*) and (*9*), shall be of "A-0" class. Bulkheads separating storerooms for flammable materials and substances from spaces of categories (*2*), (*4*), (*5*) and (*9*), shall be of "A-0" class (storerooms shall not be adjacent to accommodation spaces).

[3]Doors separating cabins from individual sanitary accommodation may be constructed of combustible materials.

[4]"A-0" class may be used if no dangerous goods, for example, fish meal, are intended to be carried. For cargo spaces intended for carriage of dangerous goods refer to 7.2.12.

[5]Where spaces are used for the same purpose, divisions between them need not be fitted.

N o t e s : 1. When an asterisk appears in the tables, the division shall be of steel or equivalent material, but is not required to be of "A" class. However, if in the deck except for the decks in a space of category (10), there are penetrations for electric cables, piping and ventilation ducts, such penetrations shall be flame and smoke tight. Divisions between control stations (emergency generators) and open decks may have air intake openings without closing appliances, except cases when fixed gas fire-fighting system is installed.

2. Refer to Note 4 to Table 2.2.1.3-1.

Table 2.6.3-2 **Fire integrity of decks separating adjacent spaces in ships**

Spaces											
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Control stations	*1)*	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0	*
Corridors and lobbies	*2)*	A-0	*	*	A-0	*	A-60	A-0	A-0	A-0	*
Accommodation spaces	*3)*	A-60	A-0	*	A-0	*	A-60	A-0	A-0	A-0	*
Stairways	*4)*	A-0	A-0	A-0	*	A-0	A-60	A-0	A-0	A-0	*
Service spaces (low risk)	*5)*	A-15	A-0	A-0	A-0	*	A-60	A-0	A-0	A-0	*
Machinery spaces of category A	*6)*	A-60	A-60	A-60	A-60	A-60	*	A-60[1]	A-30	A-60	*
Other machinery spaces	*7)*	A-15	A-0	A-0	A-0	A-0	A-0	*	A-0	A-0	*
Cargo spaces	*8)*	A-60	A-0	A-0	A-0	A-0	A-0	A-0	*	A-0	*
Service spaces (high risk)	*9)*	A-60	A-0	A-0	A-0	A-0	A-60	A-0	A-0	A-0[2]	*
Open decks	*10)*	*	*	*	*	*	*	*	*	*	-

Footnotes to Table *2.5.3-2*.
[1] Where other machinery spaces of category (7) are the spaces of low fire risk, i.e. they do not contain machinery operating on fuel oil or having a pressure lubrication systems, "A-0" class divisions are permitted.
[2]Refer to Footnote 6 to Table 2.5.3-1.
N o t e s : 1. Refer to Note 1 to Table 2.6.3-1.
2. Refer to Note 4 to Table 2.2.1.3-1.

2.6.6 In accommodation spaces, service spaces and control stations where stairways penetrate more than a single deck, shall be surrounded by "B-0" class divisions with self-closing doors at all levels.

Stairways, which penetrate only a single deck, shall be protected at least at one level by at least "B-0" class divisions and self-closing doors. Lift trunks shall be constructed of steel or equivalent material and shall be so fitted as to prevent the passage of smoke and flame from one ′ tween-deck space to another and shall be provided with means of closing so as to permit the control of draught and smoke.

2.6.7 Air spaces enclosed behind ceilings, panellings, or linings shall be divided by close fitting draught stops spaced not more than 7 m apart. In the vertical direction, such air spaces, including those behind linings of stairways, trunks, etc., shall be closed at each deck.

2.6.8 Provisions of **2.3.6**, **2.3.7** and **2.3.8** shall apply to fire doors.

2.6.9 For the purpose of application of the requirements given in **2.1.1.7**, **2.1.1.8** and **2.1.1.10** it is necessary to use Fig. 2.3.10 and Table 2.3.10-1.

2.6.10 As a lining material for specially equipped fish-processing shops (for raw fish filleting and washing, refrigerating, canning shops) moisture-resistant plywood with low flame spread characteristics may be used as specified in the FTP Code. For plastic laminated moisture-resistant plywood, both composing materials (plywood and laminate) shall have low flame-spread characteristics.

3 FIRE-FIGHTING EQUIPMENT AND SYSTEMS

3.1 GENERAL

3.1.1 General.

3.1.1.1 The requirements of this Section are applicable to all fire-fighting equipment and systems fitted in sea-going ships for the purpose of fire protection of the ship concerned.

Where provision is made in a ship for extra fire extinguishing systems in addition to those prescribed by this Section, such systems shall also comply with the requirements set out below, to an extent approved by the Register.

During design and manufacture of fire extinguishing systems, the requirements of the FSS Code and Sections **1**, **2**, **4**, **5**, Part VIII "Systems and Piping" of these Rules shall be complied with.

3.1.1.2 Fire-fighting equipment and systems shall be so constructed that they will be efficient and readily available for operation under all service conditions (refer to **2.3.1**, Part VII "Machinery Installations").

3.1.1.3 Containers and pressure vessels used in fire extinguishing systems shall meet the requirements set forth in **6.4**, Part X "Boilers, Heat Exchangers and Pressure Vessels".

3.1.1.4 The use of a fire extinguishing medium which either by itself or under expected conditions of use gives off toxic gases in such quantities as to endanger the persons shall not be permitted. It is prohibited to install in ships new fire extinguishing plants utilizing halon 1211, halon 1301 и halon 2402, as well as perfluoridecarbons.

3.1.2 Fire extinguishing systems.

3.1.2.1 In addition to the water fire main system and in accordance with the purpose for which they are intended, all ship's spaces shall be protected by one of the fixed fire extinguishing systems according to Table 3.1.2.1, unless expressly provided otherwise.

The Register may consider the use of other equivalent systems, ensuring equivalent protection.

For machinery spaces of category A and pump rooms specified in 1.5.7.1, equivalent fire extinguishing systems complying with the requirements of 3.13 may be used instead of pressure water-spraying systems and carbon dioxide smothering systems.

Instead of a pressure water-spraying system a water screen fire extinguishing system approved on the basis of circulars MSC / Circ 1165, MSC.1 / Circ. 1269, MSC.1 / Circ. 1385, MSC.1 / Circ. 1386 may be installed.

For protection of spaces specified in **1.5.4.3**, **1.5.4.4** and **1.5.9**, the Register may permit the use of fixed fire extinguishing system other than prescribed by Table 3.1.2.1, if the full-scale test in conditions simulating spilled petroleum burning in the said space will prove that alternative system is not less effective in fire fighting (refer to IMO circular MSC/Circ.914).

3.1.2.2 Calculation of the necessary quantity of the fire-extinguishing medium shall be made for each protected space. The maximum calculation values shall be taken for the quantity of stored fire extinguishing medium.

Fire extinguishing system shall be fitted with valves normally closed for transfer of fire extinguishing medium to the appropriate space.

Where two or more adjacent spaces presenting different degrees of fire risk are not separated by gastight or watertight bulkheads or decks, or where fuel oil can flow from one space into another and the possibility of such flowing is not eliminated structurally, the choice of fire extinguishing medium and, consequently, of a fire extinguishing system shall be made to comply with the requirements for the fire protection of the space which affords the greatest fire risk, and the calculation of the necessary quantity of fire extinguishing medium and the rate of application shall be made on the basis of the total area or volume, respectively, of all spaces thus communicating.

When calculating the necessary quantity of the fire extinguishing medium and its application rate for fixed gas fire extinguishing systems, the adjacent spaces with independent ventilation systems not separated by at least "A-0" class divisions shall be considered as the same space.

Table 3.1.2.1

Nos.	Description of spaces	Fixed fire extinguishing systems								
		Sprinkler	Pressure water spraying	Waterscreen	Drenching	Foam fire extinguishing	Carbon dioxide smothering	Dry powder	Aerosol	Inert gas
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	Control stations listed in 1.5.1.1, 1.5.1.5	+[1]	+							
2	Control stations listed in 1.5.1.2[2]		+			+	+		+	
3	Accommodation spaces listed in 1.5.2.1 and 1.5.2.2	+[1]								
4	Service spaces listed in 1.5.3.1, 1.5.3.2.3 and 1.5.3.2.4	+[1]								
5	Storerooms listed in 1.5.3.2.1				+					
6	Storerooms listed in 1.5.3.2.23	+[1]	+		+[4]	+	+	+[5]		
7	Cargo spaces listed in 1.5.4.3, 1.5.4.4		+	+[6]		+[7]	+[8]			+[8]
8	Tanks for petroleum products, refer to 1.5.4.1					+				
9	Cargo spaces, refer to 1.5.4.2[9,10]		+[11,12]			+[4]	+[13]			+
10	Machinery spaces of category A[2,14], hangers and spaces where refuelling and hanger facilities are located; spaces containing equipment for the fuel preparation specified in **6.8.2.5**		+			+[7]	+		+	
11	Silencers of internal combustion engines[15], regenerators of gas turbine installation[16] and exhaust ducts from		+				+			

	galley ranges[17], exhaust gas boilers									
12	Unattended machinery spaces containing propulsion electric motors, steam engines or steam turbines having power output not less than 375 kW		+[18]			+[7]	+		+	
13	Pump rooms listed in 1.5.7.1		+			+[7]	+[19]		+[5]	
14	Working spaces listed in 1.5.8.1		+			+[7]	+		+	
15	Fire zones of category A machinery spaces				+[20]					
16	Special category spaces listed in 1.5.9		+							
17	Cargo tank deck in gas carriers and cargo piping and cargo manifolds							+		
18	Rooms for separators, etc. and other spaces specified in 4.2.7, Part VII "Machinery Installations"		+			+[7]	+		+	
19	Scavenge spaces of the crosshead type internal combustion engines (refer to 2.2.4, Part IX "Machinery")						+			
20	Area of forward and aft loading/unloading arrangements in oil tankers, helidecks					+				
21	Chain stoppers and cargo hose connections on oil tankers accommodated to mooring at point berths carried out to sea and fitted up with a forward cargo gear		+							
22	Corridors and stairways	+[21]								
23	Incinirator room refer to **1.5.9**					+	+			
24	Waste storage room, combined room for incinerators and waste storage refer to **1.5.9**	+								
25	Special electrical room refer to **1.5.10**[22]						+	+[23]		

[1]Automatic sprinkler system shall be installed:
In passenger ships carrying more than 36 passengers in control stations, accommodation and service spaces including corridors and stairways. Alternatively, control stations, where water may damage essential equipment may be fitted with an approved fixed fire extinguishing system of another type (refer to **3.3.1.1**). The system may not be fitted in spaces of minor or no fire risk as void spaces, public toilets, carbon dioxide cylinder rooms and similar spaces;
in passenger ships carrying not more than 36 passengers (where fixed smoke detection alarm system is fitted only in corridors, stairways and escape routes within accommodation spaces) in accommodation and service spaces and if the Register deems it necessary, in control stations (refer to **1.5.1.2**), except in spaces of minor or no fire risk as void spaces, sanitary rooms, etc;
in cargo ships where *method IIC* is adopted in accommodation spaces, galleys and other service spaces, except spaces of minor or no fire risk as void spaces, sanitary rooms, etc;
incinerator and combined incinerator/ waste storage spaces, and the flue uptakes from such spaces (refer to **2.1.5.9**).
[2]Where the capacity of emergency diesel-generator is lower than 375 kW, the control station space may be protected by portable fire extinguishers according to Table 5.1.2.
[3]Paint lockers and storerooms for flammable liquids, liquefied and compressed gases need not be fitted with a fixed fire extinguishing system, if the area of each storage space is not more than 4 m^2 (refer to **3.1.3.4**). Spaces for storage of cargo specimen located in the tanker cargo area may not be fitted with fire extinguishing system.
[4]A system using medium expansion foam with expansion ratio of about 100:1 shall be used, except for the hangars for helicopters and enclosed garages where a system with foam expansion ratio about 1000:1 shall be employed.
[5]Explosion-proof aerosol generators shall be installed.
[6]Water screens are used in addition to the systems specified in cols 4, 7 and 10 in cases indicated in **2.2.1.2**.
[7]A system using foam with expansion ratio of about 1000:1 shall be used, provided that foam concentrate is applicable for fire extinction of the cargoes carried.
[8]A carbon dioxide smothering system may be installed only in the cargo spaces, which may be closed tightly from a location outside the said spaces. Refer also to **3.1.2.13**.
[9]A foam fire extinguishing system shall not be used for the protection of cargo spaces of container ships.
[10]On agreement with the Register spaces for general cargoes except dangerous goods may not be fitted with fixed fire extinguishing systems in the following cases:
in passenger ships engaged in short voyages;
in passenger ships of less than 1000 gross tonnage, provided the ship is fitted with portable fire- fighting equipment for cargo spaces, as well as with steel hatch covers and effective closing appliances of all ventilating and other openings leading to cargo spaces;
in cargo ships of less than 2000 gross tonnage constructed or intended only for the carriage of ore, coal, grain, green timber, non-combustible cargoes and cargoes of minor fire risk (refer to Table 1 of IMO circular MSC.1/Circ.1395), provided the ship is fitted with steel hatch covers and effective closing appliances of all ventilating and other openings leading to cargo spaces;
in cargo spaces are carried only such cargoes, for which fixed gas fire extinguishing system is not efficient (refer to Table 2 of IMO circular MSC.1/Circ.1395/Rev.2), provided the requirement of **7.2.5.2** is fulfilled.
[11]In fish meal cargo spaces the rate of water discharge shall be 1,5 l/min per 1 m2; in combined cargo spaces for fish meal and intended also for carriage and storage of packages the rate of water discharge
shall be 5 l/min per 1 m2.
[12]Spaces for the carriage of Class 1 dangerous goods, except 1.4S, in addition to the smothering system shall be protected according to 7.2.5.3. Refer also to **3.2.14.7** of Load Line Rules for Sea-Going Ships
[13]A carbon dioxide smothering system or any equivalent fire extinguishing system may not be installed in fishing vessels for protection of the refrigerated cargo holds provided they are not cargo spaces of high fire risk and/or not intended for storage and carriage of packages.

[14]Where an auxiliary oil-fired boiler or boilers as well as incinerators operating on fuel oil situated inside the machinery space is (are) not isolated from the rest of the space by gastight enclosure bulkheads and platforms, the machinery space shall be fitted with one of the above fire extinguishing systems, this system being capable of protecting the entire space, even where this machinery space does not contain any other oil-fired equipment or machinery, besides the above boilers.
[15]The silencers of medium- and high-speed engines need not to be fitted with the fixed fire extinguishing system, when there are spark arresters in the exhausts. This requirement does not apply to fishing vessels of less than 500 gross tonnage.
[16]Installation of one of the above systems is compulsory for all ships carrying flammable liquids and ships that serve them, all ships carrying readily flammable dry cargoes, irrespective of their gross tonnage, and for all other ships with a total power of main and auxiliary machinery more than 740 kW.
[17]In passenger ships carrying not more than 36 passengers and in cargo ships is required when ducts pass through some spaces located in way of accommodation spaces.
[18]Pressure water-spraying system may be used only for spaces where steam turbines or steam engines are of enclosed type.
[19]A warning notice shall be provided at the carbon dioxide smothering system controls stating that because of ignition hazard caused by electrostatic discharges the system shall be used only for fire extinguishing but not for inerting purposes.
[20]Refer to **3.12**.
[21]The sprinkler system is compulsory only on passenger ships carrying more than 36 passengers.
[22]Special electrical rooms with a deck area of 4m^2 and over.
[23]Use of powder extinguishing system is allowed in all rooms, except rooms in which the electric - or radio equipment under voltage over 1000 volts is located.

3.1.2.3 Where a fixed gas fire extinguishing system is used, the openings through which air may penetrate to or gas may escape from a protected space shall be capable of being closed from outside the protected space. Watertight and gastight doors in the bulkhead separating adjacent machinery spaces may be considered as closures of openings in such bulkhead only where they are of a self-closing type or operated remotely and the fire extinction stations, from which the extinguishing medium may be discharged, are provided with the signalling of the fully closed doors. In the absence of such signalling, the calculation of the required amount and the rate of discharge of extinguishing medium shall be based on the requirement of providing for the total volume (area) of the adjacent spaces.

3.1.2.4 In multi-deck ships, one 'tween deck is considered as separated from another 'tween deck or hold by a gastight deck, provided the cargo hatchways, other hatchways and openings in this deck are closed with watertight or gastight steel hatch closures and covers, while watertight stops are fitted where the deck is pierced in way of the framing. In the absence of such closures and stops, the spaces shall be considered as communicating, and the extinguishing medium calculation shall be made on the basis of the total volume of the spaces.

3.1.2.5 Where a space protected by means of carbon dioxide smothering system and aerosol fire extinguishing system contains air reservoirs the required quantity of extinguishing medium shall be calculated on the basis of the designed volume of the protected space plus the excess of the free volume of the compressed air. If arrangements are made for discharging the compressed air outside the protected space, by means of relief valves and fuses provided on the air reservoirs then an increase of the quantity of carbon dioxide in the carbon dioxide smothering systems need not be provided and the volume of the air in the air receivers in the aerosol fire extinguishing systems while assessment of the quantity of the aerosol generating compound may be not considered (refer to **3.11.1.3**).

3.1.2.6 In order to prevent excessive pressure in spaces protected by fire smothering systems, due to discharge of extinguishing medium, such spaces shall be fitted with breather valves, where necessary, or other available means (e.g. air pipes or ventilation ducts) shall be used.

3.1.2.7 Spaces for fuel oil units (refer to item 18 of Table 3.1.2.1) enclosed inside engine rooms may have either an independent fire extinguishing system or they may be protected by the fire extinguishing system of the engine room.

3.1.2.8 Whatever a fixed fire extinguishing system is specified in Table 3.1.2.1 for boiler spaces of oil tankers in which crude oil or clops are used for boilers, provision shall be made for 135 l capacity foam extinguisher in compliance with **5.1.10** or an equivalent foam unit both equipped with fixed foam generators capable of delivering foam to the boiler fronts and to trap under burners, valves and connections. This fire extinguisher (unit) shall be remote operated from outside the boiler room.

3.1.2.9 The systems shall be so arranged as to provide the delivery of extinguishing medium to the entire space protected, including the enclosed portions thereof (e.g. control stations, workshops, etc. in machinery spaces).

3.1.2.10 The use of steam may be permitted by the Register depending on the particular case as an addition to the required fire extinguishing medium; the boiler or boilers available for supplying steam shall have an evaporation of at least 1,0 kg of steam per hour for each 0,75 m^3 of the gross volume of the largest space so protected.

3.1.2.11 Where gas, which is a gaseous product of oil fuel combustion, is used as a fire extinguishing medium, the systems using it for protection of machinery and cargo spaces shall comply with the FSS Code.

3.1.2.12 Liquid cargoes with the flash point above 60°C other than oil products or liquid cargoes liable to the requirements of the IBC Code are treated as those with low fire risk and requiring no fixed foam fire extinguishing system.

3.1.2.13 For protection of cargo spaces fitted with partially weathertight hatchway covers on board containerships (refer to IMO circular MSC/Circ.1087), the requirements of Section 2 of the above circular shall serve as a guide when calculating the amount of carbon dioxide in the carbon dioxide fire extinguishing systems. If the clear gaps between hatchway covers exceed 50 mm, fixed pressure water-spraying system shall be fitted in the cargo spaces.

3.1.2.14 Deep-fat cooking equipment, installed in enclosed spaces or on open decks, shall be fitted with an automatic or manual fire extinguishing system tested according to the international standard ISO 15371 "Fire Extinguishing Systems for Protection of Galley Deep-Fat Cooking Equipment". Controls for manual operation of the fire extinguishing system shall be clearly labeled. When actuating this system the following shall be provided:

.1 automatic shutdown of electrical power supply to the deep-fat cooking equipment;

.2 the alarms giving warning of actuation of this system in a galley where deep fat cooking equipment is fitted.

Deep-fat cooking equipment shall be equipped with main and auxiliary thermostats with individual failure warning systems.

3.1.2.15 All doors to spaces protected by volumetric fire extinguishing systems shall be marked as follows:

“The room is protected by a volumetric fire extinguishing / aerosol fire extinguishing system and must be left after system's activation alarm."

3.1.3 Arrangement and equipment of fire extinction stations.

3.1.3.1 Mechanical equipment, such as foam mixers, reservoirs, cylinders or vessels containing extinguishing medium or compressed air, inert gas generators, or high expansion foam generators, refrigerating plants, etc., as well as the starting controls of all fire extinguishing systems, except for the water fire main system, shall be arranged as a rule in fire extinction stations outside the protected spaces (refer also to **3.1.3.5**). Spaces for storage of fire extinguishing medium located below deck or having no access from the open deck shall be provided with mechanical ventilation system in compliance with **12.9.1**, Part VIII "Systems and Piping".

The storage rooms for fixed gas fire extinguishing systems of fire extinction stations shall be used for no other purpose.

Pumps, other than those servicing the fire main, required for the water supply to fire extinguishing systems, their sources of power and controls shall be fitted outside the space or spaces protected by such systems and shall be so arranged as to prevent failure of any system in case of fire in the space or spaces protected.

3.1.3.2 Fire extinction stations shall comply with the following requirements:

.1 any entrance to the fire extinction stations shall be, as a rule, from the open deck and shall be independent of the protected space. If the station is located below deck, it shall be located no more than one deck below the open deck and shall be directly accessible by a stairway or ladder from the open deck.

The means of controlling the fixed fire extinguishing system shall be readily accessible and shall be grouped in as few locations as possible at positions not likely to be cut off by a fire in the protected space;

.2 stations shall not be arranged forward of the collision bulkhead;

.3 bulkheads and decks (including doors and other means of closing any opening therein), which form the boundaries between them and adjacent enclosed spaces shall be gastight. Such storage rooms for fire extinguishing medium shall be considered as fire control stations when applying fire integrity tables;

.4 the spaces housing stations shall be protected by heat insulation and shall be fitted with heating, if it is essential for normal operation of the station that positive temperature is maintained therein. The temperature in the spaces housing carbon dioxide extinction stations shall not exceed 45°C;

.5 air temperature in the station shall be controlled by means of thermometer so fitted therein that its readings are visible both from inside the station and, through a scuttle, from outside the station; in case of remote control of temperature limit the scuttle need not be required;

.6 fire extinction stations for cargo spaces shall be provided with telephone or other means of communication with the central control station and with the machinery space, if operation of the fire extinction station is dependent on the equipment located in the machinery space;

.7 entrance doors shall be opened outwards and kept permanently locked and one set of keys for the locks shall be kept in a closed case with a glazed door located near the lock;

.8 all valves and other arrangements of the station shall be provided with nameplates identifying them with the spaces whose protection is controlled by the individual valves or arrangements. In addition, a schematic plan of the fire extinguishing system showing the starting controls and the spaces protected, as well as brief instructions for starting and operating the system shall be displayed in a conspicuous position within the station.

.9 stations located below the deck or rooms without direct access to weather deck shall be fitted with mechanical ventilation system providing air intake in the lower part of the room and a 6-fold air exchange per hour.

3.1.3.3 For lockers of a deck area of less than 4 m2, containing combustible materials and substances (refer to **1.5.3.2.2**) which do not give access to accommodation spaces carbon dioxide portable fire extinguisher providing a minimum volume of free gas to 40 % of the gross space volume, may be accepted in lieu of fixed fire extinguishing systems. The inlet port shall be arranged in a locker bulkhead to allow discharge of extinguishing medium without entry into the protected space. This portable fire extinguisher shall be stowed adjacent to the port. Alternatively, a port or hose connection may be provided to facilitate the use of fire main water.

Alternatively, a hole may be used with a fire hose attached to it to supply water from the fire line.

.1 Painting store rooms on passenger ships shall be protected as follows:

.1.1 with a carbon dioxide fire extinguishing system designed to fill 40% grossvolume of the protected space;

.1.2 with a powder extinguishing system designed to supply extinguishing powder not less than 0.5 kg/m;

.1.3 with water spaying or sprinkler system designed to supply at least 5 l/min. per 1m^2. The water spraying system shall be connected to the fire main; or.

1.4 with a system which, in the opinion of the Register, provides equivalent protection.

In any case, the system shall be activated from a station located outside the protected space.

3.1.3.4 In passenger ships controls for any required fire extinguishing system for machinery spaces and the controls specified in **2.1.4.1**, **2.1.4.2.3**, as well as in **12.2.6** or **12.2.8** and **13.1.3**, Part VIII "Systems and Piping" shall be located together or shall be grouped in as few places as possible. A safe access to these places from the open deck shall be provided.

3.1.3.5 In equivalent fixed gas fire extinguishing systems with modular configuration the fire extinguishing medium containers may be located in the protected space subject to the requirements of para 5 of Annex to IMO MSC.1/Circ.1267. The arrangement of fire extinguishing medium containers, the electrical circuits and piping essential for the release of any system shall be such that in the event of damage to any one power release line or container valve through mechanical damage, fire or explosion in a protected space, and other equipment shall be so arranged as to provide the delivery of extinguishing medium quantity and its distribution, adequate to the minimum fire extinguishing concentration. However, NOAEL (no-observed-adverse-effect level) values calculated at the highest expected engine room temperature shall not be exceeded when discharging the total amount of extinguishing gas simultaneously.

Systems that can not comply with the above, for instance systems using only one bottle located inside the protected space, can not be accepted. Such systems shall be designed with the bottle(s) located outside the protected space, in a dedicated room in compliance with **3.1.3.2**.

3.1.3.6 Fire extinguishing medium protecting the cargo holds may be stored in a room located forward the cargo holds, but aft of the collision bulkhead, provided that both the local manual release mechanism and remote control(s) for the release of the media are fitted, and the latter is of robust construction or so protected as to remain operable in case of fire in the protected spaces.

The remote controls shall be placed in the accommodation area in order to facilitate their ready accessibility by the crew.

The capability to release different quantities of fire extinguishing medium into different cargo holds so protected shall be included in the remote release arrangement.

3.1.4 Pipes and fittings.

3.1.4.1 Pipes shall be so laid as to comply with the following requirements:

.1 the necessary pipes for conveying fire extinguishing medium into the protected spaces shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led.

Suitable provisions shall be made to prevent inadvertent release of the medium into the space.

This requirement does not apply to the foam extinguishing systems intended to deliver foam from outside the cargo tanks by means of monitors and portable air-foam nozzles or foam generators producing average expansion foam;

.2 where a cargo space fitted with a gas fire extinguishing system is used as a passenger space, the gas connection shall be blanked during such use;

.3 laying the pipes of fire extinguishing systems through spaces containing fuel oil and lubricating oil shall not be permitted.

Pipes of fire extinguishing systems, shall not be laid through refrigerated spaces;

.4 gas fire extinguishing systems may pass through accommodation spaces, provided they have sufficient wall thickness, and their gas tightness after installation on board a ship is tested by test pressure of not less, than 5 N/mm^2. Besides, pipelines running through the accommodation spaces shall be connected by welding only and shall not have condensate drainage openings or other openings within such spaces;

.5 all fire extinguishing systems shall be so designed as to permit periodical checks in operation.

Systems fitted with pipes and nozzles for supply of fire extinguishing medium shall have arrangements for checking them in operation using compressed air.

A non-return shut-off valve shall be fitted on the pipeline supplying compressed air to the manifold of the fire smothering station;

.6 gaskets and flexible joints used in fire extinguishing systems shall be made of non-combustible materials resistant to the effect of the extinguishing medium, and marine environment;

.7 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.

3.1.4.2 Pipes shall be made of steel.

Copper, copper-and-nickel or bimetallic pipes (one of the layers being steel or copper) may be used as equivalent to steel pipes.

Carbon steel pipes shall have anti-corrosive coating both inside and outside.

The fittings of fire extinguishing systems, including sprinklers and sprayers, shall be made of materials resistant to the fire extinguishing medium and to marine environment. Nozzles of fixed pressure water-spraying and equivalent water-based fire extinguishing systems (fixed water-mist fire extinguishing systems) for machinery spaces and cargo pump rooms shall be of an approved type and shall be tested in compliance with the requirements of IMO circular MSC/Circ.1165, as amended by IMO circular MSC.1/Circ.1269.

All distribution piping, valves, release piping and nozzles in protected spaces shall be made of materials with a melting point exceeding 925° C. Piping and associated equipment shall be fastened securely.

3.1.5 Starting of systems.

3.1.5.1 A system shall be put into operation without any supplementary change-over at the station and shall operate quickly and efficiently under all service conditions, including those when the temperature is below zero and during a fire.

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.

3.1.5.2 The possibility of spontaneous starting of a fire extinguishing system shall be excluded under any service conditions, including the effect of such factors as pitching and rolling, shaking and vibration.

3.1.5.3 Starting controls shall be so arranged, and if necessary so protected, that a free access to them is provided and their mechanical damage is precluded.

3.1.5.4 Arrangements shall be provided for the attachment of seals to the starting controls of the system.

3.1.5.5 Irrespective of remote control provision the system shall be capable of being manually started directly at the fire extinction station, and the pump - at the place of its location.

3.1.5.6 Remote control system (by air, nitrogen, carbon dioxide, etc.) shall be provided with two cylinders, gas quantity in each of them being sufficient for a single start.

3.1.5.7 Where provision is made for mechanical devices in the remote starting system, their valves shall be controlled with the help of hand wheel or levers to be positively connected to the valve stems or spindles.

3.1.5.8 Automatic discharge of fire extinguishing medium is not permitted except for cases stipulated by **3.3**, **3.6.3** and **3.11.2.7**.

3.1.6 Protection of vehicle, special category and ro–ro spaces[8].

3.1.6.1 Vehicle spaces and ro-ro spaces, which are not special category spaces and are capable of being sealed from a location outside of the cargo spaces, shall be fitted with one of the following fixed fire-extinguishing systems:

.1 a fixed gas fire-extinguishing system complying with the provisions of the Fire Safety Systems Code (refer to **3.8.1**);

.2 a fixed high-expansion foam fire-extinguishing system complying with the provisions of the Fire Safety Systems Code (refer to **3.7.3.3**); or

.3 a fixed water-based fire fighting system for ro-ro spaces and special category spaces complying with the provisions of the Fire Safety Systems Code and **3.1.6.2.1 − 3.1.6.2.4**.

3.1.6.2 Vehicle spaces and ro-ro spaces not capable of being sealed and special category spaces shall be fitted with a fixed water-based fire-fighting system for ro-ro spaces and special category spaces complying with the provisions of the Fire Safety Systems Code which shall protect all parts of any deck and vehicle platform in such spaces. Such a water-based fire-fighting system shall have:

.1 a pressure gauge on the valve manifold;

.2 clear marking on each manifold valve indicating the spaces served;

.3 instructions for maintenance and operation located in the valve room; and

.4 a sufficient number of drainage valves to ensure complete drainage of the system (refer to **7.6.12.3**, Part VIII «Syetems and piping»).

3.2 WATER FIRE MAIN SYSTEM

3.2.1 Number and capacity of fire pumps.

3.2.1.1 In ships provision shall be made for pumps, fire mains, hydrants and hoses complying as applicable with the requirements of this Chapter.

The number of fixed independently driven fire pumps and the minimum pressure at all hydrants at water delivery through any adjacent hydrants by two pumps simultaneously of the quantity of water specified in **3.2.5.1** shall be not less than those specified in Table 3.2.1.1, the length of hoses complying with the requirements of **5.1.4**, and the nozzle outlet diameters complying with **5.1.5**.

Table 3.2.1.1

Gross tonnage	Passenger ships		Other ships	
	Number of pumps	Minimum pressure at hydrants, in MPa	Number of pumps	Minimum pressure at hydrants, in MPa
Under 500	2	0,30	1	0,20
500 to 1000	2	0,30	2	0,25
1000 to 4000	2	0,30	2	0,25
4000 to 6000	3	0,40	2	0,25
6000 and upwards	3	0,40	2	0,27
N o t e s: 1. The number of pumps indicated above does not include the emergency fire pump, if fitted. 2. The maximum pressure at any hydrant shall not exceed pressure, at which the effective control of a fire hose can be demonstrated.				

For ships of restricted areas of navigation, which are not engaged in international voyages (except for passenger ships) and have a gross tonnage under 2000, the requirement of Table 3.2.1.1 concerning the number of pumps may be waived subject to a special agreement with the Register.

On floating cranes with a gross tonnage under 2000, one fire pump may be installed

The pressure developed by the fire pumps shall be sufficient to ensure the operation of other fire extinguishing systems using water (e.g., for pressure water spraying, froth extinguishing, etc.) and supplied from the same fire pumps.

8 Refer to IMO MSC.338(91) « Protection of vehicle, special category and ro–ro spaces».

In passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** with a length of 24 meters and over, the number of fixed fire pumps, the minimum pressure at the location of any hydrant, in the case of water supply through hydrants in the required amount, shall not be less than specified in **3.2.1.12**.

3.2.1.2 In passenger ships of 1000 gross tonnage and upwards, the of sea connections, fire pumps and their sources of power shall be so arranged that, in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

Passenger ships of less than 1000 gross tonnage, passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** with a length of 24 meters and over, intended to carry 250 passenger and over and cargo ships of 2000 gross tonnage and upwards shall be provided with an emergency fire pump of a capacity not less than 25 m^3/h and cargo ships of less than 2000 gross tonnage shall be provided with an emergency fire pump of a capacity not less than 15 m^3/h independently driven, if a fire in any one compartment could put all the pumps or their sources of power out of action. Source of power and sea connection shall be located outside the space where the main fire pumps or their sources of power are located (refer also to **3.2.4.2** and **3.2.5.7**).

3.2.1.3 Emergency fire pump, if fitted, shall meet the requirements of **3.2.4**.

3.2.1.4 In addition to the provisions of **3.2.1.2** in passenger ships of less than 1000 gross tonnage and in cargo ships the emergency fire pump shall be also fitted in the following cases:

.1 the two main fire pumps, their sea connections and sources of power are located within compartments separated at least by "A-0" class divisions, so that a fire in any one compartment will not put both fire pumps out of action;

.2 one main fire pumps is located in a compartment having more than one bulkhead or deck adjacent to the compartment containing the other main fire pump.

3.2.1.5 The total capacity of fixed fire pumps, except for an emergency pump, if any, with the pressure at any hydrant not less than that specified in Table 3.2.1.1, shall ensure discharge of water for fire fighting in a quantity, in m^3/h, not less than

$$Q=km^2 \qquad (3.2.1.5)$$

where $m=1{,}68\sqrt{L(B+D)}+25$;
L = length of the ship (refer to **1.1.3**, Part II "Hull"), in m, excluding the length of the spoil hopper, if no tanks and other storages for combustible materials are installed therein, in hopper dredgers and hopper barges;
B -moulded breadth, in m;
D - depth to the bulkhead deck amidships, in m;
k - coefficient equal to:
0,016 for passenger ships having subdivision index R equal to, or more than, 0,5;
0,012 for passenger ships having subdivision index R less than 0,5;
0,008 for all other ships;
R- subdivision index determined in accordance with **2.3**, Part V "Subdivision".

In all cases for passenger ships and cargo ships of more than 500 gross tonnage the required fire pumps shall provide the following water supply for fire-fighting purposes at the pressure specified in Table 3.2.1.1:

.1 in passenger ships - not less than two thirds of the quantity sucked from the holds by bilge pumps;

.2 in cargo ships - not less than four thirds of the quantity sucked from the holds of the same size passenger ship by each independent bilge pump according to the requirements of **7.1**, Part VIII "Systems and Piping".

3.2.1.6 For catamarans and similar ships, the total capacity of fire pumps shall be determined as twice the capacity value for one hull.

3.2.1.7 In all ships other than passenger ships the total capacity of fire pumps need not exceed 180 m^3/h, unless a larger capacity is required in order to ensure the simultaneous operation of other systems using water.

3.2.1.8 The capacity, pressure head and number of fire pumps for floating docks shall be chosen in accordance with the quantity of water required by the largest cargo ship which the dock can carry, for the operation of the water fire main system.

On non-self-contained floating docks receiving water for the water fire main system from the shore the emergency fire pump need not be installed.

3.2.1.9 Each fixed fire pump except of emergency shall be capable of supplying at least two jets of water required by **3.2.6.2**.

3.2.1.10 The capacity of each fixed pump, other than an emergency pump, shall not be less than 80% of the total required capacity divided by the required number of fire pumps, but in any case not less than 25 m^3/h.

If the number of fire pumps exceeds the required number, the feed of the additional pumps shall be at least 25 m^3/h and it shall be sufficient to support at least two nozzles in accordance with **3.2.6.2**.

3.2.1.11 If other fire extinguishing systems using water supplied by fixed fire pumps are provided in ships, the capacity of these pumps shall be sufficient for the operation of the water fire main system having the capacity not less than 50 % determined by Formula (3.2.1.5) and for parallel operation of one of the other systems requiring the largest quantity of water. In the case concerned the quantity of water for the water fire main system shall be sufficient for delivering at least two jets of water through the largest nozzles used in the ships, but more than six jets and more than 90 m^3/h for cargo ships are not required. Possible increase of water discharge through each hydrant due to the pressure rise in the pipes required for the operation of the other fire extinguishing systems shall be taken into consideration.

The quantity of water for fire extinguishing systems, other than for the water fire main system, shall be determined in accordance with the requirements in **3.3.2.2**, **3.4.2**, **3.5.2** (within one main vertical zone), **3.6.5** and **3.7**.

3.2.1.12 In passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** with a length of 24 meters and over, the number of fixed fire pumps shall be as follows:

.1 in ships intended to carry more than 500 passengers, at least three one of which may be powered by the main engine;

.2 in ships intended to carry 500 passengers or less, at least two of which may be powered by the main engine.

Necessary fire pumps shall provide water supply in the amount of not less than two thirds of the amount provided by drainage pumps when pumping water from the holds and, in the case of water supply in the required amount, the minimum pressure at the location of any hydrant:

in ships intended for the carriage of more than 500 passengers - 0.41 MPa;

in ships intended for the carriage of 500 passengers and less - 0.31 MPa.

3.2.1.3 Fixed water fire system may not be installed on ships, other than passenger ships, with a crew of less than 3 persons.

In ships with a crew of less than 3 persons and in ships without a crew, not equipped with propulsion systems and an autonomous source (s) of energy, the water fire system shall be arranged according to the applicable requirements of 6.5 or 8.11 as the case may be.

3.2.2 Location of fire pumps.

3.2.2.1 In passenger ships of 1000 gross tonnage and upwards, passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** with a length of 24 meters and over, intended to carry 250 passenger and upwards the sea connections, fire pumps and their sources of power shall be so located as to ensure that a fire in any one compartment will not put all pumps out of action.

3.2.2.2 In catamarans and similar ships, for which not less than two pumps are required in compliance with Table 3.2.1.1, it is recommended that one pump be fitted in each hull.

In this case, water supply by each pump to the water fire main of any hull of the ship shall be ensured.

3.2.3 Basic requirements for fire pumps.

3.2.3.1 In all self-propelled ships, fixed fire pumps shall have an independent power source.

In cargo ships between 500 and 1000 gross tonnage, one of the pumps shall have an independent drive.

In passenger ships of less than 150 gross tonnage with the main propulsion machinery of power output less than 220 kW, the pumps driven by the main engine may be used provided that the propulsion unit (engine-shaft-propeller) is so designed as to permit of fire pump operation when the ship is not under way.

3.2.3.2 Fixed fire pumps including an emergency pump may be used for other shipboard services, if the ship is provided with at least two independently driven pumps, one of which is at all times kept readily available for its direct purpose.

Where in conformity with Table 3.2.1.1 only one fire pump is fitted, it may be used for other purposes requiring short-time consumption of water (flushing out of decks, hawse pipes etc.).

A fire pump may be used for emergency drainage of machinery spaces.

3.2.3.3 In cargo ships where other pumps, such as general service, bilge, ballast, and etc., are fitted in a machinery space, provision shall be made to ensure that at least one of these pumps, having the capacity and pressure required by **3.2.1.11** and Table 3.2.1.1, is capable to supply water to the fire main. However, if the ship is equipped with the required number of fire pumps of necessary capacity and pressure, then it is sufficient to have a connection of the general service pump with water fire main system. Such pumps shall meet the requirements of **3.2.3.2** and **3.2.3.4**.

3.2.3.4 Pumps and piping intended for fire-fighting purposes shall not be used for the pumping of oil and other flammable liquids, nor as ballast pumps for tanks used for alternate carriage of fuel oil and water ballast.

3.2.3.5 Fire pumps shall be fitted with a pressure gauge on the discharge side.

Pumps capable of developing in the fire main hydrants and hoses a pressure exceeding the permissible value shall be provided with relief valves set to operate at a pressure not more than 10 % in excess of the fire main working pressure, and having the pipes to discharge water into the suction main. Location and adjustment of these valves shall prevent excessive pressure in any part of the fire main.

3.2.3.6 Fixed fire pumps and their sea valves shall be located below the light-draught waterline of the ship. Where the pumps are located above the lowest possible waterline, efficient arrangements shall be made for self-priming.

A fixed emergency pump shall be installed in compliance with **3.2.4**.

Fire pumps installed outside machinery spaces of category A shall have an independent sea valve in each compartment in which they are located.

In the case of ice class ships, at least one of the pumps shall be connected with the heated ice box (refer to **4.3.1** and **4.3.3**, Part VIII "Systems and Piping").

3.2.3.7 All pumps, including the emergency pump, shall be placed in spaces with positive temperature.

3.2.3.8 In passenger ships of 1000 gross tonnage and upwards as well as in ships with signs **B-R3-S**, **B-R3-RS** with a length of 24 meters and over, intended to carry 250 passenger and upwards and in all passenger ships with periodically unattended machinery spaces containing fire pumps, the water fire main system shall constantly be under pressure providing immediate the supply of at least one effective water jet from any of fire hydrants and automatic start of one of the required fire pumps at a drop of pressure.

In passenger ships of less than 1000 gross tonnage, the water fire main system shall enable the automatic and remote start-up of at least one fire pump from the navigation bridge. If the pump starts automatically or if the bottom valve can not be opened from location where the pump is remotely started, the bottom valve shall always be kept open.

3.2.3.9 In cargo ships with a periodically unattended machinery space containing fire pumps or when only one person is required on watch provision shall be made for remote starting of one of the main fire pumps from the navigation bridge and from fire station if available and for immediate water supply in the fire main without additional opening of the valves in the pump room. At the location of such arrangement a water pressure indicator shall be installed.

Where water fire main system is under pressure as required in **3.2.3.8**, remote starting need not be provided.

In ships of less than 1600 gross tonnage, fulfilment of this requirement may not be provided, if starting arrangement of the fire pump in machinery space is easily accessible.

3.2.4 Fixed emergency fire pump.

3.2.4.1 The emergency pump shall be driven by a diesel engine or an electric motor supplied with power from the emergency source of power.

3.2.4.2 The pump, its sources of power and sea connections shall be so located as not to be put out of action in the event of a fire within the spaces where the main fire pumps are located.

The emergency fire pump, its seawater inlet, and suction and delivery pipes and isolating valves shall be located outside the machinery space. If this arrangement cannot be made, the sea chest may be fitted in the machinery space if the sea inlet valve is remotely controlled from a position in the same compartment as the emergency fire pump and the suction pipe is as short as practicable. Short lengths of suction or discharge piping may penetrate the machinery space or compartments where main fire pumps are installed, provided they are enclosed in a substantial steel casing or are insulated to "A-60" class standards in accordance with IMO circular MSC.1/Circ.1456. The pipes shall have substantial wall thickness, but in no case less than 11 mm, and shall be welded except for the flanged connection to the sea inlet valve.

Location of the pump and its drive shall allow free access to them for maintenance and repair.

3.2.4.3 Where the pump is located above the lowest possible waterline, efficient arrangements shall be made for self-priming.

Under all conditions of heel, trim, pitch and roll, likely to be encountered in the ship service, the total suction head and the net positive suction head shall provide the fulfilment of the requirement of **3.2.4.6**.

The design conditions for fulfilment of these requirements are defined in IMO circular MSC.1/Circ.1388.

3.2.4.4 The space containing the emergency fire pump shall not be contiguous to the boundaries of machinery spaces of category A or those spaces containing main fire pumps. Where this is not practicable, the common bulkhead between the two spaces shall comply with the requirements of Table 2.3.3-1 for control stations.

When a single access to the emergency fire pump room is through another space adjoining a machinery space of category A or the spaces containing the main fire pumps, "A-60" class boundary is required between that other space and the machinery space of category A or the spaces containing the main fire pumps.

No direct access shall be permitted between the machinery space and the space containing the emergency fire pump and its source of power. When this is impracticable, an arrangement may be accepted where the access is by means of an air-lock where the door to the machinery space shall be made to "A-60" class and the second door shall be made at least of steel, each of the doors being self-closing and gastight, or through a watertight door capable of being operated from a space remote from the machinery space and the space containing the emergency fire pump and unlikely to be cut off in the event of fire in those spaces. In such cases a second means of access to the space containing the emergency fire pump and its source of power shall be provided.

No hold-back hooks are permitted for the above doors.

3.2.4.5 Any diesel driven source of power supplying the emergency fire pump shall be easily started manually in cold condition at a temperature up to 0°C. If this source of power is installed in unheated space, it shall be fitted with electrical means of cooling water or lubricating oil heating, which ensure its quick start. If manual start of this source of power is practically impossible, then on agreement with the Register starting arrangements or other compressed air, hydraulically or electrically driven starting mechanisms shall be used. These mechanisms shall be such as to provide starting of the source of power at least six times during half an hour and, at least twice during the first 10 min.

3.2.4.6 The emergency fire pump capacity shall be not less than 40 % of the total required capacity of fire pumps determined, considering **3.2.1.2** and **3.2.1.7**.

3.2.4.7 The emergency fire pump capacity shall comply with **3.2.4.6**.

Where a fixed pressure water-spraying system installed for the protection of the machinery space in accordance with **3.4** is supplied by the emergency fire pump, then the emergency fire pump capacity shall be adequate to supply the system at the required pressure plus two jets of water.

The capacity of the two jets shall be calculated for the largest nozzles used in the ship at not less than 25 m^3/h. When determining the largest nozzles, the nozzles in the space where the main fire pumps are located may not be considered. The capacity of the fire pump with the nozzle diameter of 16 mm shall be 16 m^3/h, the capacity of the pump with the nozzle diameter of 19 mm - 23,5 16 m^3/h accordingly, the pressure at hydrants being 0,27 MPa.

3.2.4.8 Where the sea inlet valve is in the machinery space, measures shall be taken so that the valve can be opened in the event of fire.

3.2.5 Piping.

3.2.5.1 The diameters of the fire main and water service pipes shall be sufficient for the effective distribution of the maximum required discharge from two fire pumps operating simultaneously. In cargo ships, except those specified in **6.9.2**, the diameter need only be sufficient for the discharge of 140 m^3/h.

In ships of 500 gross tonnage and upwards and floating cranes (refer to **3.2.5.6**) the pipes of the fire main shall be rated at a working pressure of at least 1 MPa.

3.2.5.2 To prevent freezing, the pipelines of the water fire main system extended to open decks or non-heated spaces shall be provided with shut-off fittings mounted in heated spaces, and with water drainage arrangements.

3.2.5.3 Each fire pump shall be fitted with shut-off valves on the suction and discharge pipes.

The use of slide valves on the suction pipe is permitted.

In ships of 500 gross tonnage and upwards the valves on the discharge side of the pumps shall be of a non-return shut-off type.

3.2.5.4 In oil tankers, the fire main shall comply with the following supplementary requirements:

.1 in the fire main at the poop front in a protected position as specified in IMO circular MSC.1/Circ.1456 and in easily accessible places on the cargo oil tank deck, the isolation valves shall be fitted at intervals of not more than 40 m. Each of such valves shall be provided with an information plate to indicate that the valve shall be kept permanently open under normal service conditions;

.2 before each isolation valve on the fire main there shall be fitted twin fire hydrants of 70 mm diameter so located that they are equally spaced, over the length of the ship and the fulfilment of the requirements of **3.2.6.2** is ensured;

.3 before the cut-off valve fitted in the poop there shall be a branch pipe on either side, led out from the fire main to the forward part of the poop deck; the diameter of each branch pipe shall be sufficient for supplying water through two fire hoses connected to two hydrants fitted at the end of each branch; in ships of 1000 gross tonnage and upwards the diameter of each hydrant provided shall be about 70 mm, and in ships of less gross tonnage this diameter shall be about 50 mm.

Where fire pumps are fitted forward of the cargo tanks, two more similar pipes branching from the fire main of the same diameter as above shall be provided on the after part of the forecastle deck, an isolation valve being fitted on the fire main within the erection, after the branches.

3.2.5.5 In catamarans and similar ships, each hull shall be provided with a water fire main system including water hydrants, hoses and nozzles.

3.2.5.6 In all ships of 500 gross tonnage and upwards, and in floating cranes facilities shall be available on the open deck enabling an international shore connection to be used on either side of the ship (refer to **5.1.18**).

3.2.5.7 Isolating valve to separate the piping within the machinery space of category A containing the fire pump (or pumps) from the main outside it shall be fitted in piping in easily accessible position (outside the machinery space).

The fire main shall be so arranged that when the isolating valves are shut all the hydrants on the ship, except those fitted in the piping separated from water supply, can be supplied with water by another fire pump located outside the machinery space.

3.2.6 Fire hydrants.

3.2.6.1 Each fire hydrant shall have a shut-off valve and a standard quick-acting coupling.

Hydrants fitted on open decks shall also have quick-acting plugs, or equivalent device.

3.2.6.2 The number and arrangement of fire hydrants shall ensure at least the delivery of two water jets from different hydrants, one of the jets being delivered through a hose of standard length as stipulated under **5.1.4.1**, to any area of the ship which is generally accessible to passengers and crew during the voyage and to any part of any cargo space that is empty, ro-ro cargo space and for special-category spaces - to any part of the space through standard length hoses. In the latter case, two jets shall be delivered to any part of the space through standard length hoses. Besides, such hydrants shall be located near entrance to the protected spaces. In passenger ships the number and location of fire hydrants in the accommodation, service and machinery spaces shall be such that this requirement may be complied with when all watertight doors and all doors in main vertical zones are closed.

On open decks for containers two jets of water shall be delivered onto each accessible vertical side of the container by standard length hoses.

3.2.6.3 It is not recommended that fire hydrants are located closer than 20 m from each other in the internal spaces and more than 30 m on open decks.

3.2.6.4 Fire hydrants shall not be placed at the ends of dead-end corridors, in special electrical spaces or closed or rarely attended spaces.

3.2.6.5 In ships, carrying deck cargoes fire hydrants shall be located to ensure easy access, while the pipes shall be located to avoid being damaged by cargo.

3.2.6.6 In machinery space of category A at least two hydrants shall be provided.

3.2.6.7 In all ships there shall be fitted a fire hydrant located in the forward part of the propeller shaft tunnels.

3.2.6.8 All fire hydrants shall be painted red.

3.2.6.9 In passenger ships two fire hydrants shall be provided in the shaft tunnel, being one of the means of escape, in the proximity to the machinery space of category A.

Where some other space is used as a means of escape, two fire hydrants shall be provided therein at the entrance to the machinery space of category A. Provision of **3.2.6.7** need not be met in this case.

3.2.7 Water fire main systems of ships marked C-R3-S, C-R3-RS and D-R3-S, DR3-RS in their class notation, with the length less than 24 m.

3.2.7.1 The requirements of this Subsection apply to water fire systems of ships marked C-R3-S, C-R3-RS and D-R3-S, DR3-RS in their class notation, with the length less than 24 m.

3.2.7.2 Every ship shall be fitted with a fixed fire pump capable of supplying at least one jet of fire-fighting water from a fire hose with monitor nozzles of 12, 16 or 19 mm, that is connected to a hydrant, in the amount of at least twothirds of the amount supplied by bilge pumps when pumping water from holds and, where a sufficient amount of water is supplied through the hydrants, the minimum pressure at the level of each hydrant:

in ships carrying more than 500 passengers − 0.41 MPa;

in ships carrying 500 passengers and less − 0.31 MPa.

3.2.7.3 In all ships carrying more than 250 passengers an additional fixed fire pump driven from an energy source shall be fitted. Such pump with an energy source and a sea chest shall not be positioned in the same machinery space in which the main fire pump is located. It shall supply at least one jet of water from any fire hydrant under pressure of not less than 0.31 MPa in the amount not less than 25 m^3/h.

3.2.7.4 Sanitary, ballast, bilge or general purpose pumps may be used as fire pumps.

3.2.7.5 All ships shall have fire mains with the diameter such as to allow efficient distribution of the maximum amount of water supplied by the concerned fire pump. The number and arrangement of fire hydrants shall be such as to ensure that at least one jet of water reaches any part of the ship from a single length of hose.

3.2.7.6 All ships shall be fitted with at least one fire hose for each hydrant.

3.2.7.7 In ships including normally unattended machinery spaces or spaces continuously manned with a single crew member, provision shall be made for immediate water supply from the fire main under proper pressure by remote actuation of the main fire pump from the navigation bridge and the fire station, where any, or by way of maintaining steady pressure in the fire main.

3.2.7.8 Every fire pump shall be provided with a non-return shut-off valve on its discharge side.

3.3 SPRINKLER SYSTEM

3.3.1 General.

3.3.1.1 Automatic sprinkler systems shall be a wet pipe type, as specified by IMO circular MSC/Circ.1165. Upon agreement with the Register for small exposited sections, as well as at control stations, where water may cause damage to essential equipment, may be fitted with a dry pipe system or a pre-action system as permitted by IMO circular MSC/Circ.1165.

Any system sections exposed to low temperatures during operation shall have proper protection against freezing.

Particular attention should be paid to the water quality specification provided by the system manufacturer to prevent internal corrosion and contamination of sprinklers due to corrosion products or scale-forming minerals.

3.3.1.2 A sprinkler system shall be automatically set in operation at temperatures in the protected space rising to the values indicated in **3.3.4.2**.

3.3.1.3 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 the present Chapter.

3.3.1.4 The air cylinder, compressor, pump and the pipes of the sprinkler system, except for the piping connecting the sprinkler system to the water fire main system, shall be independent of all other systems.

3.3.1.5 A sprinkler pump and a pressure tank shall be arranged outside the protected space, at an adequate distance from the machinery spaces of category A. A gauge indicating the pressure in the system shall be provided at each section stop valve and at a central control station.

3.3.1.6 Means shall be provided for testing the automatic operation of the sprinkler pump on reduction of pressure in the system.

3.3.1.7 When sprinkler systems equivalent to the systems specified in the present Chapter are used, they shall be approved by the Register according to the Guidelines adopted by the IMO resolution A.800(19) considering amendments introduced by IMO resolutions MSC.265(84)/Corr.1 and MSC.284(86). When approving such systems special consideration shall be given to the fulfillment of the requirements of **3.3.1.1** to **3.3.1.3**, **3.3.1.6**, **3.3.2.1**, **3.3.4.1**, **3.3.5.1** and **3.3.5.2**.

3.3.2 Sprinkler pumps.

3.3.2.1 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 actionautomatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

3.3.2.2 The pump and piping system shall be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous flow rate of water sufficient for the simultaneous coverage of the minimum floor area of 280 m^2 at the application rate specified in 3.3.4.1.

For application to a ship with a total protected area of less than 280 m^2, in particular ships with the sign **C-R3-S**,**C-R3-RS** and **D-R3-S**, **D-R3-RS** with a length of less than 40 m, the Register may specify the appropriate area for sizing of pumps and supply components.

3.3.2.3 The pump shall be fitted on the delivery side with 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 **3.3.3.2**.

3.3.2.4 The sea inlet to the pump shall wherever possible be in the space containing the pump and 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.

3.3.2.5 Provision shall be made for connection of the main supply piping with the ship's fire main.

A lockable non-return shut-off valve shall be fitted at the connection concerned.

3.3.2.6 There shall be not less than two sources of power for the pumps. Where the sources of power are electrical, the pump shall be supplied according to **4.3.1.5**, **19.1.1.1**, **19.1.1.2** and **19.1.2.1.7**, Part XI "Electrical Equipment".

One of the sources of power for the pump may be an internal combustion engine which shall be so situated (besides compliance with the instructions of **3.3.1.5**) that a fire in any protected space will not affect the air supply to the machinery.

3.3.3 Pressure tank.

3.3.3.1 The pressure tank shall be fitted with:

.1 an automatic pressure maintaining device;

.2 glass gauge;

.3 a relief valve;

.4 a pressure gauge.

3.3.3.2 The pressure tank shall contain a standing charge of fresh water equivalent to the volume of water which would be discharged in one minute by the sprinkler pump.

The volume of the pressure tank shall be equal to at least twice that of the charge of water specified above.

Arrangements shall be made for maintaining such air pressure in the tank as to ensure that where the perennial supply of fresh water in the tank has been used the pressure in that tank is not less than a working pressure at the sprinkler plus a hydrostatic pressure from the tank bottom to the highest sprinkler.

Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank shall be provided. Means shall be also provided to prevent the passage of sea water into the tank.

3.3.3.3 Pneumatic pressure tanks shall comply with the requirements for pressure vessels set out in Part X "Boilers, Heat Exchangers and Pressure Vessels".

3.3.4 Sprinklers.

3.3.4.1 Sprinklers shall be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 1/min per 1 m2 over the horizontal area of the protected space.

The Register may permit the use of other application rate depending on structural features of the protected space.

While protecting windows by sprinklers, the requirements of **2.2.4.4** shall be met.

3.3.4.2 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 to 79°C, except that in locations such as drying rooms where high ambient temperatures might be expected, the operation temperature may be increased by not more than 30 8C above the maximum deckhead temperature. In saunas, provision shall be made for empty sprinkler systems with the upper operating limit of 140 8C. Refrigerated chambers may be fitted with dry pipe sprinkler systems.

3.3.5 Control valves.

3.3.5.1 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 a fire has occurred and shall be centralised on the navigation bridge or in the continuously manned control station and, in addition, visible and audible alarms from the unit shall also be placed in a position other than on the aforementioned spaces to ensure that the indication of fire is immediately received by the crew.

3.3.5.2 Switches shall be provided at one of the indicating positions referred to in **3.3.5.1** which will enable the alarm and the indicators for each section of sprinklers to be tested. 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.

3.3.5.3 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.

3.3.6 Pipes.

3.3.6.1 Sprinklers shall be grouped into separate sections, each of them shall contain not more than 200 sprinklers. In passenger ships, 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 Register may permit such section of sprinklers to serve more than two deck or be situated in more than one main vertical zone, provided it shall not reduce, on the Register opinion, the fire protection of the ship.

3.3.6.2 Provision shall be made in each section for purging the pipes with compressed air and flushing them with fresh water.

3.3.6.3 Each section of sprinklers shall be capable of being isolated by one stop valve only after which a gauge shall be provided.

The stop valve in each section shall be readily accessible in a location outside of the associated section or in cabinets within stairway enclosures. The valve's location shall be clearly and permanently indicated.

Measures shall be taken to preclude unauthorized persons from operating the shut-off valves.

3.3.6.4 The suction pipes of the pumps feeding a sprinkler system shall be fitted with filters.

3.3.6.5 The diameters of the pipes of a sprinkler system shall be such as to ensure the operation of sprinklers at the water pressure and the rate of discharge specified in **3.3.2.2** and **3.3.4.1**.

3.3.6.6 The pipelines of the sprinkler system shall be fitted with non-return shut-off valves preventing sea water from penetrating into the pressure tank and the leakage of water from the tanks and the system.

3.4 PRESSURE WATER-SPRAYING SYSTEM

3.4.1 In machinery spaces of category A as well as in cargo pump rooms specified in **1.5.7.1** pressure water-spraying system shall be supplied from an independent pump which shall be automatically put into action by a pressure drop in the system and from the fire main. A non-return shut-off valve shall be fitted on the connection line with the fire main.

The pressure water-spraying system for ro-ro cargo spaces, vehicle spaces (refer to **1.5.4.3** and **1.5.4.4**) and special category spaces (refer to **1.5.9**) shall comply with the provisions of IMO circular MSC.1/Circ.1430 "Revised Guidelines for the Design and Approval of Fixed Water-Based Fire-Fighting Systems for Ro-Ro Spaces and Special Category Spaces". Such system shall protect all portions of any deck and sites for vehicles in the specified spaces, shall have manual control and pressure gauge at every distribution box with clear marking indicating protected spaces, as well as suitable maintenance and service instructions located at the valves section. Considering a substantial loss of stability, which may occur due to large concentration of water on decks of specified spaces during system operation, measures shall be provided as stipulated in **7.6.12**, Part VIII "Systems and Piping".

In spaces where flammable liquids are stored the system may be supplied only from the fire main.

Where high-pressure water-spraying system is used, the necessity for the reserve supply for such system shall be determined in each case on agreement with the Register, the rate of water supply shall be provided not less than specified in **3.4.2.1**.

3.4.2 The number and arrangement of the nozzles shall be such as to ensure an effective average distribution of water in the spaces to be protected of not less than:

.1 5 1/min per 1 m^2 of the horizontal area over which fuel oil is likely to spread or cargo space area;

.2 1,5 1/min per 1 m^2 of the largest horizontal cross-sectional area of the fish meal hold.

In cargo, working and special spaces, where the system may be divided into sections, the pump shall be capable of supplying two sections of the total length of at least 40 m.

3.4.3 In machinery spaces of category A of ships specified and in cargo pump rooms in **1.5.7.1** the pressure water-spraying system shall be kept charged under the required pressure up to the valves on the distribution pipes. The pump supplying the water for the system shall be put automatically into action by a pressure drop in the system.

3.4.4 Filters preventing the system and spray nozzles from becoming clogged shall be fitted on the suction pipe of the pump supplying the system and on the connection pipe with the fire main.

3.4.5 Distribution valves shall be placed in easily accessible positions outside the protected spaces so as not to be readily cut off by a fire in the protected space.

Provision shall be made in the protected spaces, where people are permanently present, for remote control of distribution valves from these spaces.

3.4.6 Spray nozzles shall be placed in the protected spaces as follows:

.1 underneath the ceiling of the space;

.2 above equipment and machinery using fuel oil or other flammable liquids and other fire hazardous objects;

.3 above bilges, double bottom floor coverings and other surfaces over which fuel oil or flammable liquids are likely to spread;

.4 above stacks of fish meal bags.

The spray nozzles shall be so disposed in the protected space that the area covered by one nozzle will overlap that covered by adjacent nozzles.

3.4.7 Pump of the system providing protection of category A machinery spaces and cargo pump rooms shall ensure a supply of water at the required pressure to all sections of the system in any compartment to be protected. The pump and its controls shall be installed outside the spaces to be protected.

The pump may be driven by independent internal combustion machinery which shall be so situated that a fire in the protected space will not affect the air supply to the machinery. If the pump is electrically driven from the emergency generator, the generator shall comply with the requirements of Section 9, Part XI "Electrical Equipment".

3.4.8 Average rate of water supply specified in **3.4.2**, shall be increased for the following spaces:

.1 20 l/min per 1 m^2 for boilers frontal parts and surfaces, fuel oil units, centrifugal separator (other than bilge water separators), and fuel filters;

.2 10 l/min per 1 m^2 for pipelines of heated fuel located near the exhaust pipes or similar heated surfaces of main and auxiliary diesel engines;

.3 in accordance with Tables 4-1, 4-2 and 4-3 of IMO circular MSC.1/Circ.1430 for ro-ro and special category spaces.

3.4.9 Fixed pressure water-spraying system of an approved type complying with the provisions of IMO circular MSC.1/Circ.1268 "Guidelines for the Approval of Fixed Pressure Water-Spraying and Water-Based Fire-Extinguishing Systems for Cabin Balconies" shall be installed to protect cabin balconies of passenger ships where furniture and furnishings on such balconies are not as defined in **2.1.1.9**.

3.5 WATER-SCREEN SYSTEM

3.5.1 The present Rules provide for the use of the water-screen system in the following cases:

.1 in special purpose ships where, subject to special agreement with the Register, water screens are permitted in lieu of "A" class divisions, in accordance with **2.2.1.2**;

.2 for protection of vertical surfaces of ships hull in compliance with **6.6.6**.

3.5.2 The design capacity of the pumps supplying the water-screen system shall be sufficient to provide at least 70 1/min per linear metre of the screen length.

3.6 DRENCHING SYSTEM

3.6.1 The present Rules provide for the use of water drenching system for drenching the racks of magazines (refer to **6.2.2.18** and Table 3.1.2.1), outside surfaces of oil recovery ships (refer to **6.6.4**).

3.6.2 The drenching system shall be fed from the fire main. The pumps and associated sources of power shall be placed outside the space protected.

3.6.3 The system shall be started from outside the space.

It is recommended that the system shall be put into action at a temperature rise in the space above admissible.

3.6.4 The drenching system of magazines and the pressure water-spraying system of the cargo spaces fitted for the carriage of explosives may be used for their flooding in emergency.

3.6.5 The capacity of the pumps supplying the system shall be sufficient to ensure the following rates of water discharge for drenching magazine racks, 24 1/min per 1 m^2 of the total magazine floor area.

3.7 FOAM FIRE EXTINGUISHING SYSTEM

3.7.1 General.

3.7.1.1 The foam fire extinguishing systems shall be capable to produce air mechanical foam for the use as an extinguishing medium depending on the foam expansion ratio:

of low expansion ratio (about 10:1);

of medium expansion ratio (between 50:1 and 150:1);

of high expansion ratio (about 1000:1).

Foam fire extinguishing systems may include units separately producing, but simultaneously supplying low expansion ratio foam and medium expansion ratio foam (combination foam).

3.7.1.2 Use shall be made of foam concentrate of types approved by the Register (refer to **1.3.3.1**).

Foam concentrates for generating low expansion and medium expansion foam shall be approved by the Register in accordance with IMO circular MSC.1/Circ.1312 and MSC./Circ.798, respectively.

A foam concentrate for generating high expansion foam shall be approved by the Register in compliance with IMO circular MSC/Circ.670.

3.7.1.3 The capacity of foam fire extinguishing systems and the quantity of a foam concentrate shall be calculated depending on the foam expansion ratio, foam solution supply rate and operation time of the system given in Table 3.7.1.3 and in **3.7.2.1**.

Table 3.7.1.3

Spaces	Foam solution supply rate, in l/min per 1 m^2, with the foam expansion ratio			Rated time of continuous operation, in min
	10:1	100:1[1,8]	1000:1	
1	**2**	**3**	**4**	**5**
Cargo oil tanks and cargo tank deck	(6 ; 0,6; 3)[2]	6[3]	-	20[4]/30
Tanks for oil products with a flash point 60°C and above (fuel oil tanks)	6[3]	4,5[3]	-	20
Dry cargo holds	-	4[3]	-	45
Machinry spaces and other spaces whose equipment is oil-fired	-	-	1[3]	-[5]
Paint lockers, storerooms for flammable liquids, flammable liquefied and compressed gases	-	4,5[3]	-	20
Hangars for helicopters, enclosed garages, as well as spaces listed in **1.5.4.3** and **1.5.8.1**	-	-	-[6]	45
Helidecks[7]	-[7]	-[7]	-[7]	-[7]

[1]The solution supply rates apply to combination-foam production as well.

[2]The rate of solution supply shall not be less than the greatest of the following:

.1 6 l/min per square metre of the horizontal sectional area of the single tank having the largest such area;

.2 0,6 l/min per square metre of cargo tanks deck area, where cargo tanks deck area means the maximum breadth of the ship multiplied by the total longitudinal extent of the cargo tank spaces;

.3 3 l/min per square metre of the area protected by the largest monitor, such area being entirely forward of the monitor but not less than 1250 l/min.

[3]For the area of the largest horizontal section of the largest protected space.

[4]Sufficient foam concentrate shall be supplied to ensure at least 20 min of foam generation in oil tankers fitted with an inert gas system and 30 min in oil tankers not fitted with an inert gas system using largest rate of solution supply stipulated in Footnote [1].

[5]Sufficient foam concentrate shall be supplied to ensure foam generation in the volume equal to 5-fold volume of the largest protected space. Foam expansion ratios shall not exceed 1000:1.

[6]The rate of solution supply shall be sufficient for filling of the protected space volume during 15 min.

[7]For foam solution supply rate refer to **6.1.1.2.1**

[8]In passenger ships with sign A, A-R1, A-R2, A-R2-RSN, B-R3-RSN, C-R3-RSN and D-R3 in the ship's class notation - the intensity that provides within 1 min. a layer of foam with a thickness of not less than 1 m when filling the largest protected room

Operation of a deck foam system at its required output shall permit the simultaneous use of the minimum required number of jets of water at the required pressure from the fire main, in compliance with the requirements for water fire main system, which shall be possible on deck over the full length of the ship, in the accommodation, service spaces, control stations and machinery spaces.

3.7.1.4 Tanks for the storage of foam concentrate shall be fitted with arrangements for filling and draining, a device for watching the level of the liquid and a manhole for cleaning and inspecting. The tanks shall be of sufficient capacity to contain the full required amount of foam concentrate.

If no excessive pressure is required to be created in tanks during the system operation, non-return valves shall be fitted between such tanks and the fire main.

Where a foam concentrate using fresh water is utilized in the high expansion foam system, at fire extinction station there shall be the reserve of water sufficient for at least single foam fill up of the protected space of the largest volume. The remainder of the water may be supplied from ship's storage tanks. Equipment (pumps, fittings, etc.) necessary for supplying fresh water to the tank shall be arranged outside the protected space, be fed from the emergency diesel-generator and have a capacity sufficient to ensure continuous operation of the system as required in Table 3.7.1.3.

3.7.1.5 The mixers for making aqueous solution of a foam concentrate of the required concentration shall be of an approved type. The mixers shall ensure operation of simultaneously used foam nozzles and/or foam generators.

3.7.1.6 The main control station of the fixed deck system shall be located in the fire extinction station outside the cargo spaces in the vicinity of accommodation spaces and be easily accessible and ensure control of the system in the event of fire in protected areas. Sampling device for measurement of the percentage of foam concentrate in a solution shall be fitted at the fire extinction station on the fire main at a maximum distance from mixers, the pressure gauge shall be fitted on the pipe supplying water to the system.

The main equipment of the deck system (tanks with a foam concentrate, pumps, mixers, etc) may be located in the engine room.

3.7.1.7 Deck foam systems applied by a common line from the fire main may be used onboard provided that the foam applicators can be effectively operated by one person when fire extinguishing medium is supplied at a pressure required for monitors. Additional foam concentrate shall be provided for 2 nozzles operation during the period of time according to Table 3.7.1.3.

3.7.1.8 Fire safety of the enclosed pipe trunk situated within the cargo tanks deck area shall comply with the requirements of IMO circular MSC.1/Circ.1276.

3.7.2 Fixed deck systems.

3.7.2.1 The expansion ratio of the foam generated by the system shall not generally be greater than 12:1. If the system generates actually low expansion foam with expansion ratio slightly in excess of 12:1, the quantity of the foam concentrate shall be calculated as for the system with foam expansion ratio 12:1. Where the system generates the foam with expansion ratio somewhat below 12:1, the quantity of the foam concentrate shall be proportionally increased.

The system shall be capable of discharging through fixed discharge outlets in no more than 5 min, a quantity of foam sufficient to produce an effective foam blanket over the largest single area over which fuel oil is liable to spread.

Where medium expansion ratio foam is used in oil tankers, the amount of the foam concentrate shall be not less than the rated quantity and sufficient for the operation of the rated number of the foam generators and one monitor during 10 min.

3.7.2.2 On oil tankers foam shall be supplied by means of monitors and portable foam generators or air-foam nozzles (refer to **5.1.6** and **5.1.19**) to the entire cargo deck area and to any cargo tank whose deck was ruptured. The number and location of the foam main hydrants shall be such as to ensure foam supply to any part of the cargo tanks deck from at least two portable foam generators or air-foam nozzles.

3.7.2.3 At least 50 % of the foam solution supply rate required in .1 and .2 of Footnote 2 to Table 3.7.1.3 shall be delivered from each monitor.

In ships of less than 4000 t deadweight only portable foam generators or air-foam nozzles may be employed.

However, in such a case the capacity of each generator according to **5.1.19** or nozzle according to **5.1.6.1** shall be at least 25 % of the foam solution supply rate required in .1 and .2 of Footnote 2 to Table 3.7.1.3.

3.7.2.4 The number and position of monitors shall be such as to comply with **3.7.2.2**, **3.7.2.6** and **3.7.2.8**. The solution-delivering capacity of any monitor shall not be less than indicated in .3 of Footnote 2 to Table 3.7.1.3.

3.7.2.5 It is recommended that a monitor shall be provided with a changing-over device for alternate supply of water and foam. Pipes branching from the fire main and foam solution supply piping shall be connected to the changing-over device.

In lieu of the changing-over device suitably inter-locked shut-off valves may be fitted.

3.7.2.6 The distance from the monitor to the farthest extremity of the protected area forward of that monitor shall be not more than 75 % of the monitor throw in still air conditions.

3.7.2.7 The foam fire main in easily accessible places of the cargo deck shall be fitted with isolation sluice or disc valves spaced 30 m apart. Next to each of such valves there shall be provided an information plate to indicate that the valve shall be kept permanently open under normal service conditions.

Before each isolation valve fitted on the foam piping there shall be twin fire hydrants, 70 mm in inside diameter, for coupling thereto fire hoses with air-foam nozzles located at such distance that the requirements of **3.2.6.2** are met.

Branches from the fire main and foam piping to the monitors shall also be fitted before the isolation valves.

Where medium expansion foam is used, twin fire hydrants shall be substituted by valve chests with a number of fire hydrants equal to 50 % of the required number of foam generators.

3.7.2.8 In oil tankers, each foam fire extinction station shall be provided with a shut-off device located on the foam fire main before it extends beyond the boundaries of the station.

Before the shut-off device there shall be a branch led out to the forward part of the poop deck, both starboard and port, to monitors and twin fire hydrant, about 70 mm in inside diameter, for coupling thereto fire hoses with air-foam nozzles. For oil tankers of less than 4000 t deadweight, it is sufficient to provide only branch pipes to the said fire hydrants.

Where medium expansion foam is used, twin fire hydrants shall be substituted by valve chests with a number of fire hydrants equal to 50 % of the required number of foam generators.

3.7.2.9 Foam fire extinguishing system for dry cargo spaces shall meet the following requirements:

.1 a shut-off valve shall be fitted where the foam fire main is led out to the open deck;

.2 provision shall be made for valve chests with fire hydrants to be fitted on the foam fire main on both sides. The distance between the valve chests of either side shall not exceed 40 m. The number of fire hydrants in each valve chest shall be equal to 50 % of the required number of foam generators.

3.7.2.10 If a ship is provided with a fixed low and/or medium expansion foam system, there shall be provided branches from solution pipe line to entrances from the upper deck to machinery spaces as also to the fuel oil filling positions. Each branch shall be fitted with two hydrants for coupling thereto fire hoses with air-foam nozzles or foam generators.

3.7.2.11 In ships where medium expansion mechanical foam is used, solution piping shall be connected to fire main to provide for the possibility of application of such foam for extinction of fires in accommodation and service spaces through the fire main. For this purpose provision shall be made for an appropriate number of portable foam generators at hydrants in accommodation and service spaces.

3.7.2.12 The foam shall be supplied to the helidecks with the area limited by the helicopter length via foam monitors or foam generators capable of feeding the foam to any part of the deck, provided that the environmental conditions are suitable for the operation of helicopters.

The system shall feed the foam within at least 5 min. at the rate as specified in Table 3.7.2.12. Helideck or helicopter landing area fixed foam fire extinguishing system on ships and FOP with distinguishing mark **HELIDECK**, **HELIDECK-F** or **HELIDECK-H** in the ship's class notation (refer to **2.2.25**, Part I "Classification") shall meet the requirements of **6.1.2.2.1**.

Table 3.7.2.12

Total length of the helicopter, in m	Solution feed rate, l/min
up to 15	250
15 to 24	500
24 to 35	800

3.7.2.13 Fixed and portable combined foam units may be utilized instead of foam monitors and foam generators.

3.7.3 Fixed high expansion foam fire extinguishing system.

3.7.3.1 General.

3.7.3.1.1 The system shall be of approved type and capable of fire extinction and tested based on the procedure in Appendix 1 of IMO circular MSC.1/Circ.1384.

3.7.3.1.2 The system shall be capable of manual release. It shall be designed to produce foam at the required application rate within 1 min of release. Automatic release of the system shall not be permitted unless appropriate operational measures or interlocks are provided to prevent any local application systems or other systems from interfering with the effectiveness of the system.

3.7.3.1.3 The system and its components shall be suitably designed to withstand ambient temperature changes, vibration, humidity, shock, clogging and corrosion normally encountered on ships, which shall be approved based on test results in compliance with the requirements of Appendix 2 to IMO circular MSC.1/Circ.1384.

Piping, fittings and related components inside the protected spaces (except gaskets) shall be designed to withstand 925°C.

3.7.3.1.4 System piping, foam concentrate storage tanks, components and pipe fittings in contact with the foam concentrate shall be compatible with the foam concentrate and be constructed of corrosion resistant materials such as stainless steel, or equivalent. Other system piping and foam generators shall be full galvanized steel or equivalent.

3.7.3.1.5 Means shall be provided for the crew to safely check the quantity of foam concentrate and take periodic control samples for foam quality. Means for testing the operation of the system and assuring the required pressure and flow shall be provided by pressure gauges at both inlets (water and foam concentrate supply) and at the outlet of the foam proportioner. A test valve shall be installed on the distribution piping downstream of the foam proportioner, along with orifices which reflect the calculated pressure drop of the system. Distribution pipework shall have self-draining capability and all sections of piping shall be provided with connections for flushing, draining and purging with air. All nozzles shall be able to be removed for inspection in order to prove clear of debris.

3.7.3.1.6 Operating instructions for the system shall be displayed at each operating position. Besides, installation, operation and maintenance instructions/plans for the system shall be supplied to the ship and be readily available on board. The above instructions shall be in English and the working language of the crew.

3.7.3.1.7 If an internal combustion engine is used as a prime mover for the sea water pump for the system, the fuel oil tank to the prime mover shall contain sufficient fuel to enable the pump to run on full load for at least 3 h. Sufficient reserves of fuel shall be available outside the machinery space of category A to enable the pump to be run on full load for an additional 15 h. If the fuel tank serves other internal combustion engines simultaneously, the total fuel tank capacity shall be adequate for all connected engines.

3.7.3.1.8 The arrangement of foam generators and piping in the protected space shall not interfere with access to the installed machinery for routine maintenance activities.

3.7.3.1.9 The system source of power supply, foam concentrate supply and means of controlling the system shall be readily accessible and simple to operate, and shall be arranged at positions outside the protected space not likely to be cut off by a fire in the protected space. All electrical components directly connected to the foam generators shall have at least an IP 54 rating.

3.7.3.1.10 The foam generator room shall be ventilated to protect against overpressure, and shall be heated to avoid the possibility of freezing. The foam generators of the outside air foam system shall be located where an adequate amount of fresh air supply can be arranged in compliance with its specification.

3.7.3.1.11 The quantity of foam concentrate available shall be sufficient to produce a volume of foam equal to at least five times the volume of the largest protected space enclosed by steel bulkheads, at the nominal expansion ratio, or enough for 30 min of full operation for the largest protected space, whichever is greater.

3.7.3.1.12 Machinery spaces, cargo pump-rooms, vehicle spaces, ro-ro spaces and special category spaces shall be provided with audible and visual alarms within the protected space warning of the release of the system.

The alarms shall operate for the length of time needed to evacuate the space, but in no case less than 20 s.

3.7.3.2 Systems for the protection of machinery spaces and cargo pump-rooms.

3.7.3.2.1 The system shall be supplied by both main and emergency sources of power in compliance with **4.3.1**, **9.3** and **19.1.2** of Part XI "Electrical equipment". The emergency power supply shall be provided from outside the protected space.

3.7.3.2.2 Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system is met and in addition shall be adequate to completely fill the largest protected space within 10 min. Where such a machinery space includes a casing (e.g. a machinery space of category A containing internal combustion machinery, and/or a boiler, with an engine casing), the volume of such casing, above the level up to which foam shall be filled to protect the highest positioned fire risk objects within the machinery space, need not be included in the volume of the protected space. The level up to which foam shall be filled to protect the highest positioned fire risk objects within the machinery space shall not be less than:

1 m above the highest point of any such object; or

the lowest part of the casing, whichever is higher.

Fire risk objects include, but may not be limited to, those listed in the definitions of "Machinery spaces of category A" and "Fuel oil unit" in **1.2** Part VII "Machinery Installations". Although not referred to in those definitions, they may also include items having a similar fire risk such as exhaust gas boilers or oil fuel tanks.

3.7.3.2.3 The arrangement of delivery ducts of the outside air foam system/foam generators of the inside air foam system shall in general be designed based on the approval test results in compliance with **3.7.3.1.1**. A minimum of two generators/ducts shall be installed in every space containing combustion engines, boilers, purifiers, and similar equipment.

Small workshops (working spaces) and similar spaces listed in **1.5.3.2.2** and **1.5.8.1**, may be covered with only one foam generator/foam delivery duct.

3.7.3.2.4 Foam delivery ducts of the outside air foam system/foam generators of the inside air foam system shall be uniformly distributed under the uppermost ceiling in the protected spaces including the engine casing.

The number and location of foam generators shall be adequate to ensure all high fire risk areas are protected in all parts and at all levels of the spaces. Extra foam delivery ducts/foam generators may be required in obstructed locations.

The foam delivery ducts/foam generators shall be arranged with at least 1 m free space in front of the foam outlets, unless tested with less clearance.

The foam delivery ducts/ foam generators shall be located behind main structures, and above and away from engines and boilers in positions where damage from an explosion is unlikely.

3.7.3.2.5 The arrangement of the foam delivery ducts of the outside air foam system shall be such that a fire in the protected space will not affect the foam-generating equipment. If the foam generators are located adjacent to the protected space, foam delivery ducts shall be installed to allow at least 450 mm of separation between the generators and the protected space, and the separating divisions shall be class "A-60" rated.

3.7.3.2.6 Foam delivery ducts shall be constructed of steel having a thickness of not less than 5 mm. In addition, stainless steel dampers (single or multi-bladed) with a thickness of not less than 3 mm shall b installed at the openings in the boundary bulkheads or decks between the foam generators and the protected space. The dampers shall be automatically operated (electrically, pneumatically or hydraulically) by means of remote control of the foam generator related to them.

The dampers shall be arranged to remain closed until the foam generators begin operating.

3.7.3.3 Systems for the protection of vehicle, ro-ro, special category and cargo spaces.

3.7.3.3.1 The system shall be supplied by the ship's main power source.

3.7.3.3.2 Sufficient foam-generating capacity shall be provided to ensure the minimum design filling rate for the system, determined during approval testing in accordance with **3.7.3.1.1**, is met and in addition shall be adequate to completely fill the largest protected space within 10 min. However, for systems protecting vehicle and ro-ro spaces and special category spaces, with decks that are reasonably gas-tight and that have a deck height of 3 m or less, the filling rate shall be not less than two thirds of the design filling rate determined during approval testing in accordance with **3.7.3.1.1** and in addition sufficient to fill the largest protected space within 10 min.

3.7.3.3.3 The system may be divided into sections. However, the capacity and design of the system shall be based on the protected space demanding the greatest volume of foam. Adjacent protected spaces need not be served simultaneously if the boundaries between the spaces are "A" class divisions.

3.7.3.3.4 A minimum of two foam delivery ducts of the outside air foam system/foam generators of the inside air foam system shall be installed in every space. The arrangement of foam delivery ducts/foam generators shall in general be designed based on the approval test results and be arranged to uniformly distribute foam in the protected spaces, and the layout shall take into consideration obstructions that can be expected when cargo is loaded on board. As a minimum, ducts/generators shall be led to/located on every second deck, including movable decks. The horizontal spacing of the ducts/generators shall ensure rapid supply of foam to all parts of the protected space. This shall be established on the basis of full scale tests.

3.7.3.3.5 The foam delivery ducts/foam generators shall be arranged with at least 1 m free space in front of the foam outlets, unless tested with less clearance.

3.7.3.3.6 The design and arrangement of outside air foam fire extinguishing systems shall be in compliance with **3.7.3.2.5** and **3.7.3.2.6**.

3.7.3.4 Systems using outside air with generators installed inside the protected space.

3.7.3.4.1 To protect spaces specified in **3.7.3.2** and **3.7.3.3**, the fixed high expansion foam fire extinguishing systems with foam generators using outside air but with generators located inside the protected space and supplied by fresh air ducts may be applied. Such systems shall be equivalent to the outside air foam systems.

3.7.3.4.2 For acceptance, the following minimum design features shall be considered:

.1 lower and upper acceptable air pressure and flow rate in supply ducts;

.2 function and reliability of damper arrangements;

.3 arrangements and distribution of air delivery ducts including foam outlets; and

.4 separation of air delivery ducts from the protected space.

3.8 CARBON DIOXIDE SMOTHERING SYSTEM

3.8.1 General.

3.8.1.1 The amount of carbon dioxide, in kg, shall be determined by the formula

$$G=1{,}79V\varphi \qquad (3.8.1.1)$$

where V - rated volume of the protected space (refer to **3.1.2.2**, **3.1.2.5**), in m^3;

φ - factor equal to:

0,3 for dry cargo holds and other spaces, except those indicated below;

0,35 for machinery spaces, the rated volume of which is determined with regard to the full volume of casings;

0,4 for machinery spaces, the rated volume of which is determined without any regard to the volume of casings from the level at which the horizontal area of the casings is equal to, or less than, 40 % of the horizontal crosssectional area of the space itself measured in the middle between the floor covering of the inner bottom and the trunk bottom and storerooms specified in **1.5.3.2.2** (refer also to Footnote 3 to Table 3.1.2.1);

0,45 for vehicles spaces and ro-ro spaces which are not special category spaces and are capable of being sealed, and for which at least two thirds of the gas required for the relevant space shall be introduced within 10 min.

For machinery spaces such value of the factor φ shall be taken which results in a greater value G.

In ships of less than 2000 gross tonnage, except for passenger ships, factors 0,35 and 0,4 may be reduced to 0,3 and 0,35, respectively, if two or more machinery spaces, which are not fully separated from each other, are considered as forming one space.

3.8.1.2 Where a carbon dioxide smothering piping is used as a smoke detection one, the carbon dioxide distributing manifold may be placed together with the CO2 release controls for each space protected by the smoke detection system near its detecting units. However, it is recomended that the provision of such manifold shall not preclude the possibility of discharging CO2 into any of the protected spaces directly from the fire extinction station, if two or more machinery spaces, which are not fully separated from each other, are considered as forming one space.

3.8.1.3 The total cross-sectional area of manifolds and the cross-section of the distributing manifold shall be not more than the sum of the cross-sections of the cylinder valves simultaneously opening for the largest by volume protected space (for high-pressure systems) and not more than the cross-section of the tank discharge valve (for low-pressure systems).

3.8.1.4 The cross-sections of distributing pipes for individual protected spaces shall be not more than the sum of the cross-sections of cylinder discharge valves simultaneously opening for the space concerned (for high-pressure system) or not more than the cross-section of the tank discharge valve (for low-pressure systems). The sum of the cross-sections of the discharge pipes shall not exceed the cross-section of the supply pipe except where the calculated pressure drop in any pipe cross section is not less than 1 MPa.

3.8.1.5 The supply shall be ensured for:

.1 machinery spaces - 85 % of the rated amount of carbon dioxide within not more than 2 min;

.2 container and general cargo spaces (primarily intended to carry a variety of cargoes separately secured or packed) as well as for spaces specified in **1.5.4.3.1** and **1.5.4.4.1**, at least two thirds of the gas shall be discharged into the space within 10 min

.3 solid bulk cargo spaces, at least two thirds of the gas shall be discharged into the space within 20 min.

The system controls shall be arranged to allow one third, two thirds or the entire quantity of gas to be discharged based on the loading condition of the hold.

3.8.1.6 The thickness of pipe walls shall be calculated in accordance with **2.3**, Part VIII "Systems and Piping"; in this case, the design pressure p is assumed as equal to the design pressure of cylinders and tankers according to **3.8.2.1** and **3.8.3.1** and shall be not less than the values specified in Table 2.3.8 of the above Part.

3.8.1.7 Carbon dioxide shall be supplied to the protected spaces through nozzles arranged in the upper part of these spaces. The piping for the distribution of fire extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of carbon dioxide is obtained. Where the floor plates of the machinery spaces of category A are placed higher than one metre above the tank top, a number of nozzles (about 15% of the total number) shall be fitted in the upper portion of the space below the plates.

3.8.1.8 The total sectional area of the outlets of the nozzles of the space concerned shall not exceed 85 % of the total cross-section of the distributing piping.

3.8.1.9 Perforated pipes may be used instead of nozzles in silencers, exhaust-gas boilers and smoke stacks. The total area of pipe perforations shall be by 10 % less than the pipe cross-section.

3.8.1.10 In addition to the alarms required by **4.3.4**, signal whistles operated by the released carbon dioxide pressure shall be fitted on pipes laid in the spaces listed in **4.3.1**.

3.8.1.11 The sealing materials for the valves and flexible hoses shall be usable at low temperatures down to 760°C.

3.8.1.12 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.

3.8.1.13 All discharge piping, pipe 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.

3.8.1.14 A fitting shall be installed in the discharge piping to permit the air testing.

3.8.2 High-pressure system.

3.8.2.1 The number of cylinders for storing liquid carbon dioxide shall be provided depending on the filling ratio (amount of carbon dioxide per 1 litre of cylinder capacity) which is not to be more than 0,675 kg/l at the design cylinder pressure 12,5 MPa and over and not more than 0,75 kg/l at the cylinder design pressure 15 MPa and over.

When filling cylinders, deviation of not more than by ±0,5 kg from the rated amount per cylinder is permitted.

In cases specified in 3.1.3.3 and 3.8.5 the filling ratio shall be reduced by 0,075 kg/l against the above values.

3.8.2.2 The cylinders shall be placed vertically in rows on the pads which may be made of wood and shall be accessible for inspection and checking of the amount of carbon dioxide contained therein. Each cylinder shall be marked with its ordinal number. Pilot cylinders shall be coated with a distinguished paint and be fitted in the fire extinction station. Pilot cylinders (carbon dioxide of at least 7 kg, compressed air or nitrogen) used for remote release may be placed at the fire stations or in the enclosures of the ship's internal spaces.

3.8.2.3 A pipe connecting a cylinder with a manifold shall be as a rule seamless and made of red copper. But use of special flexible hoses made of approved materials is permitted.

A non-return valve shall be fitted on the pipe connecting the cylinder and the manifold.

Arrangement of the manifolds shall provide their complete draining.

3.8.2.4 A manifold of the carbon dioxide extinction station shall be fitted with a pressure gauge graduated to a value at least 1 MPa in excess of the hydraulic test pressure of the carbon dioxide cylinders.

The value of the pressure gauge scale division shall not exceed 0,5 MPa.

3.8.2.5 A carbon dioxide extinction station shall have arrangements for weighing the cylinders or measuring the level of liquid therein.

3.8.2.6 Valves of cylinders.

3.8.2.6.1 The valve shall have protective devices complying with the following requirements:

protective diaphragms shall break at a pressure rise in the cylinders up to (1,3±0,1)p, in MPa (where *p* is design pressure of the cylinder). For valves with slotted diaphragms which are additionally fitted with protective diaphragms the breaking pressure of slotted diaphragms shall be at least 1 MPa more than the highest value of the protective diaphragm breaking pressure;

there shall be provided a checking device to indicate that the protective device has operated.

3.8.2.6.2 Where the lever type device is used to open the valve this device shall ensure the full opening of the valve by turning the lever to an angle not more than 90° and shall permit the valves to be opened individually or by groups.

3.8.2.6.3 The cylinder valves shall be fitted with scarfed pipes cut short at 5 to 15 mm from the cylinder bottom; the inside diameter of the said valve pipes and of the pipes connecting the cylinder valves with a manifold shall be not less than 10 mm.

3.8.2.6.4 If the design of the valves of pilot cylinders differs from that of the valves of all other cylinders, they shall be coated with a paint of another colour and have the inscription "starting".

3.8.2.7 The gas from the protective devices of cylinders shall be discharged:

.1 to the atmosphere beyond the boundaries of the station through a separate pipe provided with an audible alarm at the outlet;

.2 to the distribution manifold where provision shall be made for:

two pipes, one of which is open-ended and fitted with a shut-off valve, and the other is provided with a protective diaphragm;

a signalling device to indicate the presence of pressure in the manifold whose readings shall be transmitted to the space where watch keepers are present all the time.

In this case, a checking device to indicate that the protective device has operated is not required for the valves.

3.8.3 Low pressure system.

3.8.3.1 The rated amount of liquid carbon dioxide shall be stored in tank (tanks) at the working pressure of about 1,8 - 2,2 MPa which is ensured by maintaining a temperature of about -18°C.

The normal liquid charge in the container shall be limited to provide sufficient vapour space to allow for expansion of the liquid under the maximum storage temperatures than can be obtained corresponding to the setting of the pressure relief valves but shall not exceed 95 % of the volumetric capacity of the container.

3.8.3.2 A tank shall be served by two self-contained refrigerating plants, each consisting of one compressor, a condenser and a cooling battery.

The refrigerating capacity and the automatic control of each unit shall be so as to maintain the required temperature under conditions of continuous operation during 24 h at sea temperatures up to 32°C and ambient air temperatures up to 45°C.

When one of the plants is rendered inoperative, the other shall be automatically brought into operation.

Cooling batteries shall be separate for each plant or common, but they shall consist of not less than two isolated sections, each having a surface designed for full output.

In other respects, a refrigerating plant shall meet the requirements of Part XII "Refrigerating Plants" for unclassed plants (except for **3.3**, **3.4**, **3.5** and **6.2.6**), as well as those of **2.1.1**, **2.3.11**, **2.3.12** and **7.2.2** for classed plants.

The system control devices and the refrigerating plants shall be located within the same room where the pressure vessels are stored.

3.8.3.3 A tank shall be fitted with:

branches with shut-off valves for filling the tank;

a discharge pipe;

a device for direct monitoring of liquid carbon dioxide level, mounted on the tank;

two relief valves with discharge pipes laid to the open air and arranged so as to provide disconnection of any of them with the remaining one connected with the container;

a pressure gauge;

high (not more than setting of the relief valve) and low (not less than 1,8 MPa) pressure;

lowest acceptable level alarm device.

The setting of each relief valve shall be at least 1,1 - 1,2*p*, and its throughput shall be such that pressure in the tank with the valve fully open may not exceed 1,35*p* (here *p* is working pressure in the tank, in MPa).

The value of the design pressure of the tank shall be assumed equal to the greatest lifting pressure of a relief valve.

3.8.3.4 If fitted outside the tank, the level gauge pipe of the device for remote monitoring of the level of liquid shall be shut off with two valves (open throughout the period of operation) and provided with one control hydrant only, nominally filled (100 %). The pipe and the control hydrant shall be thermally insulated.

3.8.3.5 If the system serves more than one space, means for control of discharge quantities of CO2 shall be provided, e.g. automatic timer or accurate level indicators located at the control position(s).

It shall be also possible to regulate the discharge manually.

3.8.3.6 The tank and pipes led therefrom and permanently filled with carbon dioxide shall be provided with heat insulation preventing operation of the relief valve within 24 h after the installation is de-energized, at the ambient temperature of 45°C and initial pressure equal to the starting pressure of the refrigerating plant.

3.8.3.7 Material for a tank shall meet the requirements of **3.3**, Part XIII "Materials". Welds shall be radiographed as required for class II in Table 3.3.2-2, Part XIV "Welding".

3.8.3.8 Safety relief devices shall be provided in each section of pipe that may be isolated by block valves and in which there could be a build-up of pressure in excess of the design pressure of any of the components.

3.8.3.9 The alarm system shall give visual and audible alarm signals:

when the maximum (not higher than the setting of the relief valve) and minimum (not less than 18 bar) pressure is reached in the tank;

when the level of liquid carbon dioxide in the tank is reduced to the minimum acceptable level;

in case of refrigerating plant failure;

when the discharge of carbon dioxide begins.

The alarm signals shall be given at the central control station and in engineers' cabins.

3.8.4 Release control.

3.8.4.1 Controls of systems protecting those spaces, which are normally manned (refer to **4.3.1**), shall comply with the requirements of **3.8.4.2**.

3.8.4.2 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 conveys 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 that they can only be operated in that order. 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 in a break-glass-type enclosure conspicuously located adjacent to the box.

3.8.4.3 The pipe supplying gas from pilot cylinder to the pneumatic actuator of main bottles through a time-delay device shall be fitted with by-pass valve located across this time-delay device which can be used in case the device goes defective.

3.8.4.4 In low pressure systems, release of carbon dioxide shall be manual. Where an automatic control system is provided to supply rated amount of carbon dioxide to protected spaces, manual regulation of gas supply shall also be provided.

Where the system serves more than one spaces, facilities shall be provided to control the amount of released carbon dioxide such as an automatic flowmeter or a precision level indicator located at the control station(s).

3.8.5 Local carbon dioxide fire extinction stations.

In well-founded cases local stations with not more than five cylinders (not more than 125 kg of carbon dioxide) may be permitted for certain protected spaces.

In a machinery space carbon dioxide cylinders may be placed for fire protection of crankcases and silencers of internal combustion engines, of smoke stacks and other enclosed compartments.

3.9 EQUIVALENT FIRE EXTINGUISHING SYSTEMS FOR MACHINERY SPACES AND CARGO PUMP ROOMS MENTIONED IN 1.5.7.1

3.9.1 Fixed gas fire extinguishing systems equivalent to carbon dioxide smothering systems shall be of an approved type complying with the provisions of IMO circular MSC/Circ.848 "Revised Guidelines for the Approval of Equivalent Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS-74, for Machinery Spaces and Cargo Pump Rooms", considering the amendments introduced by IMO circular MSC.1/Circ.1267.

3.9.2 Fixed water-mist fire extinguishing systems shall be of an approved type complying with the provisions of IMO circular MSC/Circ.1165 "Revised Guidelines for the Approval of Equivalent Water-

Based Fire-Extinguishing Systems for Machinery Spaces and Cargo Pump-Rooms", considering the amendments introduced by IMO circulars MSC.1/Circ.1269, MSC.1/Circ.1385 and MSC.1/Circ.1386.

3.10 DRY POWDER SYSTEM

3.10.1 General.

3.10.1.1 An extinguishing powder approved by the Register for this purpose shall be used in the dry powder system.

3.10.1.2 Nitrogen or other inert gas approved by the Register for this purpose shall be used as a propellent gas.

3.10.1.3 The system shall consist of:

powder installations that contain dry powder containers, propellent gas cylinders and a distribution manifold;

hose stations;

pipes and fittings for bringing the system into action and powder supply to the hose stations.

3.10.1.4 Provision shall be made for a remote release of the system from any hose station.

3.10.2 Quantity of dry powder and propellent gas. Capacity and number of nozzles.

3.10.2.1 A rated quantity of dry powder shall be stored in each container of the powder installation to provide a minimum 45 continuous discharge time at rated consumption for all attached monitors and hand hose lines.

3.10.2.2 Each nozzle shall be capable of discharge at a rate not less than 3,5 kg/s, the powder throw range being not less than 8 m. In determining a maximum distance of coverage of each hand hose line the length of its hose shall be taken into account.

The capacity of each fixed monitor shall be at least 10 kg/s, maximum distance of coverage for monitors having a capacity 10, 25 and 45 kg/s shall be 10, 30 and 40 m, respectively.

3.10.2.3 The number of hand hose lines and monitors shall provide the delivery of the dry chemical powder to any part of the cargo tank deck and cargo piping from two hand hose lines or a combination monitor/hand hose line.

At least one hand hose line or monitor shall be located aft of the cargo area.

3.10.2.4 In gas carriers one monitor shall be provided in the cargo area to protect cargo manifold and capable of discharge locally and remotely.

3.10.2.5 Dry powder fire extinguishing system for the protection of spaces stipulated in **1.5.3.2.2**, shall ensure the delivery of not less than 0,5 kg powder/m3 for not more than 10 s.

3.10.2.6 The quantity of the propellent gas shall provide for a single entire release of the dry powder from the powder container.

3.10.3 Powder fire extinction stations.

3.10.3.1 The powder fire extinction stations shall be positioned on the deck in the cargo area.

3.10.3.2 The dry powder system shall consist of at least two self-contained station and in gas carriers with a cargo capacity of less than 1000 m3 only one such station may be fitted.

3.10.3.3 Ships fitted with bow or stern cargo loading and discharge manifold shall be provided with an additional dry powder fire extinction station complete with at least one monitor and one hand hose line.

3.10.3.4 Where a fire extinction station has two or more hose stations, an independent pipe with release valves shall ensure proper dry powder delivery from the manifold to each station.

The powder fire extinction station shall provide for independent and simultaneous operation of all those stations.

3.10.4 Hose station.

3.10.4.1 Each hose station shall consist of remote-release cylinders with a non-kinkable hand hose line not more than 33 m in length or of a monitor.

3.10.4.2 All hose station equipment, other than a monitor, shall be stored in a watertight box or cabinet.

3.10.4.3 Each nozzle shall be fitted with an on/off operation and discharge device.

3.10.4.4 The cross-section of the nozzle shall be equal to that of the fire hose line or less than that by not more than 50 %.

3.10.4.5 Release cylinders shall be provided with pressure gauges.

3.10.4.6 Instructions on putting the system into action shall be available at the hose station.

3.10.5 Dry powder containers, pipes and fittings.

3.10.5.1 Provision shall be made in the container for a dry powder discharge pipe cut short at about 100 mm from the bottom.

3.10.5.2 A device shall be provided in the lower part of the container for gas flow into the container preventing the powder from flowing back into the gas pipe.

3.10.5.3 The filling ratio of the containers shall be taken equal to not more than 0,95.

3.10.5.4 Pipes and fittings shall have no contractions and abrupt expansions of cross-section.

3.10.5.5 The cross-sectional area of the manifold in the powder installation shall be not less than the total area of the pipes connected thereto for simultaneous discharge of dry powder or shall be not more than twice that area.

3.10.5.6 Provision shall be made on the distribution manifold for an arrangement for purging the pipes after use.

3.10.5.7 A bending radius of the dry powder pipe shall be not less than 10 pipe diameters.

3.10.5.8 The dry powder shall be discharged into the spaces indicated in **1.5.3.2.2** through nozzles. Their construction, arrangement and number shall provide for uniform spraying of powder in the entire volume of the space. The pressure at the remotest nozzle shall be taken at least equal to a minimum pressure necessary for effective spraying of powder.

3.11 AEROSOL FIRE EXTINGUISHING SYSTEM[9]

3.11.1 General.

3.11.1.1 The fire extinguishing aerosol (which is produced while combustion of solid fuel aerosol generating compounds) generators used in the aerosol fire extinguishing systems shall be of the type approved by the Register.

3.11.1.2 The aerosol fire extinguishing system shall include:

generators of fire extinguishing aerosol;

remote control device;

predischarge alarms;

cables.

3.11.1.3 Design mass of the aerosol generating agent, in kg, shall be calculated for each protected space separately and shall be determined by the formula

$$G = (V + \sum_{J=1}^{n} V_{arj} \cdot P_{arj} \cdot P_a^{-1}) \cdot k \cdot q \qquad (3.11.1.3)$$

where V - design (net) volume of the protected space, in m^3;

V_{arj} - volume of the j-th air receiver, in m^3, refer to **3.1.2.5**;

n - number of air receivers in the protected space;

j - serial number of air receiver;

P_{arj} - working pressure in the j-th air receiver, in MPa;

P_a - atmospheric pressure, in MPa;

q - normative fire extinguishing concentration of aerosol, in kg/m3;

k - factor of safety equal to 1,5.

3.11.1.4 Normative fire extinguishing concentration of aerosol depends on the type of generator and usually does not exceed 0,2 kg/m3.

3.11.1.5 At system actuation within the protected space, the following measures shall be taken:

automatic activation of the fire warning system in compliance with the requirements of **4.3**;

automatic shutdown of ventilation;

automatic closing of ventilation fire dampers;

automatic shutdown of the electric drives of oil burner units of boilers and incinerators and other equipment capable to reduce the concentration of fire extinguishing aerosol.

3.11.1.6 The system discharge time shall not exceed 2 min.

3.11.1.7 Arrangement of generators in the protected space shall ensure equal distribution of fire extinguishing aerosol. If there are shadow zones formed by equipment and boundaries fire extinguishing aerosol shall be fed directly to the shadow zones.

3.11.1.8 Generators shall be installed considering the distance to the thermal zone boundaries (refer to **3.11.2.2**) so that the minimum safe distance away from the generators along the aerosol jet to escape routes and other areas where personnel may be present is not less than the distance to the thermal zone boundary with a temperature of 75°C, and to combustible materials - not less than the distance to the thermal zone boundary with a temperature of 200°C.

3.11.1.9 Aerosols shall have non-ozone depleting characteristics.

[9]Refer also to IMO circular MSC.1/Circ.1270 "Revised Guidelines for the Approval of Fixed Aerosol Fire-Extinguishing Systems Equivalent to Fixed Gas Fire-Extinguishing Systems, as Referred to in SOLAS 74, for Machinery Spaces".

3.11.2 Fire extinguishing aerosol generators.

3.11.2.1 Fire extinguishing aerosol generator consists of a casing, which contains an aerosol generating agent, ignitor, electrical connection, devices for mounting to the ship structures. Casing of the generator shall be fitted with the arrangement (nozzle) for the release of an aerosol.

3.11.2.2 Each type of generator shall have information about the distance (along the aerosol jet) from its exit out of the generator to the end of the thermal zone with the temperature 75°C and 200°C.

3.11.2.3 The number of fire extinguishing aerosol generators shall be calculated for each protected space separately.

Design number of generators, in pieces, shall be determined by the formula

$$N=G/m \qquad (3.11.2.3)$$

where G - design mass of aerosol generating agent, in kg, in accordance with **3.11.1.3**;

m - mass of a charge in one generator, in kg.

The number of generators in the protected space shall be such that in the event of damage to any one power release line or generator, the aerosol concentration shall be not less than normative fire extinguishing concentration of aerosol q (refer to **3.11.1.4**) provided for the selected type of generator having regard to **3.11.1.7**.

Where the estimated number of generators N = 1, their number is taken equal to 2, and when N = 2 - equal to 3.

3.11.2.4 Casing of generator, its foundation and details fastening it to the foundation shall be made of non-combustible materials.

3.11.2.5 The generators shall be designed to prevent self-activation at a temperature below 250°C.

3.11.3 The fire extinguishing remote control device.

3.11.3.1 The remote control device shall comply with Section **2**, Part XI "Electrical Equipment".

3.11.3.2 The remote control device shall enable distant starting of all generators protecting the space.

The start-up of generators by groups is permitted proceeding from their number and provided the requirement of **3.11.1.6** is met.

3.11.3.3 If several spaces are protected by the remote control device, it shall enable divided start-up of generators in each space.

3.11.3.4 There shall be two sources of electrical power - main and emergency - for the remote control device.

3.11.3.5 The remote control device shall enable automatic monitoring of electric circuits essential for the release of the system with indication of a faulty circuit and also generation of a signal for checking the operability of devices announcing about starting, as well as the signal for checking the possibility of shutdown of ventilation and other devices specified in **3.11.1.5**.

3.11.4 Local stations of the aerosol fire extinguishing.

In justified cases, to protect separate spaces other than machinery spaces of category A and containing no essential equipment, the local stations of the aerosol fire extinguishing may be equipped with at least two generators and the starting controls located outside the protected space and near the entrance to that space (without remote control device).

Stating controls shall meet the requirements of Section 2, Part XI "Electrical Equipment" and ensure:

ready starting of generators at all times;

verification of the integrity of electric circuits essential for starting the generator;

periodical checks of the aerosol fire extinguishing system operability by means of starting with the use of simulators;

short-circuit protection in each electric circuit essential for starting the generators.

In this case, the actuation of equipment listed in **3.11.1.5** is provided by the ship means.

3.11.5 Cabling.

3.11.5.1 Cabling shall comply with the requirements of Section **16**, Part XI "Electrical Equipment".

3.11.5.2 Electric circuits connecting generators shall be duplicated and widely separated. Within the protected space, electric circuits essential for the release of the system shall be fire resistant according to IMO circular MSC.1/Circ.1270.

3.12 FIXED LOCAL APPLICATION FIRE EXTINGUISHING SYSTEMS FOR USE IN MACHINERY SPACES

3.12.1 Fixed local application fire extinguishing systems shall be fitted on passenger ships of 500 gross tonnage and above and on cargo ships of 2000 gross tonnage and above. The provisions of this Chapter do not apply to fishing vessels.

3.12.2 Machinery spaces of category A above 500 m^3 in volume shall, in addition to the fixed fire extinguishing system required in Table 3.1.2.1, be protected by an approved type of fixed water-based or equivalent local application fire extinguishing system complying with the requirements of IMO Revised Guidelines[10]. 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.

Where automatic release is provided the availability of manual release is obligatory.

The manual release shall be located at easily accessible position inside and outside the protected space. The manual release inside the protected space shall not be liable to be cut off by a fire in the protected areas.

The automatic release shall be activated by fire detection system, indicating fire risk areas. Besides it shall be so designed as to prevent accidental release of the local application fire extinguishing system.

3.12.3 Fixed local application fire extinguishing systems are to protect fire risk areas of the following machinery and equipment (without the necessity of engine shutdown, personnel evacuation, or sealing of the spaces):

.1 internal combustion engines;
.2 incinerators;
.3 purifiers for heated fuel oil;
.4 boiler fronts (where nozzles are fitted);
.5 inert gas generators;
.6 fuel heaters.

In multi-engine installations, at least two sections shall be arranged.

3.12.4 The activation of any local application fire extinguishing system shall give a visual and a distinct audible alarm in the protected space in the main machinery control room and in the wheelhouse.

The alarm, which may be monotone, shall indicate the specific system activated. The system alarm requirements, described within this paragraph are in addition to, and not in lieu of, the fire detection and fire alarm systems required elsewhere in this Part.

3.12.5 Electrical equipment of the system and its release alarm shall comply with the requirements of 7.13, Part XI "Electrical Equipment".

3.12.6 Nozzles onboard shall be located in the same positions as during their testing carried out according to the IMO Revised Guidelines.

3.13 TESTING OF FIRE EXTINGUISHING SYSTEMS

3.13.1 Fire extinguishing systems shall be tested in compliance with Table 3.13.1.

3.13.2 The operational testing of the systems shall be conducted in conformity with Register - approved programs to verify their serviceability, operation of starting controls, and where prototype ships are concerned, to confirm the stipulated time for the fire extinguishing medium discharge into the protected space.

On prototype ships, a test discharge of the rated amount of carbon dioxide into one of the protected spaces is required for high-pressure carbon dioxide systems.

The test discharge may be omitted if reasonable substantiations are submitted to the Register.

[10] Refer to IMO circular MSC.1/Circ.1387.

Table 3.13.1

Nos.	Systems and assemblies to be tested	Hydraulic test pressure	
		in shop	on board ship

1	2	3	4
1	Foam and water fire extinguishing systems (refer also to Section 21, Part VIII "Systems and Piping"):		
	.1 pipes	-	In action
	.2 pipes of sprinkler system	-	1*p*
2	Pipes of dry powder system	1,5*p*	1*p* (by air)
3	Carbon dioxide systems		
3.1	High-pressure systems:		
	.1 pipes from cylinders to release control valves; transit pipe lines passing through spaces (refer to **3.1.4.1.4**)	-	1,5p
	.2 pipes from release control valves to nozzles and pipes from safety devices	-	5 MPa
3.2	Low-pressure systems:		
	.1 pipes from tank to release control valves	-	1,5*p*
	.2 pipes from release control valves to nozzles and pipes from safety devices	-	1*p*
4	Pipes and scrubber of the inert gas system	-	1p (by air)
5	Pneumatic pipes	-	1,5*p*
6	Cylinders, containers and tanks:		
	.1 operating under pressure, including cylinders without valves	1,5*p*	-
	.2 operating without pressure	By filling up to the top of the air pipe	In assembly with system
	.3 cylinders with screwed-in valves	1*p* (by air)	-
7	Fittings	1,5*p*, but not less than 0,2 MPa	-

N o t e s : 1. *p* is the maximum working pressure in the system, and for carbon dioxide p is a design pressure of a cylinder or a tank, in MPa.
2. Fittings in assembly shall be tested for the tightness of closing by a pressure of at least 1,25*p*, the valves of carbon dioxide cylinders - by the highest breaking pressure of protective diaphragms according to **3.8.2.6.1**.
3. The systems shall be tested in assembly on board ship upon completion of all erection work.
4. Pipes specified in **3.1.1** and **3.2.1**, after being tested by a pressure of 1,5*p*, may be tested on board by pressure of 1p.
5. Pipes of the water fire main system in ships of 500 gross tonnage and upwards (refer to **3.2.5.1**) shall be tested by a pressure of at least 1,0 MPa.

4 FIRE DETECTION AND ALARM SYSTEMS

4.1 GENERAL

4.1.1 All electrical equipment, devices, alerts and indicators, feeders and wiring of fire detection and alarm systems shall fully comply with the requirements of 7.5 and 7.6, Part XI "Electrical Equipment" of these Rules, the Code on Alerts and Indicators and the FSS Code as well as the requirements of the Directive of the European Parliament and of the Council[11].

All fire detection and alarm equipment and systems shall be designed to withstand ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered in ships.

4.1.2 In passenger ships, the control panel shall be located in the onboard safety centre. An indicating unit that is capable of individually identifying each detector that has been activated or manually operated call point shall be located on the navigation bridge.

In cargo ships, the control panel shall be located on the navigation bridge or in the fire control station.

In cargo ships, an indicating unit shall be located on the navigation bridge if the control panel is located in the fire control station. A space in which a cargo control console is installed, but does not serve as a dedicated cargo control room (e.g. ship's office, machinery control room), shall be regarded as a cargo control room, and therefore be provided with an additional indicating unit.

Clear information shall be displayed on or adjacent to each indicating unit about the spaces covered and the location of the sections.

In cargo ships and on passenger cabin balconies, indicating units shall, as a minimum, denote the section in which a detector has activated or manually operated call point has operated. In addition, controls for remote closing of the fire doors and shutting down the ventilation fans shall be centralized at the continuously manned central control station.

The ventilation fans shall be capable of reactivation by the crew at the continuously manned control station.

In passenger ships built on or after 1 January 2018, in the event that the whelelhouse is not attended, the audible fire alarm shall be located at the place of watch under the constant supervision of the responsible crew member.

The control panels in the central control station shall be capable of indicating open or closed position of fire doors, on or off status of the detectors, alarm and fans.

4.1.3 Fire detection and fire alarm system shall not be used for any other purpose, except for closing fire doors from the switchboard and other similar purposes (refer to **3.12.2**). Where fire doors are at the same time watertight doors (refer to **7.12**, Part III "Equipment, Arrangements and Outfit") they shell not be automatically closed upon operation of fire alarms.

Detectors and manual call points shall be connected to dedicated sections of the fire detection and fire alarm system. Other fire safety functions, such as alarm signals from the sprinkler valves, may be permitted in separate sections.

4.2 FIRE DETECTION AND FIRE ALARM SYSTEMS

4.2.1 Fixed fire detection and fire alarm systems.

4.2.1.1 The fixed fire detection and fire alarm system shall be installed to protect:

.1 accommodation and service spaces and control stations (refer to **4.2.1.2**);

.2 Category A machinery spaces periodically unattended and Category A machinery spaces in which installation of automatic and remote control systems and equipment has been approved by the Register instead of continuous manning of the space and the main propulsion plant and associated machinery including main sources of power are provided to a variable degree with automatic or remote control and permanently under supervision of the watchkeeping staff at the control station;

.3 cargo spaces in which packaged dangerous goods are carried (refer to **7.2.7**) as well as cargo spaces which are inaccessible, on passenger ships, except cases when the ship is engaged in voyages of so short duration, that application of this requirement will be unsuitable;

.4 spaces for carriage of vehicles, special category spaces and ro-ro spaces (refer to **4.2.1.3**). The fire detection and fire alarm system shall not be installed on weather decks used for the carriage of vehicles with fuel in their tanks;

.5 cabin balconies of passenger ships, when furniture and furnishings on such balconies are not as defined in 2.1.1.9. A fixed fire detection and fire alarm system for cabin balconies shall comply with the requirements of the FSS Code and IMO circular MSC.1/Circ.1242;

.6 enclosed spaces with incinerators. Enclosed spaces located on the weather deck where the incinerators are located, combined spaces for incinerators/waste and any waste storage room;

.7 special electrical spaces.

Spaces having little fire risk, such as void spaces with no storage of combustibles, private bathrooms, public toilets, fire extinguishing medium storage rooms, cleaning gearlockers (in which flammable liquids are not stored), open deck spaces and enclosed promenades having little or no fire risk and that are naturally ventilated by permanent openings, need not be fitted with detectors and manual call points.

4.2.1.2 When protecting accommodation and service spaces and control stations the following shall be provided:

[11]Directive 2009/45 / EC of the European Parliament and of the Council of 6 May 2009 on safety rules and standards for passenger ships, which entered into force on 15 July 2009 (revised version of amendments made by Commission Directives 2010/36 / EU and (EU) 2016/844 and Directive (EU) 2017/2108 of the European Parliament and of the Council).

.1 smoke detectors shall be installed in all stairways, corridors and escape routes within accommodation spaces as specified in **4.2.1.2.2 - 4.2.1.2.4**. The smoke detectors on stairways shall be located at the top level of the stair and at every each second level beneath. Consideration shall be given to installation of special smoke detectors in ventilation ducts;

.2 in passenger ships carrying more than 36 passengers the fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of smoke in service spaces, control stations and accommodation spaces including corridors, stairways and escape routes within accommodation spaces;

.2.1 the fixed fire detection and fire alarm system shall be capable of remotely identifying each detector individually.

Where the fixed fire detection and fire alarm system do not include means of remotely identifying each detector individually, no section covering more than one deck within accommodation spaces, service spaces and control stations shall normally be permitted except a section which covers an enclosed stairway;

.2.2 each cabin shall be provided with a fire detector. When the system is required to sound a local audible alarm within the cabins where the detectors are located, a means to silence the local audible alarms from the control panel shall not be permitted;

.2.3 a section of detectors and manually operated call points shall not be situated in more than one main vertical zone, except on cabin balconies;

.2.4 the entire main vertical zone containing atrium (i.e. public spaces including three or more weather decks) shall be protected over the entire area by the smoke detection system;

.3 in passenger ships carrying not more than 36 passengers, there shall be installed throughout each separate vertical or horizontal zone, in all accommodation and service spaces, and where the Register considers it necessary, in control stations, except spaces posing no substantial fire risk such as void spaces, sanitary spaces, etc. either:

.3.1 a fixed fire detection and fire alarm system so installed and arranged as to detect the presence of fire in such spaces and provide smoke detection in corridors, stairways and escape routes within accommodation spaces; or

.3.2 a fixed fire detection and fire alarm system so installed and arranged as to detect the presence of smoke in corridors, stairways and escape routes within the accommodation spaces if there is an automatic sprinkler system so arranged as to protect such spaces (refer to Table 3.1.2.1);

.3.3 the fixed fire detection and fire alarm system shall be capable of remotely and individually identifying each detector and manually operated call point;

.3.4 detectors fitted in cabins, when activated, shall also be capable of emitting, or cause to be emitted, an audible alarm within the space where they are located;

.4 detectors may be operated by heat, smoke or other products of combustion, flame or any combination of these factors. Detectors operated by other factors may be considered by the Register, provided that they are no less sensitive than the above detectors.

When fire detectors are installed in freezers, drying rooms, saunas, parts of galleys used to heat food, laundries and other spaces where steam and fumes are produced, heat detectors may be used;

.5 in cargo ships accommodation and service spaces depending on a protection method are protected by a fixed fire detection and fire alarm system and/or by an automatic sprinkler system and fire alarm and detection system as follows:

.5.1 when *method IC* is used: a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces;

.5.2 when *method IIC* is used: a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces. In addition, an automatic sprinkler system shall be so installed and arranged as to protect accommodation spaces, galleys and other service spaces (refer to Table 3.1.2.1);

.5.3 when *method IIIC* is used: a fixed fire detection and fire alarm system shall be so installed and arranged as to detect the presence of fire in all accommodation and service spaces, providing smoke detection in corridors, stairways and escape routes within accommodation spaces, except spaces posing no substantial fire risk such as void spaces, sanitary spaces, etc. In addition, a fixed fire detection and fire alarm system shall be so installed and arranged as to provide smoke detection in all corridors, stairways and escape routes within accommodation spaces.

However there is no need to provide fixed fire detection and fire alarm system in service spaces built away from the accommodation block;

.6 if the fixed fire detection and fire alarm system is required for protection of spaces other than spaces specified in **4.2.1.2.1**, at least one detector complying with the requirements of the FSS Code shall be installed in each such space;

.7 no section will pass through a space twice. When this is not practical (e.g., for large public spaces), the part of the section which by necessity passes through the space for a second time shall be installed at the maximum possible distance from the other parts of the section;

.8 a section of fire detectors which covers a ro-ro space shall not include a machinery space of category A.

4.2.1.3 The fire detection and fire alarm system installed in spaces intended for the carriage of vehicles, special category spaces and in ro-ro spaces shall provide early detection of fire. The type of automatic detectors and arrangement thereof shall be determined with consideration of effect of ventilation and other appropriate factors. After installation, the system shall be tested under normal ventilation conditions to determine the average time of its responding. The fire detection and fire alarm system may not be fitted in special category spaces if an effective watching in the form of continuous fire watch is maintained in the spaces throughout the voyage.

4.2.1.4 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.

Detectors which are located on the overhead shall be a minimum distance of 0,5 m away from bulkheads, except corridors, lockers and stairways. The maximum spacing of detectors shall be in accordance with Table 4.2.1.4.

Table 4.2.1.4

Type of detector	Maximum floor area per detector, in m^2	Maximum distance apart between centres, in m	Maximum distance away from bulkheads, in m
Heat	37	9	4.5
Smoke	74	11	5.5

The Register may permit deviation from the requirements of Table 4.2.1.4 based upon characteristics obtained during tests and agreed with the Register.

Automatic detectors located under mobile decks / platforms in vehicle spaces, special category spaces and ro-ro spaces shall also comply with the applicable requirements of Table. 4.2.1.4.

When heat-pulse detectors are used in machinery spaces, the deck area served by one detector shall be 50 m^2, and distance between centres shell be not more than 6 m.

4.2.1.5 A sample extraction smoke detection system of a type approved by the Register and meeting the requirements of 4.2.1.6 may be provided in cargo spaces specified in 4.2.1.1.3 and 4.2.1.1.4, except spaces specified in 1.5.4.3.2, 1.5.4.4.2 and 1.5.9.

4.2.1.6 A sample extraction smoke detection system shall consist of the following main components: smoke accumulators, sampling pipes, three-way valves, if the system is interconnected to a fixed gas fire extinguishing system, control panel, and shall meet the following requirements:

.1 the system shall be capable of continuous operation at all times. Systems operating on a sequential scanning principle may be permitted on agreement with the Register provided that interval I between two scannings of the same space does not exceed 120 s and provides time T mentioned in **4.2.1.6.10**. With a 20 % allowance the interval I is determined by the formula

I=1,2xTxN

where N - the number of scanning points;

.2 the sampling pipe arrangements shall be such that the location of the fire can be readily identified;

.3 the system shall be constructed and installed so as to prevent the leakage of any toxic or flammable substances or fire extinguishing media into any accommodation and service space, control station or machinery space, as well as to avoid the possibility of ignition of flammable gas-air mixture;

.4 at least one smoke accumulator shall be located in every enclosed space for which smoke detection is required. However, where a space is designed to carry oil or refrigerated cargo, or other cargoes for which a smoke sampling system is required, means may be provided to isolate the smoke accumulators in such compartments on agreement with the Register.

In cargo holds where non-gastight "tween deck panels" (movable stowage platforms) are provided, smoke accumulators shall be located in both the upper and lower parts of the holds;

.5 smoke accumulators shall be located for optimum performance and shall be spaced so that no part of the overhead deck area is more than 12 m measured horizontally from an accumulator.

Where systems are used in spaces which may be mechanically ventilated, the position of the smoke accumulators shall be considered having regard to the effects of ventilation.

At least one additional smoke accumulator shall be provided in the upper part of each exhaust ventilation duct. An adequate filtering system shall be fitted at the additional smoke accumulator to avoid dust contamination.

Smoke accumulators shall be positioned where impact or physical damage is unlikely to occur;

.6 the number of smoke accumulators connected to each sampling pipe shall ensure compliance with the requirements of **4.2.1.7**;

.7 smoke accumulators from more than one enclosed space shall not be connected to the same sampling point;

.8 sampling pipes shall be self-draining and protected from impact or damage during cargo operations;

.9 the sensing unit shall operate before the smoke density within the sensing chamber exceeds 6,65 % obscuration per metre;

.10 at least two sample extraction fans, duplicating one another, shall be provided.

The fans shall be of sufficient capacity to operate with the normal conditions of ventilation in the protected area. The connected pipe size shall be determined with consideration of fan suction capacity and piping arrangement shall satisfy the requirements of **4.2.1.7**. The fans, depending on capacity and length of piping, shall provide time *T* of total system operation delay not more than 15 s. The fan suction capacity shall be adequate to ensure the response of the most remote area within the required time criteria in **4.2.1.7**;

.11 the switchboard shall have means permitting observation of smoke in the individual sampling pipe;

.12 means shall be provided to monitor the airflow through the sampling pipes so designed as to ensure equal quantities are extracted from each interconnected accumulator;

.13 sampling pipes shall be a minimum of 12 mm inside diameter. Where the pipes are used in conjunction with fixed gas fire extinguishing systems, the minimum size of pipe shall be sufficient to permit the fire extinguishing medium to be discharged within the appropriate time;

.14 sampling pipes shall be provided with arrangement for periodically purging with compressed air;

.15 control panel shall be located on the navigation bridge, in the central control station or carbon dioxide extinction station. The indicating unit shall be located on the navigation bridge if the control panel is located in the central control station or carbon dioxide extinction station.

Clear information shall be displayed on or adjacent to the control panel and indicating units designating the spaces covered.

Provision shall be made for checking the control panel of the smoke detection system in accordance with the procedure agreed with the Register;

.16 provision shall be made for testing for correct operation and restoring to normal surveillance without the renewal of any component;

.17 detection of smoke or other products of combustion shall initiate visual and audible signals at the control panel and indicating units;

.18 power supplies necessary for the system operation shall be monitored loss of power. The loss of power shall initiate a visual and audible fault signal at the control panel and navigation bridge which shall be distinct from a fire signal (refer also to **7.5.4**, Part XI "Electrical Equipment");

.19 means to manually acknowledge all alarm and fault signals shall be provided at the control panel.

The audible alarm sounders on the control panel and indicating units may be manually silenced. The control panel shall clearly distinguish between normal, alarm, acknowledged alarm, fault and silenced conditions;

.20 the system shall be arranged to automatically reset to the normal operating condition after alarm and fault conditions are cleared;

.21 suitable instructions and component spares shall be provided for the testing, maintenance and repair of the system.

4.2.1.7 After installation, the system shall be functionally tested using smoke generating machines or equivalent as a smoke source. An alarm shall be received at the control panel in not more than 180 s for vehicle decks, and not more than 300 s for container and general cargo holds, after smoke is introduced at the most remote accumulator.

4.2.2 Manual alarms.

4.2.2.1 Manual fire alarms shall be provided in the ships which in compliance with **4.2.1.1** are equipped with fixed fire detection and fire alarm system.

4.2.2.2 Manually operated call points shall be installed to protect all accommodated spaces, service spaces and control stations, considering the requirements of **4.2.1.2.3.3**. A manually operated call point fitting is not required in an individual space within the accommodation spaces, service spaces and control stations. A manually operated call point shall be located at each exit (inside or outside) to the open deck from the corridor such that no part of the corridor is more than 20 m from a manually operated call point.

4.2.2.3 Service spaces and control stations which have only one access, leading directly to the open deck, shall have a manually operated call point not more than 20 m from the exit (measured along the access route using the deck, stairs and/or corridors).

4.2.2.3.1 A manually operated call point is not required to be installed for spaces having little fire risk, such as carbon dioxide rooms, nor at each exit from the navigation bridge, in cases where the control panel is located in the navigation bridge.

4.2.2.4 In special category spaces the manual call points shall be installed so that no part of the space is more than 20 m from the call point and one call point shall be installed close to each exits from such spaces.

4.2.2.5 All buttons of manual fire alarms shall be painted red and adequately illuminated both in normal and emergency conditions. The button shall be protected with glass.

4.2.2.6 Any required fixed fire detection and fire alarm system with manually operated call points shall be capable of immediate operation at all times.

On special agreement, particular spaces may be disconnected during specific work. In this case, the means for disconnecting the detectors shall be designed to automatically restore the system to normal surveillance after a predetermined time.

4.2.3 Protection of unattended machinery spaces.

4.2.3.1 Unattended machinery spaces of category A, as well as heated air ducts and main boiler uptakes, essential auxiliary boilers with a steam capacity over 3 t/h and boilers with thermal liquids (including exhaust gas boilers) in such spaces shall be provided with an automatic fire alarm and fire detection system (refer also to **2.2.4**, Part IX "Machinery").

4.3 FIRE WARNING ALARMS

4.3.1 Means shall be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any ro-ro spaces, container holds equipped with integral reefer containers, spaces accessible by doors or hatches, and other spaces in which personnel normally work or to which they have access.

Conventional cargo spaces and spaces with only a local release need not be provided with such an alarm.

4.3.2 The audible alarms shall be located so as to be audible throughout the protected space with all machinery operating, and the alarms shall be distinguished from other audible alarms by adjustment of sound pressure or sound patterns.

4.3.3 Fire warning alarm (the pre-discharge alarm) shall be automatically activated, when any starting control is actuated or when direct access thereto is provided (by opening the release cabinet door, switching off the interlocking, etc.).The alarm shall operate for the length of time needed to evacuate the space, but in no case less than 20 s before the fire-extinguishing medium is released.

4.3.4 The signal shall be clear, distinct and readily audible in a noisy space, and shall be of a tone distinct from all other signals. In addition to the audible signal, there shall be a visible signal: **"Gas! Go away!"** and for the spaces protected by the aerosol fire extinguishing systems - **"Aerosol! Go away!"**.

Simultaneously with the pre-discharge alarm before the entrance to the space protected by the fire extinguishing system, there shall be a visible sygnal: **"Gas! Go away!"**, **"Aerosol! Go away!"**, depending on the case.

4.3.5 Audible alarm in the cargo pump room of oil tankers shall be:

pneumatic, operated by dry and clean air; or

electrically-operated, intrinsically safe; or

electrically-operated, the electric actuating mechanism being located outside the pump room.

5 FIRE-FIGHTING OUTFIT, SPARE PARTS AND TOOLS

5.1 FIRE-FIGHTING OUTFIT

5.1.1 Items of fire-fighting outfit shall comply with the FSS Code and be of approved type and ready for use at any time.

Fire-fighting outfit shall be located in a readily accessible place.

In passenger ships the location of fire-fighting outfit shall be marked by photoluminescent material or by lighting. Such photoluminescent markers or lighting shall meet the requirements of **8.5.5**, Part III "Equipment, Arrangements and Outfit" of these Rules and the FSS Code.

5.1.2 Depending on the purpose and size of the ship the standards for supplying portable firefighting

appliances, apparatus and consumable materials shall be in compliance with Table 5.1.2 of this Part. Items of outfit in addition to those specified in the Table 5.1.2, shall be provided on

ships carrying dangerous goods in accordance with **7.2.10**,

oil recovery ships according to **6.4.10**,

ships with distinguishing marks **FF** and **FFWS** in the class notation according to **6.6.11** of this Part;

ships equipped with helidecks with descriptive notations **HELIDECK, HELIDECK-F** or **HELIDECK-H** according to **6.1.1.3**,

ships designed to carry containers on or above the weather deck in compliance with **6.7** of this Part.

5.1.3 The couplings of all portable items of outfit (fire hoses, fire hose nozzles, portable foam generators, etc.) shall be of the standard quick-acting type and size adopted for the given ship. Unless one hose and nozzle is provided for each hydrant in the ship, there shall be complete interchangeability of hose couplings and nozzles. All couplings and items of outfit shall be made of a material resistant to marine environment.

Items of fire-fighting outfit installed in the dangerous areas, rooms and spaces as well as on the open decks of oil tankers and oil recovery ships, gas carriers and chemical tankers shall be of type preventing spark formation.

Aluminium alloys may be used for hose couplings and nozzles except weather decks of oil takers and chemical tankers.

5.1.4 Fire hoses shall comply with the following requirements:

.1 shall have a length not less than 10 m, but not more than:

.1.1 15 m in machinery spaces;

.1.2 20 m in spaces other than those specified in **5.1.4.1.1** and on weather decks;

.1.3 25 m on weather decks of ships with maximum breadth more than 30 m.

In any case the fire hose length shall be sufficient to deliver a jet of water to any of the spaces where their use may be required;

The length of fire hoses, if they do not comply with the requirements of **5.1.4.1.1** to **5.1.4.1.3** (as a standard length) shall ensure effective and unobstructed use in accordance with the requirements of **3.2.6.2**, as second (continuous non-standard length) hose), and compliance with the requirements of **5.1.4.3**;

.2 they shall be made of approved materials resistant to wear and destruction by microorganisms (rotting);

.3 fire hoses in assembly with nozzles shall be stowed at hydrants or on open places on reels or in baskets. On open decks they shall be kept in spray-proof ventilated lockers or enclosures. Stowage locations for fire hoses with nozzles (fire lockers and enclosures) shall be marked with fire control signs “FH” in red color.

.4 in passenger ships, there shall be provided at least one fire hose for each of the hydrants and these hoses shall be used only for fire fighting or testing at fire drills and surveys.

Additionally, in inner spaces in passenger ships carrying more than 36 passengers fire hoses shall be connected to hydrants at all times;

Table 5.1.2

Nos.	Description of items of outfit	Number of items of outfit to be available in each ship
1	**2**	**3**
1	Fire hoses with couplings (refer to **5.1.4**):	
	.1 for water	In accordance with the number of hydrants fitted on board ship
	.2 for foam solution	In accordance with the number of fire hydrants to which foam solution is supplied from fixed foam fire extinguishing system. If the size of the water hoses

		required by **1.1** is suitable for handling foam solution, such hoses may be taken into account to complete the number of hoses to be coupled to the hydrants fitted on the upper decks
2	Fire hose nozzles:	
	.1 dual-purpose nozzles for producing a compact and a sprayed jet (refer to **5.1.5**)	**.1** In accordance with the number of hydrants fitted on board ship **.2** 2 additional fire nozzles shall be provided on ships with helideck in accordance with **6.1.1.3.3**.
	.2 air-foam nozzles (refer to **5.1.6**)	In accordance with the number of hydrants whereto foam solution is supplied from fixed foam fire extinguishing system, but not less than 4
	.3 foam extension pipes (refer to **5.1.7**)	In accordance with the number of air-foam nozzles for fire extinction in cargo tanks of oil tankers
	.4 portable foam generators or portable combination-foam production units (refer to **5.1.19**)	Twice the rated number of foam generators
	.5 extension pipes (refer to **5.1.7**)	50 % of the number of portable foam generators or combination-foam production units intended for fire extinction in the cargo tanks of oil tankers
3	Portable foam applicator (refer to **5.1.8**)	**1** In machinery spaces at least one set in spaces containing internal combustion engines and one set in each boiler room or externally close to the entrance to the boiler room **2** In each fuel distributing station and each cargo hose room, 1 set **3** In working spaces referred to in **1.5.8.1**, 1 set per fire hydrant fitted, but not more than 3 sets are required for each space. A space of less than 150 m^2 need not have more than 1 set **4** In ships with spaces specified in **1.5.4.3**, **1.5.4.4** and **1.5.9** not less than two sets for use in these spaces and additionally one set in each such space if vehicles with fuel in their tanks for self propulsion are carried therein. There is no need to provide sets for weather decks used for the carriage of vehicles with fuel in their tanks, as well as for cargo spaces used for the carriage of vehicles with fuel in their tanks which are loaded in open or closed containers **5** On open deck of container ships, 2 sets
4	Portable foam fire extinguishers, dry powder fire extinguishers and carbon dioxide fire extinguishers (refer to **5.1.9**). The use of dry powder fire extinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	Ships of gross tonnage 1000 and above shall have at least 5 portable fire extinguishers. The minimum number of fire extinguishers at control stations, accommodation and service spaces shall be determined on the basis of 2 fire extinguishers for every 25 m or part thereof, of the deck length on which such spaces are situated, but not less than the number required in accordance with the following provisions **1 Control stations:** **1.1** 1 foam fire extinguisher for each space, 1 fire extinguisher being permitted to be fitted in the corridor for a group of small spaces with a total area

	Portable foam fire extinguishers, dry powder fire extinguishers and carbon dioxide fire extinguishers (refer to **5.1.9**). The use of dry powder fireextinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	of up to 50 m^2, provided that the entrances to the spaces are adjacent and situated in the same corridor. One additional carbon dioxide fire extinguisher when main switchboards are arranged in the main machinery control room; **1.2** 1 carbon dioxide fire extinguisher for each space or group of spaces (as specified in **4.1.1** of this Table) containing electrical or radio equipment, as also for chart compartments; **1.3** 1 foam fire extinguisher for each space containing an emergency diesel-generator or a fire diesel-driven pump; **1.4** two dry powder fire extinguishers in the wheelhouse. If the wheelhouse is less than 50 m^2, only 1 fire extinguisher is required. If the wheelhouse is adjacent with the chartroom and has a door giving direct access to the chartroom, no additional fire extinguisher is required. The same applies to the safety centres if they are within the boundaries of the wheelhouse in passenger ships **2 Accommodation and service spaces:** **2.1** for each full or partial 25 m of length of corridors within each deck and main vertical zone, 1 foam fire extinguisher; **2.2** for each full or partial 250 m^2 of area of public spaces, 1 foam fire extinguisher. For spaces less than 15 m^2 in area fire extinguishers fitted near them may be used; **2.3** in galleys and bakeries with oil-fired equipment, 1 foam fire extinguisher for each space. For galleys with deep-fat fryers, 1 additional fire extinguisher fit for extinguishing cooking grease, fat and oil; **2.4** in galleys and bakeries with electrical, steam, coal- or gas-fired equipment, having the area of more than 50 m^2, 1 foam or carbon dioxide fire extinguisher; **2.5** in other domestic service spaces, 1 foam fire extinguisher (where fire extinguishers are available in the corridor, at the entrance to the space, provision of fire extinguishers within the space is not compulsory); **2.6** in each stairway enclosure and in each lobby, 1 foam fire extinguisher; **2.7** in storerooms for readily flammable (refer also to **3.1.3.4**) and combustible materials, 1 foam fire extinguisher for each space. Where the storeroom area is less than 50 m^2, the fire extinguishers may be kept in the corridor in close vicinity of the entrance to the space concerned or group of small spaces (with a total area not more than 50 m^2); **2.8** in the hospital, 1 dry powder fire extinguisher **3 In addition to the above number of fire extinguishers, within the other ship's spaces the number of fire extinguishers shall be determined as follows**

	Portable foam fire extinguishers, dry powder fire extinguishers and carbon dioxide fire extinguishers (refer to **5.1.9**). The use of dry powder fireextinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	**3.1** In machinery spaces containing internal combustion engines the portable foam fire extinguishers shall be located within 10 m from any point of the space. Each such space shall contain not less than 2 fire extinguishers **3.2** In machinery spaces containing oil-fired boilers - two foam fire extinguishers nearby each boiler front. If oilfired units are located in this space - two additional foam fire extinguishers. **3.3** In enclosed spaces with oil-fired inert gas generators, incinerators and waste disposal units, 2 foam fire extinguishers **3.4** In machinery spaces containing steam turbines or enclosed steam engines the number of fire extinguishers is determined in accordance with **4.3.2**. However, such fire extinguishers shall not be required in addition to those specified in **4.3.2** **3.5** In spaces containing electric machinery or equipment: **3.5.1** 1 carbon dioxide fire extinguisher, for spaces containing main internal combustion or steam machinery, if the total power of the main machinery is less than 740 kW; **3.5.2** 2 carbon dioxide fire extinguishers, for spaces containing main internal combustion or steam machinery, if the total power of the main machinery is equal to, or more than, 740 kW; 1 carbon dioxide fire extinguisher for each electric generator or group of generators, the total power being 500 to 1000 kW; 1 carbon dioxide fire extinguisher for each space or group (not more than three) of small spaces containing auxiliary machinery with electrical drives and for special electrical spaces. The carbon dioxide fire extinguishers required by this sub-item shall be provided in the above spaces whether or not provision is made for foam extinguishers required by other sub-items of this Table **3.6**[4] In separate spaces containing switchboards, 2 carbon dioxide fire extinguishers per space. In space having an area of 15 m^2, 1 carbon dioxide fire extinguisher, near the entrance to the space **3.7** At the entrance to accumulator battery rooms, other than those for radio stations and emergency lighting, 1 carbon dioxide fire extinguisher per space **3.8** In compartments for auxiliary machinery, 1 foam fire extinguisher, when the space area is 50 m^2 and more, otherwise the fire extinguisher placed near the entrance to such space may be sufficient **3.9** For oil fuel tanks, other than those of double bottom, not less than 2 foam fire extinguishers in each space adjacent to the walls or decks of the tanks. If such adjacent spaces are already provided with fire extinguishers, no additional fire extinguishers are required

	Portable foam fire extinguishers, dry powder fire extinguishers and carbon dioxide fire extinguishers (refer to **5.1.9**). The use of dry powder fireextinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	**3.10** In cargo pump rooms, 2 foam fire extinguishers; in other pump rooms, fuel oil distribution stations, in the fuel pipe trunks, hose spaces, 1 foam fire extinguisher for each 30 m^2 of the space floor **3.11** In working spaces, 2 foam fire extinguishers, if the space area is under 100 m^2, plus 1 foam fire extinguisher for every 250 m^2 or part thereof, if the space area is more than 100 m^2 **3.12** In welding shops and in storerooms for welding equipment, 1 foam fire extinguisher and one carbon dioxide fire extinguisher per space **3.13** In special category spaces, cargo spaces for motor vehicles with fuel in their tanks and in ro-ro cargo spaces on each deck, 1 fire extinguisher for each 20 m of deck length on both sides. At entrances to such spaces from accommodation and machinery spaces, 1 foam fire extinguisher. There is no need to provide additional fire extinguishers for weather decks used for the carriage of vehicles with fuel in their tanks, as well as for cargo spaces used for the carriage of vehicles with fuel in their tanks which are loaded in open of closed containers **3.14** At each entrance in the periodically unattended machinery spaces of category A, 1 foam fire extinguisher **3.15** In workshops forming part of machinery spaces, 1 dry powder fire extinguisher **3.16** During carriage of dangerous goods on deck, 2 fire extinguishers each having a capacity of not less than 6 kg of dry powder or equivalent **3.17** On the weather deck of tankers, 2 fire extinguishers each having weight of not more than 23 kg in the charged condition **3.18** Additional fire extinguishers shall be provided on ships with helideck in accordance with **6.1.1.3.2**.
5	Foam fire extinguishers of at least 45 l capacity or at least 16 kg carbon dioxide or dry powder fire extinguishers (refer to **5.1.10** and **5.1.11**) The use of dry powder fireextinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	**1** In machinery spaces containing internal combustion engines in number according to **5.1.10.4** **2** In machinery spaces containing steam turbines or enclosed steam engines in number according to **5.1.10.4**, however such fire extinguishers are not required if the space is protected by a fixed fire extinguishing system according to Table 3.1.2.1 **3** In the working spaces, referred to in **1.5.8.1** 1 fire extinguisher mentioned in **5.1.11** for every 300 m^2 or part thereof, of each working space (bounded by watertight and gastight bulkheads) **4** In spaces containing electric generators or propulsion motors with the total power output being 1000 to 5000 kW, 1 fire extinguisher according to 5.1.11 for each space **5** In separate spaces containing electric switchboards if the switchboard length is more than 5 m and the space is not protected by means of a fire smothering system, 1 fire extinguisher mentioned in **5.1.11** for a

		space **6** In special electrical spaces with deck area 4m^2 and upwards 1 fire extinguisher in accordance with **5.1.11** per space **7** Additional fire extinguishers shall be provided on ships with helideck in accordance with **6.1.1.3.2**.
6	Foam fire extinguishers, at least 136 l capacity, or at least 45 kg carbon dioxide fire extinguishers or dry powder fire extinguishers (refer to 5.1.10 and 5.1.11) The use of dry powder fireextinguishers is permitted in all spaces instead of foam and carbon dioxide fire extinguishers except for the spaces where the energized electrical and radio equipment is installed of over 1000 V	1 In machinery spaces containing oil fuel units as well as oil-fired boilers - one fire extinguisher per each space. In boiler rooms with domestic boilers of less than 175 kW and in case of boilers protected by fixed local application fire extinguishing systems, the fire extinguisher is not required **2** In spaces containing electric generators and propulsion motors with the total power output 5000 kW and over, 1 fire extinguisher according to 5.1.11 for a space. Three fire extinguishers in accordance with item 5 of this Table may be used instead of one fire extinguisher prescribed by this item **3** In special electrical spaces containing electrical equipment with the total power output 5000 kW and over, 1 fire extinguisher according to 5.1.11 for a space. Three fire extinguishers in accordance with item 5 of this Table may be used instead of one fire extinguisher prescribed by this item.
7	Metal receptacles containing sand or sawdust (refer to 5.1.12)	1 receptacle in each firing space in each boiler room with oil-fired boilers, and each space containing a part of the fuel oil unit, as well as near lamp and paint lockers, fuel filling and distributing positions and in other fire hazardous areas where fuel oil or other flammable liquids are liable to spread (except for machinery spaces). 1 receptacle containing sand or dry sawdust impregnated with soda may be replaced by 1 portable foam fire extinguisher
8	Blankets (refer to 5.1.13)	**1** 1 blanket for every 40 m, or part thereof, of open deck length of oil tankers and passenger ships **2** In all other ships not referred to in 8.1 of this Table, 1 blanket, if the ship is up to 1000 gross tonnage, and 2 blankets, if the ship is of 1000 gross tonnage and upwards **3** In machinery spaces of category A in ships of more than 500 gross tonnage, 1 blanket for each space **4** In working spaces indicated in 1.5.8.1, 1 blanket for each space **5** In ships with helidecks – in accordance with **6.1.1.3.5**.
9	Sets of fire fighting tools (refer to **5.1.14**)	For ships of less than 2000 gross tonnage, 1 set For ships of 2000 to 4000 gross tonnage, 2 sets For ships of 4000 to 10000 gross tonnage, 3 sets For ships of 10000 gross tonnage and upwards, 4 sets
10	Fireman's outfit (refer to **5.1.15**)	**1**[3] In passenger ships, 2 sets and additionally for every 80 m, or part thereof, of the total length of all accommodation and service spaces on the deck they

		are situated, or if there are more than one such deck on the deck with the maximum total length of the above spaces 2 sets in accordance with **5.1.15** and 2 sets of personal outfit in accordance with **5.1.15.1.1 - 5.1.15.1.3**. In passenger ships carrying more than 36 passengers, two additional fireman's outfits shall be provided for each main vertical zone. However, for stairway enclosures which constitute individual main vertical zones and for the main vertical zones in the fore or aft end of the ship, which do not contain spaces of categories (*6*), (*7*), (*8*) or (*12*) (refer to 2.2.1.3), no additional fireman's outfits are required. **2** In oil tankers and combination carriers of 500 gross tonnage and upwards, 4 sets **3** In cargo ships of 500 gross tonnage and upwards, 2 sets **4** In ships equipped with helidecks additional equipment according to **6.1.1.3.4** shall be provided
11	Portable electric or pneumatic drills (refer to **5.1.16**)	In all ships of 4000 gross tonnage and upwards, 1 drill per ship
12	Portable fire motor-pumps[1] complete with suction and delivery hoses and fire hose nozzles (refer to **5.1.17** and **8.7.2.5**)	On the ships of less than 500 gross tonnage - in accordance with 8.7.2.1, 8.7.2.6 As emergency fire pump (refer to **3.2.1.2**) – 1 per ship.
13	International shore connection (refer to **5.1.18**)	In all ships of 500 gross tonnage and upwards, and on the floating cranes, 1 set
14	Foam concentrate	Full amount of foam concentrate required by 3.7
15	Gaz analyzers (refer to **5.1.22**):	
	.1 for vapours of flammable liquids and exhaust gases;	In ships carrying motor vehicles with fuel oil (other than diesel oil) in their tanks and in ships with spaces specified in **1.5.4.3**, **1.5.4.4.1**, **1.5.9** - 1
	.2 for vapours of flammable liquids;	In oil tankers and combination carriers - 1 (refer to **5.1.22**) In oil tankers fitted with inert gas system - 1 portable gas analyzer capable to operate in the inert gas atmosphere in addition to the above
	.3 for oxygen content;	In oil tankers and combination carriers - 1 (refer to **5.1.22**)
	.4 for oxygen content and gas detection	In ships carrying solid bulk cargoes which are liable to emit toxic or flammable gases or cause oxygen depletion in the cargo space - 1
16	Fog applicator (refer to **5.1.20**)	**1** In passenger ships carrying more than 36 passengers: in each machinery space of category A, 2 pcs **2** In passenger ships carrying more than 36 passengers: for each pair of breathing apparatuses (refer to **5.1.15.2**), 1 pc **3** In each space for the carriage of vehicles, ro-ro spaces and special category spaces intended for the carriage of vehicles with fuel in their tanks for self propulsion, 3 pcs. There is no need to provide applicators for weather decks used for the carriage of vehicles with fuel in their tanks as well as for cargo spaces used for the carriage of vehicles with fuel in their tanks which are

		loaded in open or closed containers
17	Fire buckets (refer to **5.1.21**)	In ships having no water fire main system, 3 buckets
18	Emergency Escape Breathing Devices (EEBD) (refer to 5.1.23)	**1** Within accommodation spaces: **.1.1** in cargo ships, 2 pcs; **.1.2** in passenger ships, 2 pcs in each main vertical zone. In passenger ships carrying more than 36 passengers, in addition to those required, two additional EEBD shall be provided in each main vertical zone. This requirement is not applied to stairway enclosures comprising separate main vertical zones and to main vertical zones at both ends of a ship which do not have spaces of categories (*6*), (*7*), (*8*) or (*12*) specified in **2.2.1.3** **2** In machinery spaces EEBD shall be located at easily visible places, which can be easily accessed in case of fire. The location of EEBD shall take into account the arrangement of the equipment and the number of persons usually manning the space: **.2.1** in machinery spaces of category A containing internal combustion engines used for main propulsion; **.2.1.1** in the main machinery control room, if located within the machinery space, 1 pc; **.2.1.2** in workshop area, 1 pc. If there is a direct exit from the workshops, not entering the engine room, an EEBD is not required; **.2.1.3** close to each ladder constituting the means of escape from machinery space (refer to **4.5.5.2** and **4.5.10.2**, Part VII "Machinery Installations"), 1 pc at each deck or platform; **.2.2** in machinery spaces of category A other than those specified in **18.2.1**, 1 pc, as a minimum, located in accordance with **18.2.1.3**; **.2.3** in other machinery spaces, the necessity, number and location of EEBD shall be determined on agreement with the Register **3** Provision shall be made for two spare EEBD for passenger ships and one spare EEBD for cargo ships **4** Provision shall be made for at least one EEBD for training in every ship

[1] In non-self-propelled oil tankers a portable manual pump with capacity of at least 6 m^3/h with a nozzle with a diameter of 10 mm and a pressure at the shaft of at least 0.2 MPa shall be installed instead of a motor pump.

The pump shall be fitted with two receiving hoses 4 m long with a non-return valve, two ejection hoses 20 m long and a manual nozzle of the combined type with a nozzle diameter of 10 mm.

[2] In passenger ships in accommodation and service spaces, the number of fire extinguishers and their location shall be such that the distance from any place to the fire extinguisher is not more than 10 m.

Fire extinguishers shall, as far as practicable, have the same methods of application.

[3] In passenger ships of restricted navigation areas:

B-R3-RSN, with length 24m and upwards, and on new C-R3-RSN and D-R3 ships, with length 40m and upwards, but less than 60m, - two fireman's outfits;

B-R3-RSN, with length 24m and more, but less than 40m - two fireman's outfits, but there can be only one spare cylinder filled with compressed air for self-contained breathing apparatus;

B-R3-RSN, less than 24 m long, and on C-R3-RSN and D-R3 ships, less than 40 m long - no fireman's outfit is required.

[4] Fire extinguishers designed for high voltage use shall be located near each electrical switchboard or panel with a power of 20 kW or over.

.5 on cargo ships:

.5.1 of 1000 and more gross tonnage, the number of fire hoses is determined one fire hose per each 30 m of length and one spare fire hose, but not less than five hoses per ship. This number doesn't include any hoses required for machinery or boiler spaces. The Register may require to increase number of hoses in order to ensure sufficient number of hoses and their accessibility at any time, considering the type of ship and character of voyages made by the ship. A ship carrying dangerous goods shall be equipped with three additional hoses and nozzles in excess of those required above;

.5.2 of less than 1000 gross tonnage, the number of fire hoses is calculated in accordance with **5.1.4.5.1**. However, the number of hoses shall be not less than three.

5.1.5 Standard nozzle sizes shall be 12, 16 and 19 mm or close thereto.

Nozzles sizes greater than 12 mm need not be used in accommodation, service and working spaces. In ships under 150 gross tonnage nozzles having 10 mm in diameter are permitted to be used. For machinery spaces and exterior locations, the nozzle size shall be such as to obtain maximum discharge possible from two jets at the pressure at each hydrant mentioned in Table 3.2.1.1 from the smallest pump, but nozzles sizes greater than 19 mm need not be used.

Nozzles shall be of an approved dual-purpose type with a shut-off device. Fire hose nozzles made of plastic type material, e.g. polycarbonate, are considered acceptable provided capacity and serviceability are documented and the nozzles are found suitable for the marine environment.

5.1.6 Air-foam nozzles for delivery of low-expansion foam (refer to **3.7**) from fixed fire extinguishing system shall comply with the following requirements:

.1 on cargo tank deck of oil tankers each nozzle shall be capable of delivering 400 l/min of foam, in this case, the length of jet delivered by the fire hose at still-air shall be not less than 15 m (refer also to **3.7.2.3**);

.2 in ship's spaces each nozzle shall be capable of delivering at least 2 l/min of foam solution per square meter of deck area;

.3 prototype tests of the monitors and foam applicators shall be performed to ensure the foam expansion and drainage time of the foam produced does not differ more than ±10 % of that determined in **3.7.1.2**.

5.1.7 Foam extension pipes with a hook-shaped bell-mouth at the end (for low-expansion foam) and extension pipes fitted with light supports at the middle (for medium-expansion foam) shall be of about 4 m in length.

An extended air-foam nozzle having a hook-shaped bell-mouth may be used in addition to the usual air-foam nozzle instead of a foam extension pipe.

5.1.8 Portable foam applicator unit.

5.1.8.1 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.

5.1.8.2 The nozzle/branch pipe and inductor shall be capable of producing effective foam suitable for extinguishing an oil fire, at a foam solution supply rate of at least 200 l/min at the nominal pressure in the fire main.

5.1.8.3 The foam concentrate shall be approved by the Register based on IMO circular MSC.1/Circ.1312.

5.1.8.4 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 IMO circular MSC.1/Circ.1312.

5.1.8.5 The portable foam applicator unit shall be designed to withstand clogging, ambient temperature changes, vibration, humidity, shock, impact and corrosion normally encountered on ships.

5.1.8.6 The portable foam applicator units shall be located near hydrants.

5.1.9 Portable fire extinguishers shall be of type and design approved by the Register taking into account the IMO Guidelines (refer to IMO resolution A.951(23)) and shall comply with the following requirements:

.1 no fire extinguishing medium shall be used which, either by itself or under anticipated conditions of application, would give off toxic gases in amounts dangerous to human health;

.2 fire extinguishers shall have safety devices preventing the pressure therein to rise above permissible limits;

.3 for 100 % of the first ten fire extinguishers and 50 % of the remaining fire extinguishers capable of being recharged onboard shall be provided with spare chargers. No more than 60 pieces of spare charges of the total number of fire extinguishers are required;

.4 for fire extinguishers which cannot be recharged onboard, additional portable fire extinguishers of the same quantity, type, capacity and number, as determined in **5.1.9.3** above, shall be provided in lieu of spare charges;

.5 fire extinguishers shall be mounted in special brackets of quick-detachable type at places easily visible and accessible in case of fire, and in such a way that their serviceability is not impaired by the weather, vibration and other external factors.

They shall be located at the height of not more than 1,5 m from deck and not closer than 1,5 m from sources of heat;

.6 one of the portable fire extinguishers intended for use in any space shall be stowed close to the entrance to that space;

.7 each powder or carbon dioxide fire extinguisher shall have capacity not less than 5 kg, and each foam fire extinguisher - not less than 9 l.

Mass of any portable fire extinguisher shall not exceed 23 kg. Portable fire extinguishers shall have efficiency, which, in compliance with the recognized international or national standard, is at least equivalent to the efficiency of a 9-litre wetting agent fire extinguisher, which is determined when extinguishing model fire seat of A class, rating 2A;

.8 powder fire extinguishers shall be selected with regard for the purpose of the powder extinguishing medium;

.9 in the machinery spaces fire extinguishers shall be so located that an extinguisher is not more than 10 m walking distance from any point in the space;

.10 carbon dioxide fire extinguishers shall not be located in accommodation spaces. In control stations and other spaces containing electrical or electronic equipment or facilities required for ship safety, fire extinguishers shall be provided, charged with the fire extinguishing medium, which does not conduct electricity and does not cause harm to equipment and facilities;

.11 portable fire extinguishers shall be provided with a visual indication of discharge;

.12 casing and other components of the fire extinguishers subject to internal pressure shall be tested by hydraulic pressure:

2,7 times exceeding the maximum working pressure, but not less than 5,5 MPa for the low pressure fire extinguishers (with working pressure not more than 2,5 MPa at environmental temperature of 20°C);

determined in accordance with recognized national standard on safety of pressure vessels - for high pressure fire extinguishers (with working pressure more than 2,5 MPa at environmental temperature of 20°C);

.13 fire extinguishers shall be suitable for operation under exposure to ambient temperatures according to Table 2.3.1-2, Part VII "Machinery Installations" with due regard for the materials used and maximum degree of filling established by the manufacturer. The degree of filling for carbon dioxide fire extinguishers shall not exceed 0,75 kg/l;

.14 materials used for the manufacture of fire extinguishers, which can be exposed to marine environment during operation shall be selected with consideration for their compatibility;

.15 each fire extinguisher shall be clearly marked with at least the following information:

.15.1 manufacturer;

.15.2 types of fire for which the fire extinguisher is suitable and its fire-extinguishing capability (i.e. capability to extinguish a model fire seat under certain conditions);

.15.3 type and nominal quantity of extinguishing medium with which the fire extinguisher is charged;

.15.4 information on the Register approval;

.15.5 instruction on actuating the fire extinguisher in the form of several pictograms with explanatory note in the language understandable to potential user, in general case, in Ukrainian and in English;

.15.6 year of manufacture;

.15.7 range of temperatures within which the fire extinguisher is operable;

.15.8 test pressure.

5.1.10 Foam fire extinguishers of at least 45 and 135 l shall meet the following requirements:

.1 fire extinguishers shall be located within the protected space, in regular fixed places near the exits.

Only fresh water shall be used for charging the fire extinguishers;

.2 the air for an air-foam extinguisher shall be kept in a cylinder provided solely for that particular extinguisher. The quantity of air in the cylinder shall be at least 25%in excess of the rated amount. The air cylinder shall be fitted with a pressure gauge;

.3 fire extinguishers having capacity of not less than 135 l shall be provided with hoses winded on reels and provide access to any place of boiler room;

.4 location of 45-litre fire extinguishers (or their equivalents) in machinery spaces, specified in **5.1** and **5.2** of Table 5.1.2, shall ensure the delivery of the fire extinguishing medium to any part of the fuel system, to pressure lubricating systems, drives casings covering turbine parts lubricated under pressure, engines and associated drives and other fire risk equipment. In cargo ships a fire extinguisher having a capacity of 45 l (or equivalent) may be located outside the space for which it is intended.

5.1.11 Carbon dioxide or dry powder fire extinguishers of at least 16 kg, as well as carbon dioxide or dry powder fire extinguishers of at least 45 kg shall meet the following requirements:

.1 carbon dioxide fire extinguishers shall not be used in spaces of such volume that the complete discharge of the carbon dioxide contained in the cylinders is liable to cause concentration of carbon dioxide in excess of 5 %;

.2 an extinguishing medium shall be delivered to any part of the protected space through fire hoses of 10 - 15 m in length and through pipes if necessary;

.3 fire extinguishers shall be placed near the exits in the spaces and shall be protected against mechanical damage.

5.1.12 Metal receptacles containing sand or dry sawdust impregnated with soda shall comply with the following requirements:

.1 the capacity of the receptacles shall be at least 0,1 m^3;

.2 each receptacle shall be provided with a readily opening watertight cover, a scoop and a device for holding the cover in the open position unless it is an easily removable cover.

5.1.13 Fire smothering blankets shall comply with the following requirements:

.1 they shall be sufficiently stout and durable;

.2 as a rule, they are to be made of non-combustible material; clean unraised thick felt may be used;

.3 blankets shall be stowed in special cases or lockers;

.4 they shall have an area of at least 3 m^2 and be similar to a square or circle in shape.

5.1.14 Complete sets of fire fighting tools shall comply with the following requirements:

.1 one complete set shall include one fire axe and one light-weight fire crowbar;

.2 the sets of fire fighting tools shall be stowed on regular boards. The fastening of the tools shall permit of ready availability of the tools for use;

.3 in ships for the carriage of motor vehicles with fuel (other than diesel oil) in their tanks one set of tools shall be placed near the exits from the accommodation and machinery spaces to cargo spaces.

5.1.15 The fireman's outfit shall include:

.1 personal outfit consisting of:

.1.1 protective clothing of material approved by the competent bodies 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; tarpaulin and polyvinylchloride clothes are not allowed for the outer material of the fireman's outfit;

.1.2 boots and mittens of rubber or of some other dielectric material;

.1.3 a rigid helmet ensuring effective protection against impacts;

.1.4 a portable safe manual lantern with a minimum burning period of 3 h.

In ships carrying dangerous goods, in oil tankers and other ships having cargo spaces and spaces where a flammable gas, vapour or dust/air mixture is present or may arise, provision shall be made for explosionproof lamps with explosion group 1Exd or 1Exp. The explosion group and temperature class shall be consistent with the category of the cargo carried. For example, they are 1Exd IIAT3 and 1Exp IIT3 for oil, kerosene and a number of gasolines;

.1.5 a fire axe with a helve made of hard wood; if the helve is made of some other material, it shall be insulated with some suitable dielectric material;

.2 a self-contained compressed air-operated breathing apparatus, the volume of air contained in the cylinders of which shall be at least 1200 l or other self-contained breathing apparatus which shall be capable of functioning for at least 30 min. Compressed air breathing apparatus shall be fitted with an audible alarm and a visual or other device which will alert the user before the volume of the air in the cylinder has been reduced to no less than 200 l.

Each breathing apparatus shall be provided with a flexible fire resisting lifeline, not less than 30 m in length. The lifeline shall be subjected to a test by statical load of 3,5 kN for 5 min and withstand this load without damage. The lifeline shall be fastened to the harness of the apparatus or to a separate belt by means of a snap hook to preclude spontaneous separation of the line from the apparatus.

Provision shall be made for two spare charges or two spare breathing apparatuses per each required self-contained breathing apparatus. All air cylinders for the apparatus shall be interchangeable.

Passenger ships carrying not more than 36 passengers and cargo ships equipped with suitably located means for fully recharging breathing air cylinders by clean air may have only one spare charge for each breathing apparatus or one spare breathing apparatus per each required self-contained breathing apparatus.

In passenger ships carrying more than 36 passengers, two spare charges or two spare breathing apparatus shall be provided per each required self-contained breathing apparatus.

Passenger ships carrying more than 36 passengers constructed on or after 1 July 2010 shall be fitted with a suitably located means for fully recharging breathing air cylinders, free from contamination.

For fire drills, all ships shall be provided with an onboard means of recharging breathing apparatus cylinders or a suitable number of spare cylinders − at least one set of cylinders for each mandatory breathing apparatus, unless additional spare cylinders are required by the shipboard safety management system (SMS).

No additional cylinders are required for fire drills for breathing apparatus sets required by Section 7 of this Part, the IMSBC Code, the IBC Code or the IGC Code. The means for recharging shall be either:

breathing air compressors supplied from the main and emergency switchboard, or independently driven, with a minimum capacity of 60 l/min per required breathing apparatus, not to exceed 420 l/min; or

self-contained high-pressure storage systems of suitable pressure to recharge the breathing apparatus used on board, with a capacity of at least 1200 l per required breathing apparatus, not to exceed 50 000 l of free air;

.3 on existing ships contracted for construction before 1 July 2014, a minimum of two two-way portable radiotelephone apparatus of an explosion-proof type or intrinsically safe for each fire party.

Ships constructed before 1 July 2014, shall comply with the requirements of this paragraph not later than the first survey after 1 July 2018.

On ships constructed on or after 1 January 2018 a minimum of two two-way portable radiotelephone apparatus shall be provided. Theses apparatus for ships using LPG (refer to **6.8**), ro-ro shiops and ships with special category spaces shall be of an explosion-proof type.

Ships constructed before 1 January 2018, shall comply with the requirements of this paragraph not later than the first periodical survey after 1 July 2019.

.4 Fireman's outfit and personal equipment shall be ready for use and stored in readily accessible locations that are permanently and clearly marked and where more than one fireman's outfit or more than one set of personal equipment is carried on board they shall be stored in widely separated places.

In passenger ships at least two fireman's outfits and, in addition, one set of personal equipment shall be available at any such place. At least two fireman's outfits shall be stored in each main vertical zone.

5.1.16 Portable electric drills shall be provided with an electric cable of sufficient length. The use of pneumatic drills instead of electric ones is permitted. The electric or pneumatic drills specified in item 11 of Table 5.1.2 may be reckoned in the number of the items prescribed for other types of ship's outfit.

5.1.17 Portable diesel fire motor-pumps shall comply with the following requirements:

.1 the pump shall ensure simultaneous operation of at least two fire hose nozzles with an outlet diameter of at least 12 mm at a pump discharge pressure of at least 0,2 MPa and at vacuum in suction piping not less than 0,05 MPa; centrifugal pumps shall be fitted with a self-priming device;

.2 the pump motor shall be capable of being readily started either by hand or by special starters both at above-zero and below-zero ambient temperatures. The motor shall be provided with a quantity of fuel to ensure the operation of the pump for 1,5 h without refuelling; the ship shall carry an additional reserve of fuel for refuelling;

.3 each motor-pump shall be provided with suction hoses, to a total length of 8 m, fitted with a suction strainer and a non-return valve, two delivery hoses, each 10 m long, two-dual purpose fire hose

nozzles with an outlet diameter of at least 12 mm and a branch coupling for connecting two hoses;

.4 the dimensions and type of coupling for the delivery hoses and nozzles shall correspond to those used in the fixed water fire extinguishing systems fitted in the ship;

.5 the motor-pumps shall be provided with tools and accessories in compliance with the manufacturer's specification;

.6 motor-pumps for use in ships navigating under northern latitudes shall be placed in heated spaces, together with the suction and delivery hoses and nozzles.

5.1.18 The international shore connection (refer to Fig. 5.1.18) for water supply from shore shall be in accordance with the following specification:

outside diameter of flange - 178 mm;

inside diameter of flange - 64 mm;

bolt circle diameter - 132 mm;

holes - 4 equispaced holes 19 mm diameter equidistantly placed, slotted to the flange periphery;

flange thickness - at least 14,5 mm;

bolts - 4 pcs, each 16 mm in diameter and 50 mm in length;

bolt nuts - 4 pcs, 16 mm in diameter;

washers for bolts - 8 pcs.

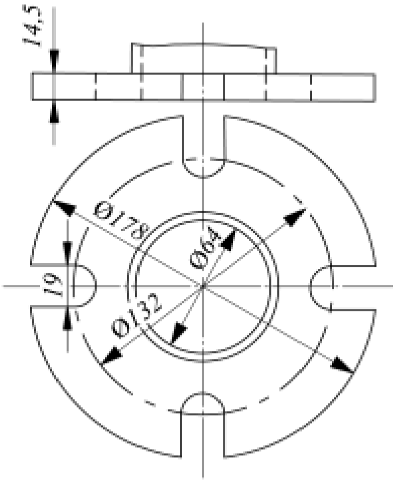

Fig. 5.1.18
International shore connection (ship)

On one side the shore connection shall have a flat-faced flange with dimensions as above, and on the other a quick-acting coupling which shall correspond to the ship's hydrants and hoses both in dimensions and design.

The shore connection, gasket, bolts and nuts shall be made of materials suitable for 1,0 MPa.

The shore connection complete with gasket, four bolts, four nuts and eight washers shall be stowed together with other items of fire fighting outfit in an easily accessible position.

5.1.19 Portable medium expansion mechanical foam generators and portable combination-foam production units shall comply with the following requirements:

.1 concentrate solution discharge at a pressure of 0,6 MPa, not less than 360 l/min (refer also to 3.7.2.2);

.2 foam jet range, at least 8 m;

.3 rated number of foam generators/units shall be determined by the formula

$$N=Q/q \qquad (5.1.19.3)$$

where Q - solution capacity of the system, in l/min;

q - solution capacity of a foam generator/unit, in l/min.

50 % of the foam generators/units and extension pipes required by items 2.4 and 2.5 of Table 5.1.2 shall be placed in the poop, the remainder, in the forecastle and midship superstructure, if any.

5.1.20 For applicator shall consist of L-shaped pipe with long side of about 2 m fitted for connection to fire hoses and short side of about 0,25 m equipped with fixed nozzle for producing water for or fitted for connecting water-spraying nozzle.

These applicators shall be located near the fire hydrants and those for breathing apparatus near the latter.

5.1.21 Fire buckets shall be provided with the hemp rope of sufficient length and shall be stowed on the open decks in easily accessible places. The buckets shall be painted red and bear inscription "**FIRE**".

5.1.22 In tankers and combination carriers gas analyzers shall meet the following requirements:

.1 provision shall be made for use of gas analyzers with gas sampling pipes as specified in 9.14.1, Part VIIII "Systems and Piping";

.2 suitable means shall be provided for the calibration of gas analyzers;

.3 gas analyzers shall be provided with a set of spares supplied by the manufacturer.

Alternatively ship may be additionally equipped with one portable instrument for measuring oxygen and one for measuring flammable vapour concentrations, or with two gas analyzers, each capable of measuring both oxygen and flammable vapour concentrations.

5.1.23 In all passenger and cargo ships of 500 gross tonnage and over provision shall be made for emergency escape breathing devices (EEBD) of a Register-approved type which shall be only used for emergency escape from a compartment with a hazardous atmosphere. EEBD shall not be used by crew for fighting fires, entering oxygen deficient void spaces or tanks. In such cases a self-contained breathing apparatus specified in **5.1.15.2** shall be used.

EEBD shall meet the following requirements:

.1 EEBD shall provide service duration of at least 10 min;

.2 EEBD shall protect eyes, nose and mouth during escape and consist of a helmet fully covering head, neck and may cover portions of the shoulders, or a mask fully covering the face so as to form a complete seal around the eyes, nose and mouth, which is secured by suitable means. The helmets and masks shall be manufactured of flame resistant materials and include a clear window for viewing;

.3 an inactivated EEBD shall be carried hands-free;

.4 EEBD shall be designed so that to enable quick and easy dressing. Brief instructions or diagrams clearly illustrating their use shall be clearly printed on each EEBD.

An EEBD, when stored, shall be suitably protected from weather exposure.

Maintenance requirements, manufacturer's trademark and serial number, shelf life and date of manufacture shall be printed on each EEBD. EEBD intended for training shall have appropriate distinct marking.

The number and location of EEBD shall be indicated on fire control plans (refer to **1.4**).

5.2 SPARE PARTS AND TOOLS

5.2.1 A ship shall carry spare parts and tools, the number of which shall be not less than that specified in Table 5.2.1.

Table 5.2.1

Nos.	Description of spare parts and tools	Number per ship
1	**2**	**3**
1	Water fire main system: .1 a fire hose of each length and diameter fitted complete with couplings	1 pc of each
	.2 connection couplings for each size fitted (if the ship is provided with hydrants of various diameters)	2 pcs
	.3 quick-acting couplings (hose couplings)	2 pcs (of each diameter)
	.4 quick-acting couplings (hose couplings) for ships of 4000 gross tonnage and upwards	4 pcs (of each diameter)
	.5 rubber rings for packing of joints between couplings, hoses and apparatuses	5 % of total number, but not less than 10 pcs
	.6 hose clamps	4 pcs (for ships of less than 300 gross tonnage, as many as the number of hoses, but not more than 4)
	.7 wrenches for engaging or disengaging couplings (where nozzles are fitted by means of a special wrench)	according to the number of hydrants.
	.8 fire hydrant of each size fitted, in assembly	1 pc of each size
	.9 handwheel to fire hydrant of each size fitted	1 pc of each size
	.10 valve disks with packing rings to fire hydrants of each size fitted	1 pc of each size
2	Sprinkler system: .1 sprinkler heads, in assembly	The number of spare sprinkler heads shall be determined proceeding from their

		type and number already fitted on board: 6 – for systems having less than 300 heads; 12 – for systems having 300 to 1000 heads; 24 – for systems having more than 1000 heads
	.2 wrenches for sprinkler heads (where heads are fitted by means of a special wrench)	1 pc per section
	.3 parts for control valve	1 set, according to delivery specification
3	Pressure water-spraying, water-screen, drenching systems: .1 spray nozzles of various types fitted in the system	5 % of total number of spray nozzles fitted
	.2 wrench for spray nozzles (where nozzles are fitted by means of a special wrench)	1 pc
4	Foam fire extinguishing system: .1 hydrant of each size fitted, in assembly	1 pc
	.2 fixed air-foam nozzle or foam generator	1 pc
	.3 gauge glasses for tanks	1 pc
	.4 rubber rings for joints	10 pcs
5	Carbon dioxide smothering system: .1 cylinder valves, assembled; for the number of cylinders: below 50 50 to 100 100 and over	 1 pc 2 pcs 3 pcs
	.2 wrenches for assembling and disassembling cylinder valves and other special valves	set per station
	.3 plugs to be fitted on pipes leading from cylinder valves, when cylinders are removed	25 % of the number of cylinders
	.4 protective diaphragms	In accordance with the number of cylinders
	.5 thrust bushes and washers for protective devices	10 % of the number of cylinders
	.6 non-return valves	5 % of total number, but not less than 1 pc
	.7 discharge nozzles of each type and size fitted	2 pcs
	.8 scales for weighing cylinders or carbon dioxide level gauge	1 pc
	.9 parts of tank carbon dioxide contents gauge	In accordance with delivery specification
6	Dry powder system: .1 parts of release devices for hand hose lines and monitors	set of each
	.2 nozzles of each type and size	1 - 2 pcs
	.3 wrenches for assembling and disassembling valves, hand hose lines, nozzles	1 set
7	Aerosol system: .1 generator of fire extinguishing aerosol	One generator of each type used
8	Miscellaneous items, for all systems: .1 instruments and gauges: pressure gauges, vacuum gauges, thermometers of each type fitted in systems	1 pc of each
	.2 adequate quantity of packing material for onboard repairs	1 set
	.3 fuses for automatic closing of fire doors and dampers	In accordance with number of doors and dampers thus controlled
	.4 spare parts for pumps, fans, compressors and engines	In accordance with Section 5, Part

	serving fire extinguishing systems	VII "Machinery Installations"
	.5 spare parts for electrical equipment of fire extinguishing systems	In accordance with Section 21, Part XI "Electrical Equipment"

The quantities prescribed in the Table apply to fixed fire extinguishing systems only.

5.2.2 The spare parts and tools for the systems shall be kept in the fire extinction stations.

Spare parts shall be suitably marked.

6 REQUIREMENTS FOR FIRE PROTECTION OF SPECIAL PURPOSE SHIPS AND SPECIAL FACILITIES ON SHIPS

6.1 SHIPS EQUIPPED WITH HELIDECKS

6.1.1 Fire protection measures for helidecks.

6.1.1.1 Requirements of this subsection supplement the requirements of Sections **1 – 5** and shall apply to helidecks and its fuel filling equipment, as well as to helicopter hangars.

H a n g a r is a purpose-built space for helicopter storage and/or maintenance and repair.

H e l i d e c k is a purpose-built helicopter take-off and landing area including all structures, firefighting appliances and other equipment necessary for the safe operation of helicopters.

H e l i c o p t e r f a c i l i t y is a helideck with helicopter refueling, compressed gases facilities, if any, and special liquids facilities, helicopter service spaces, if any, and a hangar.

6.1.2 Fire protection of helidecks.

6.1.2.1 The helideck shall be provided with both main and emergency means of escape and access for fire-fighting and rescue personnel. These shall be located as far apart from each other as practicable, and preferably on the opposite sides of the helideck.

If more than 50 % of the helideck area is projected from the main ship structure, it is recommended to arrange two entrances to helideck within the range of such overhanging parts that is providing at least one exit from helideck to windward side in case of fire.

6.1.2.2 Helideck shall be protected by a fixed foam fire extinguishing system according to item 20 of Table 3.1.2.1 of Part VI "Fire Protection".

6.1.2.2.1 Fixed foam fire extinguishing system.

The minimum foam system discharge rate shall be determined the helideck area and foam discharge rate The minimum foam system discharge rate shall be determined by multiplying the *D*-value area by 6 $l/min/m^2$.

The quantity of foam concentrate shall be adequate to allow operation of all connected discharge devices for at least 5 min. The foam system shall be designed to discharge foam with nominal flow and at design pressure from any connected discharge devices within 30 s of activation.

The foamer must be suitable for sea water and at least meet the minimum requirements of International Civil Aviation Organization (ICAO).

The location and characteristics of the equipment of the foam fire extinguishing system shall provide extinguishing of fire on helicopter high-level units.

It is recommended to provide additionally 100 % reserve of foam concentrate for supply of its calculated value in case of helicopter landing after partial use of foam concentrate in testing, drills or fire extinction.

6.1.1.2.2 Water fire extinguishing system.

The number and position of fire hydrants shall be such that at least two jets of water may reach any part of the helideck.

6.1.1.2.3 In close proximity to the helideck the following fire-fighting outfit shall be provided and stored near the means of access to that helideck:

.1 at least two dry powder fire extinguishers having a total capacity not less than 45 kg;

.2 carbon dioxide fire extinguishers having a total capacity not less than 18 kg or equivalent; fire extinguishers shall be equipped with flexible nozzles for extinguishing a fire in the upper part of a helicopter;

.3 at least two nozzles of an approved dual-purpose type with hoses sufficient to reach any part of the helideck;

.4 at least two sets of fireman's outfits in addition to those required by item **10** of Table 5.1.2;

.5 at least the following equipment stored to provide its immediate use and protection from weather exposure:

adjustable wrench;
blanket (fire resistant);
cutter with at least 60 cm handle;
hook, grab or salving;
hacksaw, heavy duty, complete with 6 spare blades;
ladder;
lift line of 5 mm diameter and 15 m in length;
pliers, side-cutting;
set of assorted screwdrivers;
harness knife complete with sheath;
large crowbar (recommended);
3 pairs of fire resistant gloves (recommended);
large rescue axe (recommended);
side cutting pliers (tin snips) or equivalent cutting tool (recommended).

6.1.1.2.4 Drainage facilities in way of helidecks shall comply with the requirements of **7.12.6**, Part VIII «Systems and piping».

6.1.3 Fire protection of hangars and spaces where helicopter refuelling and maintenance facilities are located.

6.1.3.1 Structural fire protection, fixed fire extinguishing systems and fire detection and alarm systems and fire-fighting outfit for hangars and spaces where helicopter refuelling and maintenance facilities are located shall be similar to those of category A machinery spaces.

6.1.3.2 The boundary structures of hangars and spaces where helicopter refuelling and maintenance facilities are located shall be made of steel.

6.1.3.3 Refuelling station for helicopters shall meet the following requirements:

.1 the boundaries and means of closing openings at the station shall secure gas tightness thereof. Doors leading to the station shall be of steel;

.2 deck covering shall preclude spark formation. Arrangements and machinery shall be so arranged and located as to exclude the possibility of spark formation;

.3 pipelines and cables passing through the boundaries of the station shall not cause loss of its gas tightness;

.4 storage tank fuel pumps shall be provided with means which permit remote shutdown from a safe location in the event of a fire. Where a gravity-fuelling system is installed, equivalent closing arrangements shall be provided to isolate the fuel source;

.5 where several fuel tanks are fitted, the fuel system design shall provide for fuel supply to the helicopter being refuelled only from one tank at a time;

.6 provision shall be made for the arrangement whereby a fuel spillage may be collected and drained into an off-grade fuel tank;

.7 fuel oil piping shall be of steel or equivalent material, as short as possible, and protected against damage;

.8 the refuelling facility shall incorporate a metering device to record the quantity of supplied fuel, a flexible hose with a nozzle fitted with a self-closing valve and a device to prevent over-pressurization of the fuel system.

6.1.3.4 The number and position of the hydrants shall be such that at least three jets of water may reach any part of the hangar.

6.1.3.5 "NO SMOKING" signs shall be displayed at appropriate locations in hangars and spaces where helicopter refuelling and maintenance facilities are located.

6.1.3.6 Storage of flammable liquids and materials, paint materials, lubricating oils, hydraulic liquids and any types of fuel in hangar is not allowed.

6.2 SPECIAL PURPOSE SHIPS

6.2.1 General.

6.2.1.1 The fire protection of special purpose ships shall be arranged depending on the number of persons carried on board:

.1 not more than 60 persons - equivalent to that of cargo ships of more than 500 gross tonnage;

.2 more than 60, but not more than 240 persons - equivalent to that of passenger ships carrying not more than 36 passengers;

.3 more than 240 persons - equivalent to that of passenger ships carrying more than 36 passengers.

6.2.1.2 Fire protection of working spaces specified in **1.5.8** shall be arranged with due regard for the purpose of the working space and equipment located therein. As a rule the fire protection of working spaces shall be equivalent to that of service spaces specified in **1.5.3**.

6.2.2 Storerooms for explosives (magazines).

6.2.2.1 In special purpose ships the arrangement of storerooms for explosives (magazines) may be permitted. The magazines shall be of the following types:

.1 integral magazines forming an integral part of the ship;

.2 portable magazines that are non-integral, portable magazines with a capacity of 3 m^3 or greater;

.3 magazine boxes that are non-integral, portable magazines with a capacity of less than 3 m^3.

6.2.2.2 Integral magazines shall be located in the forward or after portion of the ship and be located not less than one watertight space apart from the propeller shaft, propeller and rudder. They shall not be located below accommodation spaces, control stations and be adjacent to them.

6.2.2.3 Integral magazines shall not be adjacent to machinery spaces of category A, galleys and other dangerous spaces. If it is necessary to locate the magazine in proximity to these areas, a cofferdam of at least 0,6 m shall be provided separating two spaces. Such a cofferdam shall not be used for stowage and shall be provided with ventilation. One of the bulkheads forming the cofferdam shall be of "A-15" class, if it is adjacent to machinery space of category A it shall be "A-30" class.

6.2.2.4 Access to integral magazines shall preferably be from the weather deck, but in no case through spaces specified in **6.2.2.2** and **6.2.2.3**.

6.2.2.5 Portable magazines and magazine boxes shall be located on a weather deck in a location protected from direct impact of the sea. The location shall provide sufficient protection against warm air and hazardous vapours being emitted from galleys, pump rooms, etc. Due regard shall be paid to possible risk of subjecting certain explosives to radio emissions.

6.2.2.6 Magazine boxes shall be located on a weather deck at least 0,1 m from the deck and any deckhouse and in a position suitable for jettisoning the contents.

6.2.2.7 Bulkheads and decks bounding integral magazines shall be of watertight construction of "A-15" class. If the spaces adjacent to the magazines contain no combustible materials the construction may be of "A-0" class. Insulation shall be provided to prevent condensation of moisture.

6.2.2.8 Piping of fresh or salt water and drainage systems and piping of systems installed in the magazines themselves may be routed through magazines. Piping of other systems shall be permitted only if they are enclosed in a watertight trunk.

6.2.2.9 The magazines shall be provided with means to ensure their effective closing and to prevent unauthorized access.

6.2.2.10 Racks, supports and other means shall be installed, the construction and capacity of which shall provide safe stowage of explosives in their approved containers with minimum dunnage and to prevent them from shifting and falling when the ship is rolling.

The upper rack shall not be located higher than 1,8 m above the deck. The racks shall have holes for water flowing from the upper to the lower racks during operation of the drenching system.

6.2.2.11 Decks of magazines shall be covered with a permanent non-slip, non-sparking covering.

6.2.2.12 A free volume of the magazine, when loaded, shall be at least 70 % of the entire magazine volume. Not more than 100 kg of explosives or 1000 detonators shall be placed for each 1 m^2.

6.2.2.13 Integral magazines shall be provided with natural or mechanical ventilation fitted with flame arresters sufficient to maintain the magazine temperature not higher than 38°C.

6.2.2.14 Portable magazines shall have watertight metal construction insulated with non-combustible materials on the inside as a construction of "A-15" class.

6.2.2.15 Portable magazine shall bear a label indicating mass in light condition and maximum permissible mass of explosives.

6.2.2.16 Portable magazines shall be provided with efficient natural ventilation fitted with flame arresters.

6.2.2.17 Magazines shall be fitted with automatic heat detectors operating at temperatures rising above 40°C. An appropriate visible and audible alarms actuated by this detector shall be provided in the wheelhouse and in the chief mate's cabin.

6.2.2.18 Integral and portable magazines shall be fitted with drenching systems in accordance with 3.6. The controls shall be clearly marked with indication of their purpose.

6.2.2.19 Magazines shall be fitted with scuppers. The scupper pipes shall be provided with valves which shall be kept permanently closed under normal service conditions. The valves shall be controlled from outside the magazines.

6.2.2.20 Integral and portable magazines shall be clearly marked:

"The space is a magazine";

"Open lights and flame shall be kept away";

"The magazine door shall be locked";

"Matches and lighters shall be removed prior to entering";

"Do not lift with contents" (in case of portable magazines).

6.2.2.21 Magazine boxes shall have watertight metal construction with walls and lids not less than 3 mm thick. Boxes exposed to sunrays shall be protected with solar screens.

6.2.2.22 Magazine boxes shall be clearly labeled:

"The container is a magazine box";

"Open lights and flame shall be kept away";

"The box shall be locked".

6.2.2.23 Electrical equipment in magazines shall comply with the requirements of **19.4.3**, Part XI "Electrical Equipment"and other applicable requirements of the above Part.

6.2.2.24 Detonators shall be stowed separately from other explosives.

6.2.2.25 Charging of cartridges and other preparatory operations for using explosives shall be made in charging rooms which shall be specially provided for that purpose. Charging rooms shall be arranged in steel enclosures and located on the weather deck apart from control stations, accommodation and service spaces. Bulkheads, decks and equipment of the charging rooms shall be faced with non-sparking materials.

6.2.3 Carriage of dangerous goods.

Dangerous goods on special purpose ships shall be carried in accordance with the provisions of Chapter 7 "Dangerous Goods" of the SPS Code[12], as amended.

6.3 OIL TANKERS (> 60°C)

6.3.1 The fire protection of oil tankers (> 60°C) shall be equivalent to that of cargo ships having regard of the following:

.1 a fixed deck foam fire extinguishing system complying with the requirements of **3.7** shall be fitted;

.2 the water fire main system shall additionally meet the requirements of **3.2.5.4**;

.3 two additional sets of fireman's outfit in accordance with item **10.2** of Table 5.1.2 shall be provided.

6.3.2 In addition to the requirements of **6.3.1** the following shall be provided:

.1 cargo tanks shall not be adjacent to accommodation spaces;

.2 air intakes and other openings leading to accommodation spaces shall not be faced to cargo area.

Entrance doors in bulkheads of superstructures and deckhouses facing cargo area may be installed only in cases if they do not lead to accommodation spaces;

.3 a continuous coaming not less than 150 mm high extending from side to side shall be fitted on the upper deck at a distance of about 2 m from a superstructure where accommodation and service spaces are arranged;

.4 machinery spaces of category A shall be in general arranged aft beyond cargo and slop tank area.

6.3.3 Where cargo heating arrangements are fitted, provision shall be made to prevent cargo from heating up to the temperature which is not less than 15°C lower than the flash temperature.

6.4 OIL RECOVERY SHIPS AND BILGE WATER REMOVING SHIPS

6.4.1 The fire protection of oil recovery ships shall be equivalent to that of oil tankers to the extent applicable for the individual ship project and, in addition, meet the requirements of 6.4.4 - 6.4.10.

When exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks, which support such accommodation, are protected by a steel bulkhead screening

[12] Refer toIMO Resolution MSC.266 (84): "Special Purpose Ship Safety Code 2008 (SPS Code)".

them from the cargo area and installed at a distance of minimum 3 m from them from side to side, compliance with the requirements of **2.4.3**, as well as of **2.4.4** and **2.4.5** is not required. Openings for free passage of people, ship systems piping, mooring and towing lines etc., the total area of which at each tier of a superstructure or a deckhouse shall not exceed 10 % of the area equal to the width of the side multiplied by the height of the tier of the superstructure or deckhouse, are permitted in the screening bulkhead.

6.4.2 The fire protection of oil recovery ships (> 60°C) shall be equivalent to that of oil tankers (> 60°C) and in addition meet the requirements of **6.4.4** and **6.4.10**.

6.4.3 The fire protection of bilge water removing ships shall be equivalent to that of oil tankers (> 60 °C) and in addition meet the requirements of **6.4.10**.

6.4.4 The hull, superstructures, structural bulkheads, decks and deckhouses shall be manufactured of steel. The use of aluminium alloys for this purpose is not permitted.

6.4.5 The spaces intended for removable equipment which is used for oil recovery shall meet the following requirements:

.1 fire integrity of their structures shall meet the requirements of **2.4.2** for service spaces of category (*9*);

.2 they shall be protected by fire extinguishing system according to item 6 of Table 3.1.2.1;

.3 may be regarded as cofferdams specified in **2.4.7**.

6.4.6 The ship shall be protected by a fixed water spraying system with the rate of water discharge

.1 10 l/min per 1 m of the exterior boundaries of superstructure;

.2 5 l/min per 1 m^2 of the horizontal area of the cargo zone.

A fixed water spraying system, specified in **6.4.6.2**, may not be installed if the fixed deck foam system provides effective cooling by water of all area of a cargo zone by monitors remotely controlled from the wheelhouse.

controlled from the navigating bridge.

6.4.7 The water fire main system and drenching and foam fire extinguishing systems specified in **6.4.6** shall use sea water coming only from sea openings arranged in ship's bottom.

6.4.8 Remote starting of fire pumps, fixed fire extinguishing systems for machinery space of category A and drenching systems specified in **6.4.6** shall be provided from navigation bridge.

6.4.9 The high expansion foam system shall not be used for protection of spaces specified in **6.4.5**.

6.4.10 The ship shall be provided with a fixed or portable oil flash point tester.

6.4.11 For small ships of up to 1000 t deadweight periodically engaged in recovery of oil products at the sea surface, the fixed automatic system for atmosphere monitoring may be replaced, on agreement with the Register, by a monitoring system with portable analyzers specified in item **15.1** of Table 5.1.2.

Atmosphere monitoring shall be applied during the whole period of stay of the ship within oil spot in locations specified in **9.14.5**, Part VIII "Systems and Piping".

6.5 BERTH-CONNECTED SHIPS

6.5.1 The fire protection of berth-connected ships used as floating hotels, hostels, offices and restaurants shall be designed depending on the number of residents or persons who sojourn therein during working hours:

.1 up to 60 persons - equivalent to that of cargo ships of more than 500 gross tonnage;

.2 from 60 up to 200 persons - equivalent to that of passenger ships carrying not more than 36 passengers;

.3 more than 240 persons - equivalent to that of passenger ships carrying more than 36 passengers.

6.5.2 The fire protection of floating docks, cranes, power plants, workshops, warehouses and other ships shall be equivalent to that of cargo ships of more than 500 gross tonnage.

However, in case of 50 and more residents or persons who sojourn therein during working hours, other than crew members, the fire protection shall comply with the requirements of **6.5.1.2** or **6.5.1.3**.

6.5.3 For berth-connected ships operating at shore quay wall the Register may revise the requirements specified in **6.5.1** and **6.5.2**, taking into account operating conditions of the ship and its fire protection determined by the ship designer on agreement with the customer.

6.6 SHIPS HAVING A DISTINGUISHING MARK FOR A SHIP CARRYING EQUIPMENT FOR FIRE FIGHTING ABOARD OTHER SHIPS

6.6.1 The fire protection of ships having a distinguishing mark for a ship carrying equipment for fire fighting aboard other ships shall be equivalent to that of other ships with due regard for the following:

.1 hull, superstructures, deckhouses and decks shall be made of steel. In ships having distinguishing marks **FF1WS**, **FF2WS**, **FF3WS** in class notation, the superstructures and deckhouses may be manufactured of aluminum alloys, provided they are protected with fire protection systems in compliance with **6.6.6** or **6.6.7**;

.2 structural fire protection shall be made in compliance with the *IC method*.

6.6.2 Ships shall be provided with a fire and rescue operations control station. The control station shall be placed so that the ship structures do not impair, as far as practicable, the vision of the water around the ship.

6.6.3 The ships shall have:

special systems and equipment, the minimum number of which is indicated in Tables 6.6.3-1 and 6.6.3-2;

items of fire-fighting outfit in compliance with **6.6.11.1**;

additional bilge arrangements (systems) and additional reserve of fuel in accordance with **7.1.10** and **13.7.7**, Part VIII "Systems and Piping";

additional internal service communications in compliance with **7.2.2**, Part XI "Electrical Equipment".

6.6.4 Special systems installed on board ships for fire-fighting on other objects and for their own protection (water-screen, drenching, water fire main, foam fire extinguishing, dry powder systems) shall also comply with the requirements of Section **3** of this Part and Sections **2**, **4**, **5**, Part VIII "Systems and Piping".

Where special systems other than specified in this Section of the Rules are installed, they shall comply with the requirements of the Rules to the extent agreed with the Register in each particular case.

Table 6.6.3-1

Special systems	Distinguishing mark in the class notation				
	FF1	**FF1WS**	**FF2**	**FF2WS**	**FF3WS**
Water-screen system[1]	-	+	-	+	+
Drenching system[1]	-	+	-	+	+
Water fire main system	+	+	+	+	+[2]
Foam fire extinguishing system	+	+	+	+	+
Dry powder system	+[3]	+[3]	+[3]	+[3]	+[3]
Bilge system[4]	+	+	+	+	-

[1]Refer to **6.6.6.6**.
[2]Refer to **6.6.8.2**.
[3]Refer to **6.6.10.1**.
[4]Refer to **7.1.10**, Part VIII "Systems and Piping".

Table 6.6.3-2

Special equipment	Distinguishing mark in the class notation		
	FF1 **FF1WS**	**FF2** **FF2WS**	**FF3WS**
Pumps, in pcs			
Monitors:			
water monitors, in pcs	4	3	2
with supply rate of each monitor, in m3/hour	2500	1200	100[1] /500/1000
jet range, in m	150	120	80[1] /100/120
foam monitors, in pcs	2	-[2]	-[2]
Dry powder monitors[3]), in pcs	1	1	1
Distribution valve manifolds, in pcs	4	4	2

[1]The smaller value is for ships referred to in **6.6.8.2**.
[2]A necessity in installation and characteristics to be indicated by the customer in accordance with the requirements of **6.6.9.2**.
[3]For ships referred to in **6.6.10.1**.

6.6.5 The equipment of special systems (pumps, fittings, monitors) may be remote-controlled from the fire and rescue operations control station.

Air-operated and hydraulic control systems shall be supplied from two independent sources of power.

Electrically driven items shall comply with the requirements of **5.1** to **5.3**, Part XI "Electrical Equipment".

6.6.6 Water-screen system.

6.6.6.1 In ships having distinguishing marks **FF1WS**, **FF2WS** and **FF3WS** in the class notation, outer vertical hull surfaces, including superstructures and deckhouses, shall be protected with the water-screen system.

The water-screen system shall totally cover the ship and not impede visibility from the wheelhouse, fire and rescue operations control stations and manually operated monitor platforms.

6.6.6.2 Doors and side scuttles of ships having distinguishing marks **FF1** or **FF2** in the class notation, which are not fitted with the above system, shall comply with the requirements of **7.2.1.10**, Part III "Equipment, Arrangements and Outfit".

6.6.6.3 The capacity and pressure of pumps serving the system shall be sufficient to supply water through spray nozzles at a rate indicated in **3.5.2**.

6.6.6.4 Where the system is subdivided into sections, manual operation shall be provided from the place of their installation in spite of the provision of the remote control.

6.6.6.5 The water-screen system shall protect also the manually operated monitor platforms; the system shall be put into operation directly at each monitor.

6.6.6.6 The ship shall be fitted with water-screen system in combination with the drenching system or pressure water-spraying system, or drenching system with water discharge rate specified in **6.6.7.2** or pressure water-spraying system with water discharge rate specified in **6.6.7.2** provided they are capable to ensure adequate protection of all the outer surfaces of the ship. In any case the letters **WS** shall be retained in the class notation.

6.6.7 Drenching and pressure water-spraying systems.

6.6.7.1 The drenching and pressure water-spraying system in ships having distinguishing marks **FF1WS**, **FF2WS** or **FF3WS** in the class notation shall protect outer vertical surfaces of the hull, superstructures and deckhouses as well as horizontal surfaces of the hull where it is appropriate with regard to **6.6.6.6**.

6.6.7.2 The rate of water discharge to the protected surface shall be: 10 l/min per 1 m^2 for vertical areas (non-insulated) and 5 l/min per 1 m^2 for vertical areas insulated to "A-60" class;

6.6.7.3 For protection of superstructures and deckhouses the sections of the system shall be arranged on each tier; the arrangement of spray nozzles shall ensure uniform discharge of water onto the protected outer surface. Where the system is subdivided into sections, the requirements of **6.6.6.4** shall be met.

6.6.8 Special water fire extinguishing system.

6.6.8.1 The system is generally intended for water supply to water monitors, distribution valve manifolds, as well as for supply of water-screen and pressure water-spraying systems. The system may be used for pumping out the water from compartments of a ship in distress (refer to **7.1.10**, Part VIII "Systems and Piping").

The requirements for installation of pumps, laying of pipes, water intake arrangements, fittings and tests shall comply with the provisions of the present Part and Part VIII "Systems and Piping" as far as they are applicable and reasonable with regard to the requirements given below.

6.6.8.2 The special water fire extinguishing system in ships having distinguishing marks **FF1**, **FF1WS**, **FF2** or **FF2WS** in the class notation shall be independent.

In ships having distinguishing mark **FF3WS** in the class notation, the ship water fire main system may be used as part of the special water fire extinguishing system.

6.6.8.3 Availability of remote starting and control of the system shall not prevent starting of the pumps, control of monitors and fittings from the place of their installation (refer to Section 5, Part XI "Electrical Equipment"). Remote-controlled fittings shall have devices for their opening/closing during the time allowing to prevent water hammers.

6.6.8.4 Provision shall be made for operation of pumps without overheating in case of no or small supply of water to consumers.

6.6.8.5 The number of monitors shall be not less than that indicated in Table 6.6.3-2 and their arrangement shall: provide supply of water from each monitor to both sides of the ship; prevent water from being discharged to the ship's own deck and its equipment; provide the water jet range in accordance with Table 6.6.3-2.

6.6.8.6 Each monitor shall have an independent connection to the main of the system.

6.6.8.7 Distribution valve manifolds shall be arranged on the weather deck. The number of valves on the manifold shall be determined by the designer upon agreement with the customer.

6.6.8.8 The capacity of the pumps shall be calculated so that water can be simultaneously delivered to monitors, the number of which shall comply with Table 6.6.3-2 depending on the distinguishing mark in the class notation.

6.6.9 Special foam fire extinguishing system.

6.6.9.1 The special foam fire extinguishing system shall be provided in ships having distinguishing marks for a ship carrying equipment for fire fighting aboard other ships. The system may use totally or partly the equipment of the special water fire extinguishing system (pumps, pipes, monitors).

The number and type of the equipment of the foam fire extinguishing system shall be determined by the designer on agreement with the customer.

6.6.9.2 Ships with distinguishing marks **FF2**, **FF2WS** or **FF3WS** in the class notation may have the system fitted with air-foam nozzles, foam generators or combination foam units, in this case foam monitors may be omitted.

6.6.9.3 Ships with distinguishing marks **FF1** or **FF1WS** in the class notation shall be fitted with foam monitors or foam nozzles for monitors of the special water fire extinguishing system, The number of foam monitors shall be not less than that indicated in Table 6.6.3-2; the requirements for their installation shall be in line with those for monitors of the special water fire extinguishing system (refer to 6.6.8.5).

6.6.9.4 The reserve of foam concentrate shall be calculated on the basis of the operating time of a specified number of foam generators or one monitor during at least 30 min.

6.6.9.5 The type of foam concentrate shall be chosen with regard for water salinity in the prescribed ship service area, and class of liquids, materials or goods the concentrate is intended to extinguish (oil and petroleum products, alcohols, ketons, aldehydes, etc.).

6.6.10 Special dry powder system.

6.6.10.1 The system shall be generally installed on ships servicing the operation area of gas carriers and chemical tankers.

6.6.10.2 Applicable requirements of 3.10 also cover the special dry powder system.

6.6.10.3 The powder rate through the monitor shall be not less than 40 kg/s. The monitor shall be placed on a special platform fitted with devices for remote starting of the system (refer to 6.6.6.5).

6.6.10.4 The quantity of the extinguishing powder shall be determined by the designer on agreement with the customer.

6.6.11 Fire-fighting outfit.

6.6.11.1 In addition to the fire-fighting outfit specified in Table 5.1.2, the following outfit shall be provided on board ships:

fireman's outfits;
fire hoses;
dual-purpose manual fire nozzles;
portable air-foam nozzles, foam generators or combination foam units;
international shore connections;
complete sets of fire-fighting tools;
gas analyzers for flammable vapours and gases;
induced-draught fans.

The number and composition of the additional fire-fighting outfit and spare parts thereto shall be determined by the designer on agreement with the customer.

6.6.11.2 Additional fire-fighting outfit shall be kept in special storerooms.

Part of the fire-fighting outfit (hoses, hand nozzles, foam generators, air-foam nozzles, hose wrenches) may be placed at the fire stations near each distribution valve manifold.

6.6.11.3 For charging cylinders of self-contained compressed air breathing apparatus ships shall be provided with compressors approved by competent authorities.

The capacity and the number of simultaneously charged cylinders shall be specified by the customer.

There shall be at least four charged cylinders on board the ship.

The need for a compressor to be provided on board ship may be specially considered by the Register depending on the main purpose of the ship and number of crew.

6.6.11.4 Ships shall have two searchlights in accordance with **9.2.12**, Part III "Equipment, Arrangements and Outfit".

6.7 CONTAINER SHIPS AND SHIPS DESIGNED TO CARRY CONTAINERS ON OR ABOVE THE WEATHER DECK

6.7.1 For open-top container holds and on deck container stowage areas on container ships and other ships designed to carry containers on or above the weather deck, fire protection arrangements shall be provided for the purpose of containing a fire in the space or area of origin and cooling adjacent areas to prevent fire spread and structural damage.

6.7.2 Container ships and other ships designed to carry containers on or above the weather deck shall carry, in addition to the equipment and arrangements required for cargo ships by Sections **3** and **5**, at least one water mist lance (refer to **1.2**).

6.7.3 Ships designed to carry five or more tiers of containers on or above the weather deck shall carry, in addition to the requirements of **6.7.2**, mobile water monitors as follows:

.1 mobile water monitors shall be of an approved type and shall comply with the requirements of IMO circular MSC.1/Circ.1472;

.2 mobile water monitors with all necessary hoses, fittings and required fixing hardware shall be kept ready for use in a location outside the cargo space area not likely to be cut-off in the event of a fire in the cargo spaces;

.3 the mobile water monitor can be securely fixed to the ship structure ensuring safe and effective operation, and the jet reaches the top tier of containers with all required monitors and water jets from fire hoses operated simultaneously, that shall be tested during initial survey on board the ship.

6.7.4 The number and arrangement of mobile water monitors shall comply with the following requirements:

.1 for ships with breadth less than 30 m: at least two mobile water monitors, or ships with breadth of 30 m or more: at least four mobile water monitors;

.2 all provided mobile water monitors can be operated simultaneously for creating effective water barriers forward and aft of each container bay;

.3 fire hydrants for connecting mobile water monitors shall be so arranged that two jets of water required by 3.2.6.2 shall be supplied at the pressure required by **3.2.1.1**;

.4 each of the required mobile water monitors can be supplied by separate hydrants at the pressure necessary to reach the top tier of containers on deck.

6.7.5 In cases where the mobile water monitors are supplied by separate pumps and piping system, the total capacity of the main fire pumps and the diameter of the fire main and water service pipes shall be determined in accordance with **3.2.1.7** and **3.2.5.1**.

6.7.6 in cases where the mobile water monitors are supplied by the main fire pumps; the total capacity of main fire pumps and the pipework diameter shall be sufficient for simultaneously supplying both the required number of fire hoses and mobile water monitors. However, the total capacity shall not be less than the following values, whichever is smaller:

.1 required under **3.2.1.5.2**;

.2 180 m^3/h.

6.7.7 In cases where the mobile water monitors and the water spraying system required for carriage of dangerous goods by **7.2.5.3**, are supplied by the main fire pumps, the total capacity of the main fire pumps and the pipework diameter need only be sufficient to supply whichever of the following is the greater:

.1 the mobile water monitors and the four nozzles required by **7.2.5.2**; or

.2 the four nozzles required by **7.2.5.2** and the water spraying system required by **7.2.5.3**.

The total capacity, however, shall not be less than **6.7.6.1** or **6.7.6.2**, whichever is smaller.

6.7.8 On board container ships designed to carry five or more tiers of containers on or above the weather deck, the total capacity of the emergency fire pump need not exceed 72 m^3/h.

6.8 SHIPS USING NATURAL GAS AS FUEL

6.8.1 General.

6.8.1.1 Fire protection of ships using natural gas as fuel shall comply with the requirements of this Chapter in addition to the requirements of **1 - 5** depending on the ship purpose.

6.8.2 Structural fire protection.

6.8.2.1 Structures enclosing acommodation and service spaces, control stations, evacuation routes, machinery spaces facing gas fuel storage tanks located on the weather deck shall be protected by class A-60 divisions. These class A-60 divisions shall extend to the lower boundary of the wheelhouse/ deck house deck.

Structures above the enclosures, including wheelhouse/deck house windows, shall be of class A-0.

Gas fuel storage (FCS) tanks shall be isolated from the cargo and placed in accordance with the requirements of the IMDG Code (srefer to 7.1.2), and shall be considered as cargo in Class 2.1 package.

6.8.2.2 Spaces for storage of gas fuel tanks and servicing ventilation ducts shall be separated from acommodation, service, cargo and machinery spaces by fire-protecting structures of class A-60, from other spaces with low fire danger they may be separated by class A-0 fire-divisions.

Spaces, in which fuel retention system equipment is located shall be separated from category A machinery spaces and other spaces with high fire risk by a cofferdam not less than 900 mm wide, insulated according to class A-60. If this space is adjacent to spaces with low fire risk, it is considered as category A machinery space.

For type C tanks, the gas fuel storage space can be considered as a cofferdam.

Note: Other spaces with a high fire risk include at least the following spaces (but not limited to):

.1 cargo spaces other than liquid fuel tanks with a flash point over 60° C and except cargo spaces for general cargo, except dangerous goods which may not be equipped with fixed fire-extinguishing systems (on passenger ships engaged on short voyages, on passenger ships with gross tonnage of less than 1000, as well as on cargo ships with gross tonnage of less than 2000 or built and intended exclusively for the carriage of ore, coal, grain, undried timber, non-combustible cargo or cargo with low fire hazard - refer to footnote "[10]" Table 3.1. 2.1.);

.2 vehicle spaces, ro-ro spaces and special category spaces;

.3 service spaces (with high fire hazard) on passenger ships carrying not more than 36 passengers, cargo ships and tankers: galley, buffet, containing hot cooking equipment; painters, cabinets, pantries with an area of 4m^2 and upwards; spaces where flammable liquids are stored; saunas; workshops and similar spaces not forming a part of machinery spaces; waste storage facilities and associated waste piping (refer to **2.2.1.5-1 (*9*)**, **2.2.1.5-2 (*9*)**, **2.3.3-1 (*9*)**, **2.3.3-2 (*9*)**, **2.4.2-1 (*9*)**, **2.4.2-2 (9)**);

.4 acommodation of high fire risk on passenger ships carrying more than 36 passengers:

public spaces with furniture and furnishings other than those with limited fire risk having a deck area of 50 m^2 or upwards, trade kiosks; hairdressing and beauty salons, saunas (refer to **2.2.1.3-1 (*8*)**, **2.2.1.3-2 (8)**).

6.8.2.2-1 Structural fire protection of fuel containment system spaces[13].

.1 The space containing the fuel containment system (refer to **2.10.1.2** Part VII «Machinery Installations») shall be separated from the machinery spaces of category A or other rooms with high fire risks. The separation shall be done by a cofferdam of at least 900 mm with insulation of A-60 class. When determining the insulation of the space containing the fuel containment system from other spaces with lower fire risks, the fuel containment system shall be considered as a machinery space of category A.

.2 For type C tanks, the fuel storage hold space (refer to **2.10.1.2** Part VII «Machinery Installations») may be considered as a cofferdam provided that:

the type C tank is not located directly above machinery spaces of category A or other rooms with high fire risk; and

the minimum distance to the A-60 boundary from the outer shell of the type C tank or the boundary of the tank connection space, if any, is not less than 900 mm.

6.8.2.3 Gas fuel piping in weather ro-ro cargo spaces shall be protected against damage by vehicles.

6.8.2.4 If there is more than one machinery space on board, they shall be separated by Class A-60 divisions.

6.8.2.5 Spaces, in which fuel preparation equipment, such as pumps, compressors, heat exchangers, evaporators and pressure vessels, are located shall be considered as Category A machinery spaces, which shall be protected by a fixed fire-extinguishing system complying with the requirements of **3.1.2** taking into account the intensity of the extinguishing medium used to extinguish gas fires.

6.8.2.6 The gas fuel reception room shall be separated from category A machinery spaces, acommodation, control stations and spaces with high fire risk by class A-60 divisions.

The fire resistance of structures separating this spaces from tanks, empty spaces, auxiliary machinery spaces of low fire or non-fire, sanitary and other similar spacesmay be reduced to class A-0.

6.8.2.7 Fuel containment spaces shall not be used to house mechanical or other fire-hazardous equipment (refer also to 6.8.2.2).

6.8.2.8 If the machinery space, protected by the ESD system, is bounded by a single structure, it shall be of class A-60.

6.8.3 Water fire extinguishing system.

6.8.3.1 The water fire extinguishing system shall comply with the requirements of 3.2 taking into account the type of ship.

6.8.3.2 If water fire pumps are used for the drenching system, the joint work of the water fire extinguishing system and the drenching system shall be taken into account when determining the required capacity of water fire pump.

6.8.3.3 If the FCT is located on weather deck, shut-off valves shall be provided on the main fire main to isolate the damaged section of the pipe so that the system remains operational.

6.8.4 Drenching system.

6.8.4.1 Drenching system shall be provided to ensure fire protection and cooling of the external parts of the FCT located on the weather deck. Drenching system shall also protect the external surfaces of superstructure, compressor and pump rooms, cargo control stations, bunkering stations and other commonly attended areas facing the FCT, located on the weather deck, if the distance between them does not exceed 10 m.

6.8.4.2 The system shall be designed to provide the following intensities of water supply to the surface specified in **6.8.4.1**:

.1 for horizontal surfaces - 10 l/min. per 1m^2;

.2 for vertical surfaces – 4 l/min per 1m^2.

6.8.4.3 The fire main shall be fitted with shut-off valves to disconnect its damaged sections, the distance between which shall not exceed 40 m. Instead, the system may be divided into two or more sections capable of operating independently, provided that their controls are located in one easily accessible place, access to which will not be blocked in the event of a fire in the protected spaces.

6.8.4.4 The connection of the water fire main and the drenching system shall be made through a shut-off valve located on the open part of the deck in a protected place outside the bunkering station.

6.8.4.5 Remote activation of drenching system pumps and remote control of valves shall be carried out from a safe, easily accessible place which cannot be cut off in the event of a fire in the protected spaces.

6.8.4.6 Nozzles of drenching system shall be fully permeable and ensure efficient distribution of water on the protected surfaces.

6.8.105 Dry powder system.

6.8.5.1 Dry powder system complying with the requirements of 3.10 shall be provided to protect the fuel bunkering area, including any areas of possible fuel spillage and the bunkering station. The powder rate shall be not less than 3.5 kg/s, and the quantity of the extinguishing powder shall be sufficient for its operation for at least 45 seconds.

6.8.6 Fire detection alarm system.

6.8.6.1 Fire detection alarm system of the approved type shall be provided in the fuel containment spaces, the tank strapping and the ventilation ducts leading to them, as well as in all other spaces of fuel containment system. The fire alarm system shall provide a clear identification and location of the activated sensor.

6.8.6.2 The smoke detection system shall not be considered as an effective and efficient means of fire detection in accordance with **6.8.6.1**, unless other means of fire detection are additionally provided.

6.8.7 Fire protection outfit.

6.8.7.1 Two portable powder fire extinguishers with a powder content of not less than 5 kg in each shall be provided, one of which shall be located near the bunkering station.

6.8.7.2 The engine room, in which gas heavier than air is used as fuel, shall be fitted with two portable powder fire extinguishers with a content of not less than 5 kg of powder in each, located near the entrance.

6.9 SHIPS CONTINUOSELY OPERATED AT LOW TEMPERATURES.

6.9.1 All fire pumps, including the emergency fire pump, shall be located in spaces with a positive temperature. If the pumps of other fire-extinguishing systems using water are located independently of the pumps of the water fire extinguishing system in a separate room and are connected to their own sea connection, this sea connesction shall also be protected from clogging with ice.

6.9.2 The design of the water fire extinguishing system and foam extinguishing system shall meet the requirements of **3.2** and **3.7**, taking into account the requirements of **10.4** of Part III "Equipment, arrangement and outfit".

6.9.3 The foamer shall be approved by the Register and stored in a space with a positive temperature.

6.9.4 Foam generators and air-foam monitors intended for installation on ships with descriptive notation **WINTERIZATION (-40)** and **WINTERIZATION (-50)** shall be operational at the required design ambient temperature and shall be approved by the Register.

6.9.5 Fire hoses shall meet the requirements of **5.1.4**, be approved by the Register and be suitable for operation at the design ambient temperature. It is allowed to keep fire hoses in a protected place near fire hydrants in disconnected condition.

6.9.6 Fire extinguishers shall be located, as far as practicable, in heated rooms, protected from the effects of temperatures below freezing.If the fire extinguisher is located in a place where freezing may occur, a fire extinguisher capable of operating at the polar operating temperature shall be provided in accordance with **5.1.9.15.7**.

6.9.7 Fireman's outfit shall be stored on board in heated spaces.

The radiotelephone shall be operational at the polar operating temperature.

6.10 SHIPS OPERATED IN POLAR WATERS

6.10.1 General.

6.10.1.1 The requirements of this Chapter are in addition to the requirements of **1 - 5** and apply to fire protection of ships intended for operation (independent navigation) in polar waters (Arctic waters and / or the Antarctic region), covered with ice, subject to the requirements of the POLAR Code.

6.10.1.2 The requirements of this paragraph shall ensure that fire protection systems and facilities are effective and in working condition and that evacuation facilities are available so that persons on board ships can move safely and quickly for evacuation under the expected environmental conditions to the life-saving appliances embarkation deck.

6.10.2 Functional requirements.

6.10.2.1 To comply with the requirements of **6.10.1.2**, the following shall be provided:

.1 all components of fire safety systems and equipment, if installed in such a way as to be exposed to the environment, shall be protected from icing and snow accumulation;

.2 controls for local equipment and machinery shall be so arranged as to avoid freezing, icing and accumulation of snow and to be maintained at all times;

.3 the design of fire safety systems and facilities shall take into account the need for people to be able, when required, to wear bulky outfit for protection against the cold;

.4 means shall be provided to remove accumulated snow and ice from access points or to prevent the accumulation of snow and ice; and

.5 fire extinguishers shall be suitable for their intended use under the expected ambient conditions.

6.10.2.2 In addition, the following shall apply to ships intended for operation at low air temperatures:

.1 the design of all components of fire safety systems and facilities shall be such as to ensure their readiness for use and efficiency at polar operating temperatures; and

.2 materials used in fire protection systems exposed to the environment shall be suitable for operation at polar operating temperatures.

6.10.3 Fire protection systems and appliances.

6.10.3.1 To comply with the requirements of **6.10.2.1.1**, the following shall be provided:

.1 shut-off and pressure / vacuum valves shall be protected from icing in areasnd

.2 all two exposed to external influences and shall be maintained at all times; a-way portable radio equipment shall operate at polar operating temperature.

6.10.3.2 To comply with the requirements of **6.10.2.1.2**, the following shall be provided:

.1 fire pumps, including emergency fire pumps, water mist pumps and water spray pumps, shall be located in spaces where the temperature is maintained above freezing;

.2 the fire main shall be so arranged that areas exposed to external influences can be isolated and provided with facilities for draining such areas.

There is no need for fire hoses and hydrants to be permanently connected to the fire main, they can be stored in a protected place near fire valves;

.3 fireman's outfit shall be stored in a warm place on the ship; and

.4 if fixed water fire extinguishing systems are located in a space other than that for main fire pumps and use separate seawater pipes, they shall also be capable of being cleared of ice.

6.10.3.3 In addition, for vessels designed to operate at low temperatures, the following shall apply:

.1 portable and mobile fire extinguishers shall be located as far as practicable to meet the requirements of **6.10.2.2.1** in places protected from freezing temperatures.

Fire extinguishers capable of operating at polar operating temperatures shall be provided in places subject to freezing;

.2 to meet the functional requirements of **6.10.2.2.1**, the materials of externally exposed fire protection systems shall be approved by the Administration or a recognized organization subject to standards acceptable to IMO[14] or other standards that offer an equivalent level of polar working safety temperature.

6.10.4 Alternative designs, measures and arrangements (refer to IMO Resolution MSC.386 (94)).

Alternatively, a complete study of the design, measures and proposed arrangement may be submitted to the Register for verification according to an agreed program.

7 SPECIAL REQUIREMENTS FOR SHIPS CARRYING PACKAGED DANGEROUS GOODS AND DANGEROUS GOODS IN BULK

7.1 GENERAL

7.1.1 The requirements of the present Section are aimed at providing additional safety measures in respect of ships carrying packaged dangerous goods and dangerous goods in bulk.

7.1.2 For the purpose of the present Section, the following additional definitions and abbreviations have been adopted.

INF cargo means packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes carried as cargo in accordance with Class 7 of the IMDG Code.

High-level radioactive wastes means liquid wastes resulting from the operation of the first stage extraction system or the concentrated wastes from subsequent extraction stages, in a facility for reprocessing irradiated fuel, or solids into which such liquid wastes have been converted.

INF Code means the International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships adopted by IMO resolution MSC.88(71), as amended.

Dangerous goods means substances, materials and products covered by the IMDG Code.

Dangerous goods in bulk means any materials other than liquid or gas, consisting of mixture of particles, granules or larger pieces of material, generally homogenous, covered by the IMSBC Code, and which are loaded directly into cargo spaces without the use of any intermediate package, including the same materials loaded into shipborne barges.

Irradiated nuclear fuel means material containing uranium, thorium and/or plutonium isotopes which has been used to maintain a self-sustaining nuclear chain reaction.

Plutonium means the resultant mixture of isotopes of that material extracted from irradiated nuclear fuel from reprocessing.

Package means cargo container established by the IMDG Code.

7.2 SHIPS CARRYING PACKAGED DANGEROUS GOODS OR DANGEROUS GOODS IN BULK

7.2.1 The requirements of the present Chapter apply to the following types of ships and cargo spaces:

.1 ships and cargo spaces not specially designed for the carriage of freight containers but intended for the carriage of packaged dangerous goods including goods in freight containers and portable tanks;

.2 purpose-built container ships and cargo spaces intended for the carriage of dangerous goods in freight containers and portable tanks (refer to 8.4.8, Part III "Equipment, Arrangements and Outfit");

.3 ro-ro ships and ro-ro cargo spaces, spaces for vehicles and special category spaces intended for the carriage of dangerous goods. A ro-ro cargo space completely open from above and on both sides may be treated as the weather deck;

.4 ships and cargo spaces intended for the carriage of dangerous goods in bulk;

.5 ships and cargo spaces intended for the carriage of dangerous goods other than liquids and gases in bulk in shipborne barges.

7.2.2 Cargo and passenger ships shall comply with the following:

7.2.2.1 Cargo and passenger ships including cargo and passenger ships of less than 500 gross tonnage intended for the carriage of packaged dangerous goods shall meet the requirements of this Chapter considering applicable provisions of IMO resolution MSC.269(85), Annex 2.

7.2.2.2 Cargo ships with cargo spaces intended for the carriage of dangerous goods in bulk shall meet the requirements of this Chapter; however, these requirements for cargo ships of less than 500 gross tonnage may be reduced by the Register with an appropriate note in the Certificate of Compliance with the

[14] Refer to UR S6 Rev.9 (July 2018) IACS Use of Steel Blades for Various Hull Members - Ships of 90 m in Length and above or IACS URI Rev.3 (Apr. 2016) for polar classes.

Special Requirements for Ship Carrying Dangerous Goods, issued by the Register.

7.2.2.3 A fixed fire extinguishing system of the type agreed with the Register shall be provided in cargo spaces of the following ships engaged in the carriage of dangerous goods:

passenger ships constructed on or after 1 September 1984;

cargo ships of 500 gross tonnage and upwards constructed on or after 1 September 1984.

7.2.3 In addition to the requirements of this Chapter, the applicable provisions of the IMDG Code and the IMSBC Code shall be complied with.

Carriage of dangerous goods on all ships without complying with the provisions of the IMDG Code andThe IMSBC Code is prohibited.

7.2.4 Depending on the modes of carriage of dangerous goods in ships and cargo spaces specified in **7.2.1** the requirements of Table 7.2.4-1 shall apply; depending on the class of dangerous goods carried in bulk the requirements of Table 7.2.4-2 shall apply; depending on the class of dangerous goods other than those carried in bulk the requirements of Table 7.2.4-3 shall apply.

Table 7.2.4-1

Requirements of paragraphs	Ships and cargo spaces						
	Weather deck of ships and cargo spaces listed in **7.2.1.1** - **7.2.1.5**	Ships not specifically designed (refer to **7.2.1.1**)	Container cargo spaces (refer to **7.2.1.2**)	Closed cargo spaces as given in **1.5.4.3.1**[1] (refer to **7.2.1.3**)	Open cargo spaces as given in **1.5.4.3.2** (refer to **7.2.1.3**)	Ships for the carriage of solid dangerous goods in bulk (refer to **7.2.1.4**)	Shipborne barges (refer to **7.2.1.5**)
7.2.5.1	+	+	+	+	+	For application of the requirements of **7.2** to different classes of dangerous goods, refer to Table 7.2.4-2	+
7.2.5.2	+	+	+	+	+		-
7.2.5.3	-	+	+	+	+		+
7.2.5.4	-	+	+	+	+		+
7.2.6	-	+	+	+	+		+[3]
7.2.7	-	+	+	+	-		+[3]
7.2.8.1	-	+	+[2]	+	-		+[3]
7.2.8.2	-	+	+[2]	+	-		+[3]
7.2.9	-	+	+	+	-		-
7.2.10.1	+	+	+	+	+		-
7.2.10.2	+	+	+	+	+		-
7.2.11	+	+	-	-	+		-
7.2.12	+	+	+[4]	+	+		-
7.2.13	-	-	-	+[5]	+		-
7.2.14	-	-	-	+	-		-
7.2.15	-	-	-	+	-		-

[1]Special category spaces shall be treated as closed ro-ro cargo spaces when dangerous goods are carried.

[2] In special cases where the barges are capable of containing flammable vapours or alternatively if they are capable of discharging flammable vapours to a safe space outside the barge carrier compartment by means of ventilation ducts connected to the barges, these requirements may be reduced or waived, which is subject to special consideration by the Register.

[3] For classes 4 and 5.1 solids not applicable to closed freight containers. For classes 2, 3, 6.1 and 8 when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour. For classes 4 and 5.1 liquids when carried in closed freight containers, the ventilation rate may be reduced to not less than two air changes per hour. For the purpose of this requirement, a portable tank is a closed freight container.

[4] Applicable to decks only.

[5] Applies only to closed cargo spaces as given in **1.5.4.3.1**, not capable of being sealed.

Note. Wherever + appears in the table, it means that this requirement is applicable to all classes of dangerous goods as given in the appropriate line of Table 2.8.2-3, except as indicated in the footnotes

Table 7.2.4-2

Requirements of paragraphs	Class of dangerous goods						
	4.1	4.2	4.3[1]	5.1	6.1	8	9
7.2.5.1	+	+	-	+	-	-	+
7.2.5.2	+	+	-	+	-	-	+
7.2.6	+	+[2]	+	+[3]	-	-	+[3]
7.2.7	-	+[2]	+	-	-	-	-
7.2.8.1	+[4]	+[2]	+	+[2,4]	-	-	+[2,4]
7.2.8.2	+	+	+	+	+	+	+
7.2.10	+	+	+	+	+	+	+
7.2.12	+	+	+	+[2]	-	-	+[5]

[1]The hazards of substances in this class which may be carried in bulk are such that special consideration shall be given to the construction and equipment of the ship involved in addition to meeting the requirements of this table.
[2]Only applicable to oilcake containing solvent extractions, ammonium nitrate and ammonium nitrate fertilizers.
[3]Only applicable to ammonium nitrate and ammonium nitrate fertilizers. However, the degree of protection in accordance with the standards contained in the International Electrotechnical Commission, publication 60079 - Electrical Apparatus for Explosive Gas Atmospheres, is sufficient.
[4]Only suitable wire mesh guards are required.
[5]The requirements of IMSBC Code/BC Rules are sufficient.

7.2.5 The following additional measures shall be taken to ensure supply of water:

.1 the water fire main system shall ensure immediate availability of water supply at the required pressure either by permanent pressurization in the fire main or by suitably placed remote starting arrangements for the fire pumps from the locations referred to in **3.2.3.9**;

.2 the water fire main system shall ensure the delivery of the quantity of water capable of supplying four nozzles with applicators provided on board under the pressure as specified in **3.2.1.1** to any part of the cargo space when empty. Upon agreement with the Register, this amount of water may be applied by equivalent means.

The number and arrangement of fire hydrants shall be such that at least two water jets out of four required can be delivered through fire hoses of standard length to any part of the empty cargo space and that all the four jets can be delivered through hoses of standard length to any part of cargo ro-ro space;

.3 the water fire main system shall effectively cool a cargo space by a pressure water-spraying system with a rate of water supply specified in **3.4.2.1** or by flooding (refer to 3.6.4).

Hoses capable to ensure the delivery of the required quantity of water may be used for this purpose in small spaces and in small areas of larger cargo spaces on agreement with the Register.

The drainage and pumping arrangements shall be such as to prevent the build-up of free surfaces as specified in **7.14.2**, Part VIII "Systems and Piping".

If this is impossible a calculation shall be made to prove that the ship with the cargo space flooded with water complies with the requirements of Sections **2** and **3**, Part V "Subdivision";

.4 in lieu of compliance with the requirements of **7.2.5.3** the high expansion foam system may be used in accordance with **3.7.3** using a supply rate and time of continuous supply according to Table 3.7.1.3 for machinery or by other special suitable extinguishing media;

.5 the total required quantity of water shall satisfy the requirements of **7.2.5.2** and **7.2.5.3**, if applicable, simultaneously calculated for the largest designated cargo space.

The requirements of **7.2.5.2** shall be met by the total capacity of the main fire pumps not including the capacity of the emergency fire pump, if fitted.

If a drencher system is used to satisfy the requirements of **7.2.5.3**, the drencher pump shall also be taken into account in this total capacity calculation;

.6 the pressure water-spraying system required in accordance with 9.2, 9.3 and 9.4 of IMO circular MSC/Circ.608/Rev.1 "Interim Guidelines for Open-Top Containerships" also satisfies the requirements for dangerous goods. The quantity of water required to fire fighting in the largest cargo space shall be capable to ensure simultaneous operation of the pressure water-spraying system and four jets from fire nozzles.

Table 7.2.4-3

Requirements of paragraphs	Class of dangerous goods											
	1.1-1.6	1.4S	2.1	2.2	2.3		3		4.1	4.2	4.3	
					e	*f*	*b*	*c*			*a*	*d*
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
7.2.5.1	+	+	+	+	+	+	+	+	+	+	+	+
7.2.5.2	+	+	+	+	+	+	+	+	+	+	+	+
7.2.5.3	+	-	-	-	-	-	-	-	-	-	-	-
7.2.5.4	+	-	-	-	-	-	-	-	-	-	-	-
7.2.6	+	-	+	-	+	-	+	-	-	-	+[6]	-
7.2.7	+	+	+	+	-	+	+	+	+	+	+	+
7.2.8.1	-	-	+	-	-	+	+	-	+[1]	+[1]	+	+
7.2.8.2	-	-	+	-	-	-	+	-	-	-	-	-
7.2.9	-	-	-	-	-	-	+	-	-	-	-	-
7.2.10	-	-	+	+	+	+	+	+	+	+	+	+
7.2.11	-	-	-	-	-	-	+	+	+	+	+	+
7.2.12	+[3]	-	+	+	+	+	+	+	+	+	+	+
7.2.13	+	+	+	+	+	+	+	+	+	+	+	+
7.2.14	+	+	+	+	+	+	+	+	+	+	+	+
7.2.15	+	+	+	+	+	+	+	+	+	+	+	+

Requirements of paragraphs	Class of dangerous goods										
	5.1	5.2[5]	6.1				8				9
			b	*c*	*a*	*d*	*b*	*c*	*a*	*d*	
1	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
7.2.5.1	+	+	+	+	+	+	+	+	+	+	+
7.2.5.2	+	+	+	+	+	+	+	+	+	+	-
7.2.5.3	-	-	-	-	-	-	-	-	-	-	-
7.2.5.4	-	-	-	-	-	-	-	-	-	-	-
7.2.6	-	-	+	-	-	-	+	-	-	-	+[8]
7.2.7	+	-	+	+	+	+	+	+	+	+	-
7.2.8.1	+[1]	-	+	+	-	+[1]	+	+	-	-	+[1]
7.2.8.2	-	-	+	-	-	-	+	-	-	-	+[8]
7.2.9	-	-	+	+	+	-	+	+[9]	+[9]	-	-
7.2.10	+	+	+	+	+	+	+	+	+	+	+[2]
7.2.11	+	-	+	+	-	-	+	+	-	-	-
7.2.12	+[4]	+	+	+	-	-	+	+	-	-	-
7.2.13	+	+	+	+	+	+	+	+	+	+	+
7.2.14	+	+	+	+	+	+	+	+	+	+	+
7.2.15	+	+	+	+	+	+	+	+	+	+	+

[1]When "mechanically ventilated" spaces are required by the IMDG Code.
[2]As appropriate to the goods being carried.
[3]In all cases cargoes shall be stowed 3 m horizontally away from the machinery space boundaries.
[4]Refer to the IMDG Code.
[5]Stowage of class 5.2 dangerous goods under deck or in enclosed ro-ro spaces is prohibited.
[6]Applicable only to cargoes specified in the IMDG Code and having a flash point lower than 23°C.
[7]According to provisions of the IMDG Code, stowage of class 2.3 cargoes featuring additional dangerous properties of class 2.1 goods under deck or in enclosed ro-ro spaces is prohibited.
[8]Applicable only to cargoes specified in the IMDG Code and releasing flammable vapours.
[9]Applicable only to cargoes featuring additional dangerous properties of class 6.1 goods.
Symbols: *a)* liquids; *b)* liquids (<23°C); *c)* liquids (≥23°C ≤60°C); *d)* solids; *e)* flammables; *f)* non-flammables.

7.2.6 Electrical equipment shall comply with the requirements of **2.9.2**, **2.9.3**, **2.9.9**, **2.9.10**, **2.9.12**, **16.8.1.6**, **16.8.4.5**, 16.8.6.1 and **19.11**, Part XI "Electrical Equipment".

Any other equipment which may constitute a source of ignition of explosive mixtures of vapours, gases or dust with air shall not be permitted in cargo spaces.

7.2.7 Ro-ro cargo spaces shall be fitted with a fixed fire detection and fire alarm system complying with the requirements of **4.2.1**. All other types of cargo spaces shall be fitted either with a fixed fire detection and fire alarm system complying with the requirements of **4.2.1** or sample extraction smoke detection system complying with the requirements of **4.2.1.6**.

If a sample extraction smoke detection system is fitted, particular attention shall be given to the requirements of **4.2.1.6.3** to prevent leakage of toxic smoke into areas where people stay.

7.2.8 Ventilation of cargo spaces shall comply with the following requirements of Part VIII "Systems and Piping":

.1 arrangement of the ventilation system, with the requirements of 12.1.7, 12.1.8, 12.7.1, 12.7.3 and **12.7.5**. For bulk cargoes of class **4.3**, as well as oilcake, which contain solvents that extract the oil, additionally with the requirements of **12.7.7**;

.2 construction of ventilation fans, with the requirements of **12.7.4**;

.3 natural ventilation system in compliance with the requirements of **12.7.2** shall be provided in enclosed cargo spaces intended for the carriage of dangerous goods in bulk unless not fitted with mechanical ventilation.

7.2.9 The bilge system of cargo spaces shall comply with the requirements of **7.14.1**, **7.14.4 - 7.14.9** Part VIII "Systems and Piping".

7.2.10 Ships shall be provided with the following outfit:

.1 four full sets protective clothing resistant to chemical exposure and intended for use in emergency situations. The protective clothing shall cover all skin so that no part of the body is unprotected and, subject to cargo characteristics, shall meet the recommendations of the IMDG Code, the IMSBC Code/BC Rules;

.2 at least two self-contained breathing apparatus in addition to those required by item **10** of Table 5.1.2.

Two spare charges or two spare breathing apparatus shall be provided in addition to those required for the fireman's outfit (refer to **5.1.15.2**).

7.2.11 Portable fire extinguishers with a total capacity of at least 12 kg of dry powder or equivalent shall be provided for cargo spaces. These extinguishers shall be in addition to any portable fire extinguishers required by the present Part.

7.2.12 Bulkheads forming boundaries between cargo spaces and machinery spaces of category A shall be of "A-60" class, unless dangerous goods are stowed at least 3 m horizontally away from such bulkheads. Other boundaries between such spaces shall be of "A-60" class.

When a cargo space is partially located above the machinery space of category A and bounding structures do not have the required insulation, such cargo space is unfit for carriage of dangerous goods. The same refers to areas of bare weather deck located above the machinery space of category A.

7.2.13 Each open ro-ro space having a deck above it and each space considered to be a closed ro-ro space not capable of being sealed shall be fitted with an approved manually operated fixed pressure waterspraying system which shall protect all parts of any deck and vehicle platform in such space. The Register may permit the use of any other fixed fire extinguishing system that has been shown by full-scale tests to be not less effective.

However, the drainage and pumping arrangements shall be such as to prevent free surfaces as specified in **7.14.2**, Part VIII "Systems and Piping". If this is impossible, a calculation shall be made to prove that the ship with flooded cargo space meets the requirements of Sections **2** and **3**, Part V "Subdivision".

7.2.14 In ships having ro-ro spaces, subdivision shall be provided between a closed ro-ro space and an adjacent open ro-ro space. The subdivision shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such subdivision need not be provided if the ro-ro space is considered to be a closed cargo space over its entire length and shall fully comply with the relevant special requirements of the present Chapter.

7.2.15 In ships having ro-ro spaces, subdivision shall be provided between a closed ro-ro space and the adjacent weather deck. The subdivision shall be such as to minimize the passage of dangerous vapours and liquids between such spaces. Alternatively, such subdivision need not be provided if the arrangements of the closed ro-ro spaces are in accordance with the requirements for the carriage of dangerous goods on the adjacent weather deck.

7.2.16 Cargo spaces in ships other than ro-ro ships shall not be adjacent to accommodation and service spaces, except service spaces of low fire risk referred to in **1.5.3.2.3**.

7.2.17 Hatch covers of dry-cargo holds shall comply with the requirements of Part III "Equipment, Arrangements and Outfit".

7.3 SHIPS CARRYING PACKAGED IRRADIATED NUCLEAR FUEL, PLUTONIUM AND HIGH-LEVEL RADIOACTIVE WASTES (INF CARGO)

7.3.1 The requirements of the present Chapter are based on the provisions of the INF Code and apply to all ships regardless of their date of build and size, including cargo ships of less than 500 gross tonnage, engaged in the carriage of INF cargo.

7.3.2 For the purpose of the present Chapter, ships carrying INF cargo are assigned to the following three classes, depending on the total activity of INF cargo which is carried on board.

Class **INF1** ship is a ship, having certificate to carry INF cargo with an aggregate activity less than 4000 TBq.

Class **INF2** ship is a ship, having certificate to carry irradiated nuclear fuel or high-level radioactive wastes with an aggregate activity less than $2x10^6$ TBq and ship which is certified to carry plutonium with an aggregate activity less than $2x10^5$ TBq.

Class **INF3** ship is a ship, having certificate to carry irradiated nuclear fuel or high-level radioactive wastes and ship which is certified to carry plutonium with no restriction of the maximum aggregate activity of the materials.

The compliance of the ship with the requirements of this Chapter shall be certified by the appropriate distinguishing mark added to the class notation in accordance with **2.2.13**, Part I "Classification" and by the International Certificate of Fitness for Carriage of INF Cargo issued by the Register.

7.3.3 In addition to the requirements of the present Chapter, the applicable provisions of the IMDG Code shall be complied with.

7.3.4 The INF cargo which is required to be carried on Class **INF3** ships shall not be carried on passenger ships.

7.3.5 The damage trim and stability shall comply with the requirements of **3.4.9**, Part V "Subdivision".

7.3.6 In addition to the requirements of the present Part, the ship shall be fitted with a fixed pressure water-spraying system to protect cargo spaces which shall ensure the rate of water discharge as indicated in **3.4.2.1**. In Class **INF1** ships the pressure water-spraying system need not be installed provided the requirements of **7.2.5.1** and **7.2.5.2** are complied with.

7.3.7 In Class **INF3** ships accommodation spaces, service spaces, control stations and machinery spaces of category A shall be fitted forward or aft of the cargo spaces, due regard being paid to the overall safety of the ship.

7.3.8 The cargo spaces of the ship shall be fitted with temperature control systems complying with the requirements of **12.7.8**, Part VIII "Systems and Piping".

7.3.9 The ship hull structure shall comply with the requirements of Part II "Hull".

7.3.10 Permanent devices shall be provided to secure packages of INF cargo within the cargo spaces. The devices shall meet the requirements of the Guidelines for the Development of the Cargo Securing Manual.

7.3.11 The electrical equipment of systems and arrangements referred to in **7.3.6** and **7.3.8** shall comply with the requirements of Part XI "Electrical Equipment". The requirements for the emergency source of electrical power to supply these systems are set forth in Section **9**, Part XI "Electrical Equipment".

7.3.12 Depending upon the characteristics of the INF cargo to be carried and upon the design of the ship, additional arrangements and equipment for radiological protection meeting the requirements of the competent state authorities on radiological safety shall, if necessary, be provided.

7.3.13 Every ship shall carry on board an approved shipboard emergency plan based on the Guidelines for Developing Shipboard Emergency Plans for Ships Carrying Materials Subject to the INF Code adopted by IMO resolution A.854(20).

7.3.14 Every ship shall carry on board equipment (individual personnel protection outfit, apparatus, etc.) for use in emergency. The type and amount of such equipment depend upon the INF cargo to be carried and is specified by the shipboard emergency plan referred to in **7.3.13**.

8 REQUIREMENTS FOR FIRE PROTECTION OF CARGO SHIPS OF LESS THAN 500 GROSS TONNAGE

8.1 GENERAL, DEFINITIONS AND APPLICATION

8.1.1 The requirements of the present Section are aimed at ensuring the safety of cargo ships of less than 500 gross tonnage (except fishing vessels, chemical tankers and gas carriers) as regards their fire protection.

8.1.2 The following definition has been adopted in the present Section. Gross tonnage is as defined in IMO resolution A.493(XII), calculated in accordance with the International Convention on Tonnage Measurement of Ships, 1969.

8.1.3 The requirements of the present Section are intended to apply to new and - as far as reasonable and practicable, - to existing cargo ships of less than 500 gross tonnage.

8.1.3.1 For ships of restricted service, the Register may reconsider the requirements specified in the present Section taking into account the service conditions of the ship and the measures for its fire safety stipulated by the ship designer on agreement with the customer.

8.1.3.2 As to fire protection documentation, requirements of the present Rules shall be complied with considering the provisions of **8.1.3.1**.

8.2 FIRE CONTROL PLANS

8.2.1 In all ships in the wheelhouse or in conspicuous positions in corridors, general arrangement plans shall be permanently exhibited, using graphical symbols that are in accordance with IMO resolution A.952(23), as amended by IMO resolution A1116(30), which show clearly for each deck:

.1 control stations;

.2 fire-resistant and fire-retarding divisions;

.3 fire detection and fire alarm systems;

.4 spaces protected by fixed fire extinguishing systems, indicating the location of their devices and valves controls, as well as the location of fire hydrants;

.5 means of access to different compartments and decks indicating evacuation routes;

.6 position of the fireman's outfits;

.7 location and arrangement of the emergency stop for oil fuel unit pumps and for closing the valves on the pipes from oil fuel tanks;

.8 ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of ventilating fans.

8.2.2 Alternatively, the details required by **8.2.1** may be set out in a booklet, a copy of which shall be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

8.2.3 General arrangement plans and booklets shall be kept up to date, any alterations to the fire protection being recorded as specified in **8.2.1** and **8.2.2**.

8.2.4 In all cargo ships greater than or equal to 150 gross tonnage, a duplicate set of general arrangement plans (refeer to **8.2.1**) shall be permanently stored, and the booklet containing such plans shall be kept in a weathertight enclosure outside the deckhouse, painted red in accordance with the applicable requirements of **1.4.3**.

In ships of less than 150 gross tonnage, the duplicate set of the plans or the booklet may be omitted and the position of the booklet for the assistance of shoreside fire-fighting personnel shall be agreed with the Register.

8.2.5 Description in general arrangement plans and booklets shall be in the official language of the flag state and in English.

For ships engaged in domestic service only, the plans and booklets may not be translated into English.

Graphic symbols shall be in color.

8.2.6 In all ships in addition to **8.2.1** and **8.2.2** general arrangement plans and booklets the instructions concerning the maintenance and operation of all the equipment and installations on board for the **fighting and containment of fire shall be kept under one cover, readily available in an accessible position.**

8.3 ALTERNATIVE DESIGN AND ARRANGEMENTS

8.3.1 Alternative design and arrangements which may be applied on ships shall comply with provisions of **1.7** (except **1.7.2.1.4**) considering the requirements of **8.3.2** and **8.3.3**.

8.3.2 The required fire safety performance criteria for the ship or the space(s) concerned shall:

.1 be based on fire safety objectives and the functional requirements of the present Section;

.2 provide a degree of safety not less than that achieved when using the prescribed requirements;

.3 be quantifiable and measurable.

8.3.3 The engineering analysis of alternative design and arrangements shall be evaluated and approved by the Register.

A copy of the Register-approved documentation shall be carried on board the ship.

8.4 STRUCTURAL FIRE PROTECTION

8.4.1 The minimum fire integrity of bulkheads and decks separating adjacent spaces shall meet the requirements of Table 8.4.1.

Nos.	Space	Separation by	From space
1	Machinery space category	A-60	1. accommodation spaces
			2. control stations
			3. corridors
			4. stairways
			5. service spaces of high fire risk
			6. ro-ro spaces
			7. vehicle spaces
2	Machinery space category	A-0	Other than above (item 1)
3	Galley	A-0	Unless specified otherwise
4	Service spaces of high fire risk	B-15	Unless specified above (item 1)
5	Corridor. Staircase	B-0	Unless specified above (item 1)
6	Cargo spaces (other than ro-ro spaces and vehicle spaces)	A-0	Unless specified above (item 1)
7	Ro-ro spaces and vehicle spaces (except weather deck)	A-60	1. control stations 2. machinery spaces of category
8	Ro-ro spaces and vehicle spaces (except weather deck)	A-0	Unless specified above (item 1)

8.4.1.1 Divisions used to separate spaces not mentioned in Table 8.4.1 shall be of non-combustible material.

In ships of less than 500 gross tonnage it is allowed to install non-combustible bulkheads, linings and ceilings with combustible covering at most 2 mm thick except corridors, stairway enclosures as well as control stations where thickness of covering shall not exceed 1,5 mm.

8.4.1.2 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, the applicable fire exposure shall be one hour.

Ships built of materials other than steel shall be considered compliant to **8.3**.

8.4.1.3 Stairways shall be enclosed, at least at one level, by divisions and self-closing doors or hatches.

8.4.1.4 Stairways serving machinery spaces, accommodation spaces, service spaces or control stations shall be of steel or other equivalent material.

8.4.1.5 Openings in "A" class divisions shall be provided with means of closing which shall be at least as effective for resisting fires as the divisions in which they are fitted which is determined in accordance with the FTP Code.

8.4.1.6 In "A" class divisions, arrangements shall be made to prevent the transmission of heat to uninsulated boundaries at the intersections and terminal points of other structural members and penetrations by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm either side.

8.4.1.7 Doors shall be self-closing in way of machinery spaces of category A and galleys, except where they are normally kept closed.

8.4.1.8 In cargo ships of less than 300 gross tonnage, storerooms for flammable materials and substances may be arranged in way of accommodation spaces, but not adjacent thereto.

Where a separate storeroom for flammable liquids is impeded, it is permissible to store them in steel ventilated lockers or cases. Such lockers or cases shall not be adjacent to the accommodation spaces and their doors shall open outwards.

All electrical equipment shall be intrinsically safe.

8.5 REQUIREMENTS FOR MATERIALS

8.5.1 Except in cargo spaces or refrigerated compartments of service spaces, insulating materials shall be non-combustible.

8.5.2 Insulating materials shall not contain asbestos.

8.5.3 In spaces where penetration of oil products is possible, the surface of the insulation shall be impervious to oil or oil vapours.

8.5.4 Vapour barriers and adhesives used in conjunction with insulation, as well as the insulation of pipe fittings, for cold service systems need not be of non-combustible materials, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

8.5.5 Paints, varnishes and other finishes used on exposed interior surfaces shall comply with the requirements of 2.1.1.7, 2.1.1.8.2.1, 2.1.8.2.2 and 2.1.1.8.3 accordingly as regards producing excessive quantities of smoke, toxic gases or vapours and shall be of the low flame spread type in accordance with the FTP Code.

8.5.6 Pipes conveying oil or combustible liquids through accommodations and service spaces shall be of steel or other approved materials having regard to the fire risk.

8.5.7 Where pipes penetrate "A" or "B" class divisions, the pipes or their penetration pieces shall be of steel or other approved materials.

8.5.8 Primary deck coverings within accommodation spaces, service spaces and control stations shall be of an approved material which will not readily ignite or give rise to toxic or explosive hazards at elevated temperatures, as defined by the FTP Code.

8.5.9 Materials readily rendered ineffective by heat shall not be used for overboard scuppers, sanitary discharges and other outlets where the failure of the material would give rise to the danger of flooding.

8.6 FIRE-FIGHTING EQUIPMENT AND SYSTEMS

8.6.1 Fixed fire extinguishing systems where required, shall meet the requirements of the FSS Code.

8.6.2 Machinery spaces of category A on ships with gross tonnage greater than or equal to 150 and operating in unrestricted or restricted waters, except ships for port, roadstead and coastal navigation shall be provided with an approved fixed fire extinguishing system, as specified in **8.6.1**.

8.6.3 Fixed fire extinguishing systems not mandatory under the requirements of the present Section, but installed on board ships of less than 500 gross tonnage shall be of an approved type.

8.6.4 Protection of paint lockers and flammable liquid lockers shall be agreed with the Register.

8.6.5 Spare parts and instruments for fixed fire extinguishing systems shall be available on board.

The number of spare parts and instruments shall be determined and agreed with the Register.

8.6.6 In ships of less than 150 gross tonnage where arranging a fire extinction station outside the protected spaces is hardly feasible, as well as in special cases, on ships of less than 500 gross tonnage where the volume of individual protected spaces does not exceed 100 m^3, cylinders containing the fire extinguishing medium may be fitted within the protected space on condition that such stations are provided with efficient remote control for immediately starting the system from outside the protected space. The remote starting control position shall be distinctly indicated and lighted both from the main and emergency sources of electrical power.

8.7 WATER FIRE MAIN SYSTEM

8.7.1 Fire pumps, pipelines, hydrants and hoses required by the present Section shall be provided in all ships.

8.7.2 Number and capacity of fire pumps.

8.7.2.1 One main fixed fire pump with an independent power source and one portable fire pump shall be provided, and the latter shall be located considering the requirements of **8.7.2.7.1**.

For ice class ships the main fixed fire pump with an independent power source and the fire pump shall be provided, and the latter shall be fixed in compliance with the requirements of **8.7.2.7**.

8.7.2.2 The total capacity of the main fixed fire pump, in m3 /h, shall not be less than

$$Q = (0{,}145\sqrt{L(B+D)} + 2{,}17)^2 \qquad (8.7.2.2)$$

where L - length of ship (refer to **1.1.3**, Part II "Hull"), in m;

B = greatest moulded breadth of ship, in m;

D = moulded depth to bulkhead deck amidships, in m.

The main fixed fire pump capacity need not exceed 25 m^3/h.

8.7.2.3 Relief valves shall be provided in conjunction with main fixed fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. A pressure gauge shall be fitted on the discharge end of the main fixed fire pump.

8.7.2.4 Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping fuel oil.

8.7.2.5 Portable fire pumps shall comply with the following requirements:

.1 the pump shall be self-priming;

.2 the pump shall be capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room, whichever is the greater;

.3 arrangements shall be provided to secure the pump at its anticipated operating position;

.4 the pump set shall be stored in a secure, safe and enclosed space, accessible from open deck and clear of the machinery space of category A.

The room where the pump set is stored shall be illuminated from the emergency source of electrical power;

.5 the pump set shall be easily moved and operated by two persons and be readily available for immediate use;

.6 the pump set shall operate the pump for at least three hours.

For electric pumps, their batteries shall have sufficient capacity for three hours.

If the fuel type used for the pump set has a flash point below 60°C, further consideration to the fire safety aspects of fuel oil storage on board shall be given.

A diesel motor pump may be used as the pump set.

The power source for the pump shall be capable of being readily started in its cold condition by hand (manual) cranking or by special heating arrangements.

The diesel motor pump shall comply with the requirements of **5.1.17** (except **5.1.17.2**);

.7 the overboard suction hose shall be non-collapsible and of sufficient length, to ensure suction under all operating conditions.

A suitable strainer shall be fitted at the inlet end of the hose.

8.7.2.6 In ships of less than 150 gross tonnage fitted with a fixed fire extinguishing system in the engine room, portable pumps may be omitted.

8.7.2.7 Alternatively to portable fire pumps (refer to **8.7.2.5**), fixed fire pumps may be fitted, which shall comply with the following requirements:

.1 the pump, its source of power and sea connection shall be located in accessible positions, outside the compartment housing the main fixed fire pump required by **8.7.2.1**;

.2 the sea valve shall be capable of being operated from a position near the pump and be fitted below the lightship waterline;

.3 the pressure of water delivered by the pump shall be sufficient to produce a jet of water of not less than 12 m in length, at any hose nozzle of 12, 16 and 19 mm size or as near thereto as possible.

For ships of less than 150 gross tonnage, the jet of water shall be agreed with the Register in each particular case;

.4 pump is required to supply water for the fire extinguishing system in the space where the main fixed fire pump is situated, it shall be capable of simultaneously supplying water to this system and the fire main at the required rates;

.5 the pump may also be used for other suitable purposes on agreement with the Register;

.6 the room where the fire pump prime mover is located shall be illuminated from the emergency source of electrical power, and shall be well ventilated.

8.7.3 Fire hoses and nozzles.

8.7.3.1 For fire hoses, the nozzle sizes shall be 12, 16 or 19 mm or as near thereto as possible.

8.7.3.2 For accommodations and service spaces, the nozzle size need not exceed 12 mm.

8.7.3.3 The size of nozzles used in conjunction with a portable fire pump need not exceed 12 mm.

8.7.3.4 All nozzles shall be of an approved type incorporating a shut-off.

Plastic fire hose nozzles may be used in accordance with **5.1.5**.

8.7.4 Fire main.

8.7.4.1 The diameter of the fire main shall be based on the required capacity of the main fixed fire pump and the diameter of the water service pipes shall be sufficient to ensure an adequate supply of water for the operation of at least one fire hose.

8.7.4.2 Pipes of the water fire main system shall comply with all the requirements of **3.2.5.2**.

8.7.4.3 The valves of water fire main pipes shall be located where they will not be damaged by cargo.

8.7.4.4 Where a fixed fire pump is fitted outside the engine room, in accordance with **8.7.2.7**:

.1 an isolating valve shall be fitted on the fire main so that at all the hydrants in the ship, except that or those in the machinery space of category A, can be supplied with water;

.2 the isolating valve shall be located in an easily accessible position outside the machinery space of category A.

8.7.5 Pressure in the fire main.

8.7.5.1 When the main fixed fire pump or the fixed fire pump specified in **8.7.2.7** is delivering water through the fire main, fire hoses and nozzles specified in **8.7.3**, the pressure maintained at any hydrant shall be sufficient to produce a jet throw at any nozzle of not less than 12 m in length.

8.7.6 Number and position of fire hydrants.

8.7.6.1 For ships equal to or greater than 150 gross tonnage the number and position of hydrants shall be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, as specified in **5.1.4.1**, may reach any part of the ship normally accessible to the crew while the ship is being navigated and any part of any cargo space when empty.

Furthermore, such hydrants shall be positioned near the accesses to the protected spaces.

8.7.6.2 For ships less than 150 gross tonnage the number and position of the hydrants shall be such that at least one jet of water from a single length of hose, as specified in **5.1.4.1**, may reach any part normally accessible to the crew, while the ship is being navigated and any part of any cargo space when empty. Furthermore, such hydrants shall be positioned near the accesses to the protected spaces.

8.7.6.3 At least one hydrant shall be provided in each machinery space of category A.

8.7.6.4 An isolating valve and a standard quick-acting coupling shall be fitted at each fire hydrant.

8.7.6.5 All exposed hydrants shall comply with the requirements of **3.2.6.1** and **3.2.6.5**.

8.7.6.6 The hydrants shall be so placed that the fire hoses may be easily coupled to them.

8.7.6.7 All the hydrants shall be painted red.

8.7.7 Fire hoses.

8.7.7.1 Fire hoses shall be of approved non-perishable material resistant to destruction by microorganisms (rotting).

8.7.7.2 The hoses shall be sufficient in length to project a jet of water to any of the spaces, but their length, in general, shall not exceed 18 m.

8.7.7.3 Fire hoses in assembly with nozzles shall be stowed at hydrants or in conspicuous positions on reels or in baskets.

8.7.7.4 Ships equal to or greater than 150 gross tonnage shall be provided with fire hoses the number of which shall be one for each 30 m length of the ship and one spare, but in no case less than three in all.

8.7.7.5 For ships less than 150 gross tonnage, one hose shall be provided for each hydrant. In addition, one spare hose shall be provided on board.

8.7.7.6 Unless one hose and nozzle is provided for each hydrant in the ship, there shall be complete interchangeability of hose couplings and nozzles.

8.8 FIXED FIRE DETECTION AND FIRE ALARM SYSTEMS

8.8.1 An approved fixed fire detection and fire alarm system shall be installed in all machinery spaces of category A and cargo pump rooms.

8.8.2 On agreement with the Register, buttons of manual fire alarms may be provided on board.

8.9 FIRE-FIGHTING OUTFIT

8.9.1 Portable fire extinguishers.

8.9.1.1 All fire extinguishers shall be of type approved by the Register and shall comply with the requirements of **5.1.9**, except **5.1.9.3** and **5.1.9.4**.

8.9.1.2 The extinguishing media employed shall be suitable for extinguishing fires in the compartments in which they are intended to be used.

8.9.1.3 The extinguishers required for use in machinery spaces shall be of a type discharging foam, carbon dioxide gas, dry powder or other approved media suitable for extinguishing oil fires.

8.9.1.4 The number of portable fire extinguishers and spaces where they shall be stowed is determined as follows:

.1 accommodations and service spaces of ships greater than or equal to 150 gross tonnage - not less than 3 (three) fire extinguishers;

.2 accommodations and service spaces of ships less than 150 gross tonnage - not less than 1 (one) fire extinguisher considering the applicable requirements of 8.9.1.5;

.3 machinery spaces - 1 (one) fire extinguisher per every 375 kW of internal combustion engine power; however, their number shall be not less than 2 (two) and not more than 6 (six).

8.9.1.5 Accommodation spaces, service spaces and control stations shall be provided with a sufficient number of portable fire extinguishers to ensure that at least 1 (one) extinguisher will be readily available for use in every compartment of the crew spaces. In any case, on ships greater than or equal to 150 gross tonnage their number shall be not less than 3 (three), except where this is impractical for very small ships, in which case 1 (one) extinguisher shall be available at each deck having accommodation or service spaces, or control stations.

8.9.1.6 The extinguishers shall be stowed in readily accessible positions and shall be spread as widely as possible and not be grouped.

8.9.1.7 One of the portable fire extinguishers intended for use in any space shall be stowed near the entrance to that space.

8.9.1.8 A spare charge shall be provided for each required portable fire extinguisher that can be readily recharged on board. If this cannot be done, the same number of duplicate (additional) extinguishers of the same capacity, type and fire extinguishing capability shall be provided.

8.9.2 1 (one) fire blanket complying with the requirements of **5.1.13** shall be provided.

8.9.3 All ships greater than or equal to 150 gross tonnage shall carry at least one firefighter's outfit consisting of a set of personal equipment, breathing apparatus and lifeline complying with the requirements of IMO resolution MSC.98(73).

8.10 ADDITIONAL FIRE SAFETY MEASURES FOR OIL TANKERS

8.10.1 The requirements for tankers of SOLAS Chapter II-2 shall apply to oil tankers carrying crude oil and petroleum products, having a flash point not exceeding 60°C and a Reid vapour pressure which is below atmospheric pressure.

8.10.2 Oil tankers carrying petroleum products having a flash point exceeding 60°C shall comply with the requirements of **6.3**, except **6.3.1.1**, and of **8.10.3** and **8.10.4**. The flash point shall be determined by a closed cup test using an approved flash point apparatus.

8.10.3 Cargo area deck protection shall be carried out considering the following:

.1 at least one mobile foam appliance shall be provided for use on the cargo tank deck including the cargo manifolds. Where the appliance is of the inductor type it shall comply with **5.1.8**.

The nozzle shall be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3/min.

Self-contained appliances shall have a foam solution capacity of at least 135 l;

.2 use shall be made of foam concentrate of types approved by the Register considering the requirements of **3.7.1.2**.

8.10.4 The type of foam used shall be suitable for the cargoes to be carried.

8.11 SHIPS NOT FITTED WITH PROPELLING MACHINERY

8.11.1 Arrangements for fire protection, detection and extinction in ships not fitted with propelling machinery shall be considered by the Register taking into account the size and purpose of the ship, its operation conditions and the presence of accommodation spaces, machinery and combustible materials on board.

8.11.2 On ships with a crew of less than 3 persons and on ships without a crew, not fitted with an autonomous source (s) of energy, which have premises, protected in accordance with the requirements of table. **3.1.2.1**, the water fire-extinguishing system shall be constructed in accordance with the applicable requirements of **8.7**, except **8.7.2**, except for the requirement of **8.7.2.5** regarding the use of a portable fire pump as the main fire pump, the fire pipe shall be fitted with a connection to receive water from other sources, including from onshore systems, as appropriate.

For ships operated only near the shore berth, the Register may consider the requirements, taking into account the operating conditions of the ship and the measures for her fire protection, which are established by the ship's designer in agreement with the customer.

8.12 SHIPS CARRYING PACKAGED DANGEROUS GOODS OR DANGEROUS GOODS IN BULK

8.12.1 Ships carrying packaged dangerous goods or dangerous goods in bulk shall comply with the requirements of **7.2**.

8.12.2 Ships carrying packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes (INF cargo) shall comply with the requirements of **7.3**.

8.13 OIL RECOVERY SHIPS AND BILGE WATER REMOVING SHIPS

8.13.1 The fire protection of oil recovery ships and bilge water removing ships shall comply with the requirements of **6.4**, except the requirements for fitting of fixed deck foam fire extinguishing system, and of **8.10.2 - 8.10.4**.

8.13.2 On vessels with a gross tonnage of less than 150, which have a main engine capacity of less than 220 kW, the use of a fire pump driven by the main engine is allowed, provided that the design of the engine-shaft-screw complex ensures the operation of this pump if the vessel is not underway.

8.14 SPECIAL PURPOSE SHIPS

8.14.1 The fire protection of special purpose ships shall be in compliance with the requirements of **6.2**.

PART VII MACHINERY INSTALLATIONS

1. 1 GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to ship machinery installations, equipment of machinery spaces, shafting lines, propellers, machinery condition monitoring systems, spare parts and active means of the ship's steering, as is specified in **1.2.8**, Part III «Equipment, arrangements and outfit».

In this case, requirements of Sections **1** to **4** and **9**, **10** and recommendations of Appendix 1 of the machinery installations and machinery space equipment on ships of gross tonnage less than 500, as well as the requirements of Part IX "Machinery" may be applied in so much as applicable and sufficient. It also refers to berth-connected ships.

Requirements for the reservation of propulsion installation and steering gear of passenger ships of 120 m or over in length (determination of length in accordance with **1.2** of the Load Line Rules for Sea-Going Ships), or having three or more main fire vertical zones (refer to **2.2.6.1**, Part VI "Fire protection"), in accordance with the requirements of SOLAS Regulation II-2/21 as amended, as amended by IMO Resolution MSC.216 (82), Annex 3), to the main character of class of which one of the relevant signs is added, which determines the amount of reservation of propulsion installation machinery and systems (refer to **2.2.26**, Part I "Classification" of the Rules for the Classification and Construction of Ships), are set forth in **2.7**.

The requirements for machinery installations of polar class ships (refer to **2.2.3**, Part I "Classification") are set forth in **2.8**.

The requirements to machinery installations of Baltic ice class ships (refer to **2.2.3**, Part I "Classification") are set forth in **2.9**.

The requirements for machinery installations of ships equipped to ensure long-term operation at low temperatures (refer to **2.2.30**, Part I "Classification") are set forth in **2.11**.

1.1.2 The requirements of the present Part are set forth proceeding from the condition that the flash point of fuel oil (refer to 1.2, Part VI "Fire Protection") used in ships of unrestricted service for the engines and boilers is not below 60°C and the flash point of fuel for emergency generator engines, not below 43°C.

In ships certified for restricted service within areas having a climate ensuring that ambient temperature of spaces where such fuel oil is stored will not rise to within 10°C below its flash point may use fuel oil with flash point not less than 43°C. In this case, measures shall be taken to ensure checking and maintenance of the above condition.

- The use of fuel with a flash point not exceeding 60°C, but not below 43°C, is allowed (for example, for emergency fire pumps engines and auxiliary machinery not located in Category A machinery spaces) subject to the following:
- liquid fuel tanks, except in double-bottom compartments, are outside the Category A machinery spaces;
- fuel temperature measurement at the fuel pump inlet has been provided;
- the inlets and outlets of the fuel filter are provided with shut-off valves and / or valves; and
- as far as possible, welded structures or circular cone or sphere type structures are used in piping connections.

Crude oil and slops may be used as boiler fuel in oil tankers. The conditions of such use are stated under **13.17**, Part VIII "Systems and Piping".

1.1.3 Provided that the following requirements have been met, gases or other fuels with low flashpoint may be used as fuel (refer to **2.2.27**, Part I "Classification").

1.1.3.1 Requirements for the use of gas fuel (take into account, in relation to such fuel, the requirements of the IGF Code) are set forth in **2.10** of this Part; in **7.15.1**, **9.16.2**, **12.14, 13.11** and **13.12,** Part VIII «Systems and Piping»; in **6.8,** Part VI «Fire Protection»; in **8.10** and **9** Part IX «Machinery»; in **3.6**, Part X «Boilers, Heat Exchangers and Pressure Vessels», as well as in **7.23**, Part XI «Electrical Equipment».

If gas other than natural gas or other types of fuel with a low flash point, is used as fuel, in addition to these requirements, the ship shall comply with the requirements of the IGF Code.

1.1.3.2 If the vessel is an LG gas carrier [1] and uses LNG[2] cargo as a fuel it shall comply with the

[1] *Gas carrier LNG means a* ship intended for the carriage of liquefied gases in bulk, in particular liquefied natural gas, in bulk and other cargoes listed in the table of technical requirements (refer to Annex 1) of the Rules for the Classification and Construction of Ships for the Carriage of Liquefied Gases in Bulk.

[2] *LNG* means liquefied natural gas.

requirements of the International Gas Carrier Code (IGC Code) and the Rules for the Classification and Construction of Gas Carriers (for the use of cargo as fuel, see Section 11, Part VI, "Systems and Piping").

If the ship is a gas carrier and when gas other than LNG or other low-flash point fuel is used as fuel, in addition to the requirements of the IGC Code for the use of fuel ((CNG (compressed natural gas) carrier) refer to the Rules for the Classification and the construction of ships for the carriage of compressed natural gas), shall meet the above requirements for the use of gas fuel and the requirements of IGF Code.

1.1.3.3 In addition to seagoing ships requirements, specified in **1.1.3.1** and **1.1.3.2,** the above conditions of use of gas fuel may be applicable to other offshore facilities under the technical supervision of the Register, mobile offshore drilling units and offshore structures.

In addition to these conditions, such objects shall comply with the relevant national requirements applicable to such objects.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to general terminology of the Rules are given in General Regulations for the Classification and Other Activity and Part I "Classification".

The following definitions, as adopted in the present Part, are equally applicable for the purpose of Part VIII "Systems and Piping" and Part IX "Machinery".

Alternative propulsion plant is a combination of machineries, systems and devices that can produce reverse or direct thrust for ship propulsion in emergency situations in case of failure of the main propulsion plant. The following items can be used as alternative propulsion plant: standby emergency engine, electrical motor or shaft generator, which can be used as a propulsion electrical motor.

The total power output of the alternative propulsion plant engines shall be at least 1/8 of the total power output of the main propulsion plant.

Alternative liquid fuel is a liquid fuel that can substitute the appropriate conventional fuels, is produced (mined) from non-conventional sources and kinds of energy materials or is a combination of alternative and conventional fuels and may differ from conventional fuel due to its properties.

Shafting is a structural complex that kinematically connects ship's main machinery or the main gearing (if available) with a propeller including propeller, intermediate and other shafts complete with couplngs and also a sterntube arrangement with bearings, seals, lubrication and cooling systems, other arrangements (e.g. the propeller shaft sag measuring gauges, protective covers, braking arrangement, etc.) and involved in transmitting torque from the engine to propeller.

The upper ice waterline (UIWL) shall be defined by the maximum draughts fore, amidships and aft.

Exit is an opening in bulkhead or deck provided with closing means and intended for the passage of persons.

Means of escape comprise the escape routes leading from the lowest part of the machinery space floor plates to the exit from that space.

Main active means o f the ship's steering is a propulsion and steering unit being part of the propulsion plant.

Main machinery is the machinery being part of the propulsion plant.

Main propulsion plant is a combination of machineries, systems and devices that can produce reverse or direct thrust for ship propulsion and is comprised of propulsion machineries of roughly equal power output, auxiliary machineries and systems supporting their operation, propellers and all necessary monitoring, control and alarm systems.

In case several engines comprise the main propulsion plant, each of the propulsion engines comprising it is be considered as the main engine.

In case each propulsion plant in multi-shaft propulsion plant is completely independent, each such plant is to be considered as the main propulsion plant.

Remote control is the changing of the speed and direction of rotation as well as starting and stopping of the machinery from a remote position.

Technical condition diagnosis is a process of establishing causes for the deviation of diagnostic parameters when performing condition monitoring and/or detecting malfunctions, as a rules, by stripless methods in order to provide maintenance and repair on the actual condition basis.

Auxiliary active means of the ship's steering is a propulsion and steering unit ensuring propulsion and steering of a ship at low speed or steering of a ship at zero speed when the ship is equipped with main means of propulsion and steering, and is used either in combination with the latter or when the main means of propulsion and steering are inoperative.

Auxiliary machinery and systems of propulsion plant are all support systems (including machinery and equipment, fuel, lubrication, cooling, compressed air systems, hydraulics, etc.) that are necessary for operation of propulsion machinery and propeller.

Auxiliary machinery is the machinery necessary for the operation of main engines, supply of the ship with electric power and other kinds of energy, as well as functioning of the systems and arrangements subject to survey by the Register.

Among the essential auxiliary machinery are:

a generating set, which serves as a main source of electrical power;

steam supply source;

condensate pump and arrangements used for maintaining vacuum in condensers;

the mechanical air supply for boilers;

an air compressor and receiver for starting or control purposes;

as well as machinery ensuring operation or functioning of:

boiler feed water systems;

the fuel oil supply systems for boilers or engines;

the sources of water pressure;

the hydraulic, pneumatic or electrical means for control in main propulsion machinery including controllable pitch propellers.

Common control station is a control station intended for simultaneous control of two or several main engines and fitted with indicating instruments, alarm devices and means of communication.

Active means of the ship's steering (AMSS) are special propulsion and steering units and any combinations of them or with the main propulsion devices, capable of producing thrust or traction force both at a fixed angle to the centre plane of the ship and at a variable angle, either under all running conditions (main AMSS) or part thereof including small and zero speed (auxiliary AMSS) (refer to **7.1.1**).

IGF Code is the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels, 2015, adopted by IMO MSC.391(95), as amended, including amended by IMO MSC.458(101).

IGC Code is the The International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, 1999, reissued in accordance with IMO MSC.370(93), as amended, adopted by IMO MSC.411(97) and MSC.441(99).

SOLAS-74/78/88[3] – International Convention for the Safety of Life at Sea 1974 and Protocols 1978 and 1988 to it, including the applicable Codes.

Engine room is a machinery space intended for the main engines and, in the case of ships with electric propulsion plants, the main generators.

Machinery spaces are all machinery spaces of category A and all other spaces containing main machinery, shafting, boilers, fuel oil units, steam and internal combustion engines, generators and other major electrical machinery, fuel oil filling stations, ventilation and air-conditioning installations, refrigerating plants, steering engines, stabilizing equipment and similar spaces, and trunks to such spaces.

Machinery spaces of category A are those spaces and trunks to such spaces, which contain:

internal combustion machinery used for main propulsion; or

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

any oil-fired boiler or oil fuel unit, or any oil-fired equipment other than boilers, such as inert gas generators, incinerators, etc.

Local control station is a control station fitted with controls, indicators, means of communication (if necessary), located in proximity to, or directly on, the engine.

Torsional vibration stresses are stresses resulting from the alternating torque, which is superimposed on the mean torque.

Dead ship condition (as well a s black out) is 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 shall be assumed available. It is assumed that means are available to start the emergency generator at all times.

The lower ice waterline (LIWL) shall be defined by the minimum draughts fore, amidships and aft. The lower ice waterline shall be determined with due regard to the ship's ice-going capability in the ballast loading conditions. The propeller shall be fully submerged at the lower ice waterline.

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[3] Hereinafter – SOLAS Convention as amended.

Equipment comprises all types of filters, heat exchangers, tanks and other arrangements ensuring normal operation of a machinery installation.

Single failure of propulsion plant is a failure either of one active element (main engine, generator, their local control system, remote-controlled valve, etc.) or of one passive element (pipeline, power cable, manual-controlled valve, etc.) that does not cause failures of other elements.

Propulsion plant power output is a total power output of all propulsion machinery onboard.

If not otherwise specified, propulsion plant power output does not include power output produced by propulsion machinery but utilized in normal operation conditions for the purposes other than ship propulsion (e. g., shaft generator power output).

RTSM – Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

Propulsion plant is the totality of machinery and arrangements intended for generating, converting and transmitting power ensuring propulsion of the ship at all specified rates of speed and comprising propellers, shafting, main gearing and main machinery, including electric propulsion motors.

Cargo control room (CCR) is a room or part thereof where the control, monitoring means and alarm devices, related to performance of cargo handling operations are located; and onboard the tankers, in addition, means for monitoring and alarm of cargo, ballast, atmosphere parameters of cargo and ballast tanks and cargo pump rooms as well as discharge of oil containing and flushing water.

Technical condition prediction is a process of determining causes for the changes in control item for the forthcoming time period, based on the trend of the diagnostic parameter values during the preceding time period.

Propulsion plant is the totality of machinery and arrangements intended for generating, converting and transmitting power ensuring propulsion of the ship at all specified rates of speed and comprising propellers, shafting, main gearing and main machinery, including electric propulsion motors.

Propulsion plant redundancy is a single or multiple duplication of its elements, provided that the propulsion plant is designed so that a single failure of one of its active or passive elements does not cause a loss of ship propulsion and controllability in external conditions specified in the Rules.

Rated power means the maximum continuous (not time-limited) power adopted in calculations under the Rules and stated in documents issued by the Register.

Rated speed means the speed corresponding to the rated power.

Steering system is ship's directional control system, including main steering gear, auxiliary steering gear, steering gear control system and rudder if any (refer to **1.2.9**, Part III "Equipment, Arrangements and Outfit").

Propeller is a mechanism (propeller, steerable propeller, water jet, etc.) that converts the mechanical energy of the propulsion machinery into reverse or direct thrust for ship's propulsion.

Onboard power plant is a combination of machinery, systems and devices that provides a ship with all types of energy and may include the following items: main propulsion plant, alternative propulsion plant, onboard electrical power plant, auxiliary systems and machinery.

Technical condition monitoring system is a complex of inspection facilities and actuators interacting with the control item on demand set forth by the appropriate documentation.

The condition monitoring system provides for the identification of the type of the item technical condition and systematic observation (tracing) of its change on the basis of measurement of the controlled (diagnostic) parameters and comparison of these values with the set standards.

Trend in diagnostic parameter (parameter trend) is a time history of the diagnostic parameter shown graphically or in other form (previous history of the parameter change).

Fuel oil unit is any equipment used for the preparation and delivery of fuel oil (heated or unheated) to boiler, inert gas generator or engine (including gas turbines) and includes any fuel oil pumps, separators, filters and heaters at a pressure of more than 0,18 MPa.

Fuel oil transfer pumps are not considered as fuel oil units.

Main machinery control room is a space containing the remote controls of main and auxiliary machinery, CP-propellers, main and auxiliary AMSS, indicating instruments, alarm devices and means of communication.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions covering the procedure of classification and surveys during construction and in service are stated in the General Regulations for the Classificaiton and Other Activity and in Part I "Classification".

1.3.2 Survey by the Register, including the approval of technical documentation according to **4.1**, Part I "Classification", shall cover the following parts and components:

.1 shafting as assembled, including propeller shaft with liners and waterproof coatings, shaft bearings, thrust blocks and sterntube bearings, couplings, sterntube seals;

.2 propellers, inclusive vertical-axis propellers and jets, steerable propellers, athwartship thrusters and propulsive systems of active rudders, pitch control units, oil distribution boxes and control systems of propellers;

.3 parts indicated in Table 1.3.2.3, as well as spare parts in **10.2**.

1.3.3 Subject to survey by the Register is the assem-bling of the machinery space equipment and testing of the following components of the machinery installation:

.1 main engines with reduction gears and couplings;

.2 boilers, heat exchangers and pressure vessels;

.3 auxiliary machinery;

.4 control, monitoring and alarm systems of the machinery installation;

.5 shafting and propellers;

.6 active means of the ship's steering.

1.3.4 After assembling of machinery, equipment, systems and piping arrangements on board the ship, the machinery installation shall be tested in operation under load according to the program approved by the Register.

Table 1.3.2.3 **Parts to be surveyed**

Nos.	Item	Material	Chapter of Part XIII "Materials"
1	**2**	**3**	**4**
1	**Shafting**		
1.1	Intermediate, thrust and propeller shafts	Forged steel	3.7
1.2	Propeller shaft liners	Copper alloy Corrosion-resistant steel	4.1 On agreement with the Register
1.3	Half-couplings	Forged steel Cast steel	3.7 3.8
1.4	Coupling bolts	Forged steel	3.7
1.5	Sterntubes	Rolled steel Cast steel Forged steel Cast iron	3.2 3.8 3.7 3.9
1.6	Sterntube and strut bushes	Cast steel Copper alloy Forged steel Cast iron	3.8 4.2 3.7 3.9, 3.10
1.7	Lining of sternbush bearing	Non-metallic materials Metal alloys	On agreement with the Register 3.7
1.8	Thrust block casing	Rolled steel Cast steel Cast iron	3.2 3.8 3.9
2	**Propellers**		
2.1	Solid propellers	Cast steel Copper alloy	3.12 4.2
2.2	Built propellers		
2.2.1	Blades	Cast steel Copper alloy	3.12 4.2
2.2.2	Boss	Cast steel Copper alloy	3.12 4.2
2.2.3	Bolts (studs) for securing of blades, hub cones and seals	Copper alloy Forged steel	4.1 3.7
2.3	Hub cones	Cast steel Copper alloy	3.12 4.1,4.2

Nos.	Item	Material	Chapter of Part XIII "Materials"
1	**2**	**3**	**4**
2.4	CPP crosshead in **Ice4** - **Ice6** ice class ships and icebreakers	Forged Steel Cast Steel	3.7 3.8
2.5	Casings of main AMSS in **Ice4** - **Ice6** ice class ships and icebreakers	Forged Steel Cast Steel Rolled Steel	3.7 3.8 3.2

Notes: 1. The materials shall be selected in accordance with **2.4**.
2. All shafts (propeller, thrust, intermediate), propeller blades shall be subjected to non-destructive testing when manufactured. The methods, standards and scope of such tests shall be agreed with the Register.
3. The nomenclature and material of the CPP components: crank pin rings, sliding shoes (other than those given under item **2.4**), push-pull rods; hydraulic cylinders, etc., as well as the AMSS parts (other than those given under item **2.5**) shall be agreed with the Register.

2 GENERAL REQUIREMENTS

.1 POWER OF MAIN MACHINERY

2.1.1 The requirements to power at the propeller shafts P_{min}, in kW, of icebreakers and ice class ships are specified in **2.1.1.1** to **2.1.1.4** depending on their ice class.

2.1.1.1 The power at icebreaker propeller shafts shall be substantiated and correspond to their ice class in compliance with **2.2.3**, Part I "Classification".

2.1.1.2 The minimum required power P_{min}, in kW, delivered to the propeller shaft of ships of ice classes **Ice2** and **Ice3** shall not be less than bigger of the values determined according to **2.1.1.3** and **2.1.1.4**.

The minimum required power P_{min}, in kW, delivered to the propeller shaft of ice ships of arctic category **Ice4** shall not be less than the lesser of values determined according to **2.1.1.3** and **2.1.1.4**.

The minimum required power delivered to the propeller shaft of ships of ice classes **Ice5** ÷ **Ice6** shall be determined according to **2.1.1.3**.

2.1.1.3 Power P_{min}, in kW, shall be determined by the formula

$$P_{min} = f_1 f_2 f_3 (f_4 \Delta + P_0), \qquad (2.1.1.3)$$

where:
f_1 = 1,0 – in kW, shall be determined by the formula;
f_1 = 0,9 – for propulsion plants with controllable pitch propellers or electric drive;
$f_2 = \varphi / 200 + 0{,}675$, but not more than 1,1;
φ – slope of stem (refer to **3.10.1.2**, Part II "Hull");
f_2 = 1,1 – for a bulbous stem;
the product $f_1 \cdot f_2$ shall be taken in all cases not less than 0,85;
$f_3 = 1{,}2B/\Delta^{1/3}$, but not less than 1,0;
B – breadth of the ship, m;
Δ – breadth of the ship, m; D = ship's displacement to the summer load waterline (refer to **1.2.1**, Part III "Equipment, Arrangements and Outfit"), t.
When calculating for ships of ice classes **Ice2** and **Ice3** Δ need not be taken more than 80000 t;
f_4 and P_o – from Table 2.1.1.3.

Irrespective of the results obtained in calculating the power as per Formula (2.1.1.3), the minimum power, in kW, shall not be less than:
3500 – for **Ice6** ice class ships**;**
2600 – for **Ice5** ice class ships;
1000 – for **Ice4** ice class ships;
740 – for **Ice3** and **Ice2** ice class ships**.**

Table 2.1.1.3 **Values of f_4 and P_0**

Displacement Δ, t	Value	Ice class ships				
		Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**
< 30000	f_4	0,18	0,22	0,26	0,3	0,36
	P_0, in kW	0	370	740	2200	3100
≥ 30000	f_4	0,11	0,13	0,15	0,20	0,22
	P_0, in kW	2100	3070	4040	5200	7300

2.1.1.4 The power P_{min}, in kW, shall be determined as the maximum value calculated for the upper (UIWL) and lower ice waterlines (LIWL)

$$P_{\min} = K_e \frac{\left(R_{CH} / 1000 \right)^{3/2}}{D_P}, \qquad (2.1.1.4\text{-}1)$$

where:
K_e – coefficient given in Table 2.1.1.4;
R_{CH} – parameter determined as per the formula

$$R_{CH} = 845 \cdot C_\mu \cdot (H_F + H_M)^2 \cdot (B + C_\psi \cdot H_F) + 42 \cdot L_{PAR} \cdot H_F{}^2 + 825 \cdot \left(\frac{L \cdot T}{B^2} \right)^3 \cdot \frac{A_{wf}}{L}, \qquad (2.1.1.4\text{-}2)$$

де:
$C_\mu = 0{,}15 \cos \varphi_2 + (\sin \psi / \sin\alpha)$, parameter determined as per the formula 0,45;
$H_F = 0{,}26 + (H_M \cdot B)0{,}5$;
$H_M = 1{,}0$ for **Ice4** ice class ships;
$H_M = 0{,}8$ for **Ice3** ice class ships;
$H_M = 0{,}6$ for **Ice2** ice class ships;
B – = breadth of the ship, m (refer to Fig. 2.1.1.4);
$C_\psi = 0{,}047\ \psi - 2{,}115$;
$C_\psi = 0{,}0$ at $\psi < 45^o$;
L_{PAR} – length of the parallel midship body, m;
L – length of the ship between the perpendiculars, m;
T– draught at UIWL or LIWL, m;
A_{wf} – area of the waterline of the bow, m^2;
α – angle of the waterline at B/4, degree;
φ_1 – rake of the stem at the centreline, degree;
$\varphi_1 = 90^o$ – for a ship with a bulbous bow;
φ_2 – rake of the bow at B/4, degree;
χ– buttock area, at B/4;
$\psi = \arctan(\tan \varphi_2 / \sin\alpha)$;
D_p – diameter of the propeller, m;
L_{BOW} – length of the bow, m.
The value $(L{\cdot}T/B^2)^3$ shall be taken within the range $5 < (L{\cdot}T/B^2)^3 < 20$.

Formula (2.1.1.4-1) may be used when the conditions given in Table 2.1.1.4-2 are fulfilled.

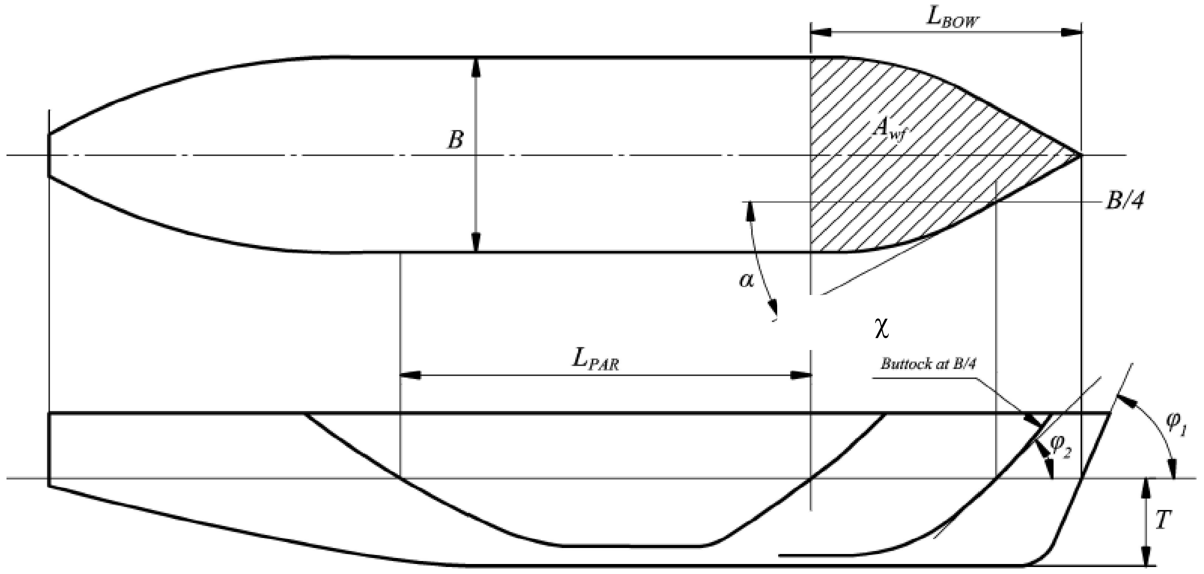


Fig. 2.1.1.4 Geometrical features of the ship for determination of the power delivered to the propeller shaft of ice class ships

Table 2.1.1.4-1 **Values of coefficient K_e**

Number of propellers	Propulsion plant with controllable pitch propeller or electric drive	Propulsion plant with fixed pitch propeller
1	2,03	2,26
2	1,44	1,60
3	1,18	1,31

Table 2.1.1.4-2 **Applicability conditions of Formula 2.1.1.4-1**

Parameter	α, in deg	φ_1, in deg.	φ_2, in deg.	L, in m	B, in m	T, in m	L_{BOW}/L	L_{PAR}/L	D_p/T	$A_{wf}/(L \cdot B)$
Minimum value	15	25	10	65,0	11,0	4,0	0,15	0,25	0,45	0,09
Maximum value	55	90	90	250,0	40,0	15,0	0,40	0,75	0,75	0,27

2.1.1.5 The minimum power values may be reduced subject to the technical substantiation submitted to the Register in each particular case.

2.1.2 In icebreakers and **Ice6** ice class ships, turbines and internal combustion engines with mechanical transmission of power to the propeller may be utilized as main engines, provided use is made of the devices to protect turbines, reduction gears of gas-turbine geared sets and diesel-engine geared sets against the loads exceeding the design torque determined with regard to operation of such ships under ice conditions in compliance with the requirements of **4.2.3.2**, Part IX "Machinery".

2.1.3 Propulsion plant shall provide sufficient astern power to maintain manoeuvring of the ship in all normal service conditions.

2.1.4 Propulsion plant shall be capable of maintaining in free route astern at least 70 per cent of rated ahead speed for a period of at least 30 min. By the rated ahead speed is meant a speed corresponding to the maximum continuous power of the main machinery.

The astern power shall be sufficient to take way off a ship making a full ahead speed on an agreeable length, which must be confirmed during trials.

2.1.5 In propulsion plants with reversing gears or CP-propellers as well as in electric propulsion plants, precautions shall be taken against possible overload of main engines in excess of permissible values.

2.1.6 Means shall be provided to ensure that the machinery may be brought into operation from the dead ship condition without external aid (refer to **16.2.3**, Part VIII "Systems and Piping").

On ships where internal combustion engines are started by compressed air, the set of equipment for starting shall ensure the supply of air in quantity sufficient for the initial start without external aid.

Where the ship is not fitted with an emergency generator, or an emergency generator does not comply with the requirements specified under **2.9.4**, Part IX "Machinery", the means for bringing main and auxiliary machinery into operation shall be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, the machinery shall be powered by a hand-starting ICE or a hand-operated compressor.

The emergency generator and other means needed to restore the propulsion shall have a capacity such that the necessary propulsion starting energy is available within 30 min of black out/dead ship condition (refer to **1.2**).

Emergency generator stored starting energy shall not be directly used for starting the propulsion plant, the main source of electrical power and/or other essential auxiliaries (emergency generator excluded).

For steam ships, the 30 min time limit may be interpreted as time from black out/dead ship condition to light-off of the first boiler.

2.1.7 In the event of failure of one or all turbochargers (refer to **2.5.1**, Part IX "Machinery") the machinery installation with one main internal combustion engine shall provide the ship speed at which the steerability of the ship is maintained. The main engine shall provide not less than 10 per cent of the rated power.

2.1.8 The power of main machinery in ships of river-sea navigation shall provide the ahead speed in load condition of at least 10 knots in calm water. Another speed may be set for the ships intended for navigation in geographically restricted areas while providing sufficient speed to maintain the ship's handling capability in load condition.

2.1.9 Supercharged high-speed engines (over 1400 rpm), which increased noise level makes direct local control difficult, may be admitted by the Register for use as main engines in sea-going ships, if provision is made for remote control and monitoring so that constant presence of the attending personnel in the engine room will not be necessary. The control and monitoring facilities shall comply with the requirements of Part XV "Automation".

2.1.10 In the case of ships with twin hulls, the failure of the machinery installation of one hull will not put the machinery installation of the other hull out of action.

2.1.11 Long run of the propulsion plant at all specified rates during its operation under the conditions corresponding to the assigned class shall not lead to the overload. Technically substantiated power supply shall be provided.

2.1.12 Propulsion plants and auxiliary machinery of passenger ships having length, as defined in **1.2.1** of the Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones, shall comply with the requirements of **2.2.6.7.1** and **2.2.6.8**, Part VI "Fire Protection".

2.1.13 Passenger ships shall be provided with facilities to maintain or restore normal operation of the main engines in the event of one of the responsible auxiliary machinery failure.

2.1.14 For a ship with a single engine, automatic stopping of this engine shall be excluded, except to prevent override of more than 20% (refer to **3.2.1.7** of this Part and refer to **2.11.2,** Part IX «Machinery» and **2.4.2.1.3, Part** XV «Automation».

2.1.15 Standby ships shall be fitted with at least two propulsion installations.

Propulsion installation shall provide both ahead and astern propulsion**.**

2.1.16 For a ship with gas engines installed in an ESD (emergency shutdown devices)-protected machinery space, the minimum power of the main and auxiliary engines shall be assessed on a case-by-case basis from the operational characteristics of the ship, ensuring that the requirements of para **9.12.2.5**, Part IX "Machinery" are met, taking into account the design and purpose.

2.1.17 For a ship with a single gas engine, the requirements of paras **9.12.2.7 — 9.12.2.8**, Part IX "Machinery" shall be met. The minimum power shall be determined to ensure that this requirement is fulfilled, taking into account the particular design and purpose of the ship.

2.2 NUMBER OF MAIN BOILERS

2.2.1 In general, not less than two main boilers shall be fitted in ships of unrestricted service. Using a steam power plant with one main boiler may be permitted provided the technical substantiation is submitted to the Register.

2.3 ENVIRONMENTAL CONDITIONS

2.3.1 The machinery, equipment and systems installed in the ship shall remain operative under environmental conditions stated in Tables 2.3.1-1 and 2.3.1-2, unless provided otherwise in the other parts of the Rules. Sea water temperature is assumed to be equal to 32°C.

For ships designed for geographically restricted service other temperatures may be adopted if technical substantiation is available.

Table 2.3.1-1 **List, motions and trim[1, 2]**

Machinery and equipment	Steady list either way under static conditions	List either way under dynamic conditions (rolling)	Steady trim by bow or stern	Dynamic inclination by bow or stern (pitching)
Main and auxiliary machinery	15,0	22,5	5,0 [4]	7,5
Emergency machinery and equipment (emergency power installations, emergency fire pumps and their devices)	22,5 [3]	22,5 [3]	10,0	10,0

[1]Steady list and trim shall be taken into account simultaneously. Rolling and pitching are also to be considered simultaneously.

[2] On agreement with the Register, the values of inclinations may be altered depending on the type and dimensions of the ship and its service conditions as well.

[3] In gas carriers and chemical tankers emergency power sources shall remian operative when the ship is listed up to 30 deg.

[4] Where the length of the ship exceeds 100 m, the static trim by bow or stern may be taken as (500/L)° where L is the length of the ship, in m, as defined in **1.1.3**, Part II "Hull".

Table 2.3.1-2 **Air temperature**

Installed location	Temperature range, °C
In enclosed spaces	0 to + 45°C
Machinery or boilers in spaces subject to temperatures exceeding 45°C and below 0°C	According to specific local conditions
On the open deck	– 25 to + 45°C

Note. For ships intended for geographically restricted service other temperatures may be adopted on agreement with the Register.

2.4 MATERIALS AND WELDING

2.4.1 Materials for the manufacture of parts of the shaftings and propellers shall comply with the requirements given in the relevant Chapters of Part XIII "Materials", as indicated in column 4, Table 1.3.2.3.

The materials of shaft components stated in item **1.7** of Table 1.3.2.3 may be chosen in accordance with the relevant standards.

The materials used for the components stated in items **1.2** – **1.6**, **1.8**, **2.2.3** and **2.3** of Table 1.3.2.3 may also be chosen in accordance with the relevant standards. In such a case, the application of materials shall be agreed with the Register when examining the technical documentation.

The materials used for the components (semi-finished products) stated in items **1.1**, **2.1**, **2.2.1** and **2.2.2** of Table 1.3.2.3 subject to supervision by the Register during manufacture; a survey of the materials for the other parts listed in this table may be required at the discretion of the Register.

2.4.2 Intermediate, thrust and propeller shafts shall generally be made of steel with tensile strength R_m between 400 and 800 MPa.

2.4.3 The mechanical properties and chemical composition of materials used for the manufacture of propellers shall be in compliance with **3.12** and **4.2**, Part XIII "Materials". Whereas steel of martensitic grade is permitted for the manufacture of propellers for ships of all types, steel of austenitic grade is permitted for the manufacture of propellers for ships without ice strengtheming.

The possibility to use carbon steel for the manufacture of propellers shall be agreed with the Register considering the requirements of **3.8**, Part XIII "Materials".

Copper alloys of Type CU3 and Type CU4 are admitted for propellers in all ships, except icebreakers; copper alloys of Type CU1 and Type CU2 may be used exclusively for propellers in ships not having ice classes.

2.4.4 Where it is intended to make shafting and propellers of alloy steels, including corrosionresistant and high strength steels, data on chemical composition, mechanical and special properties, confirming suitability of the steel for intended application, shall be submitted to the Register.

2.4.5 Intermediate, thrust and propeller shafts as well as coupling bolts (studs) may be made of rolled steel in accordance with **3.7.1**, Part XIII "Materials".

2.4.6 Securing and locking items of propeller blades, hub cones, sterntubes, sternbushes and sealings shall be made of corrosion-resistant materials.

2.4.7 Welding procedure and non-destructive testing of welded joints shall comply with the requirements of Part XIV "Welding".

2.4.8 For all ships, new installation of materials which contain asbestos shall be prohibited in machinery installations, machinery and equipment covered by the requirements of Part VI "Fire Protection", Part VII "Machinery Installations", Part VIII "Systems and Piping", Part IX "Machinery", Part X "Boilers, Heat Exchangers and Pressure Vessels" and Part XII "Refrigerating Plants".

2.5 INDICATING INSTRUMENTS

2.5.1 All the indicating instruments, with the exception of liquid-filled thermometers, shall be checked by competent bodies. Pressure gauges fitted on boilers, heat exchangers, pressure vessels and refrigerating plants shall meet the requirements of **3.3.5** and **6.3.8**, Part X "Boilers, Heat Exchangers and Pressure Vessels" and 7.1, Part XII "Refrigerating Plants", respectively.

2.5.2 The tachometer accuracy shall be within ±2,5 per cent. With restricted speed ranges, the accuracy shall not be below 2 per cent, and the ranges shall be marked with bright colour on the scales of tachometers or in another way.

2.6 APPLICATION OF THE RELIABILITY MEASURES OF THE MACHINERY INSTALLATIONS

2.6.1 The reliability measures are established and specified during design and/or order of the machinery installation components by agreement of the appropriate technical documentation between the customer (shipowner) and the designer or supplier. The specific list of the reliability measures to be determined shall be established for each type of products with regard to the peculiarities of its application, failure effects, maintenance and repair system adopted.

2.7 REQUIREMENTS FOR PROPULSION PLANT REDUNDANCY

2.7.1 General.

2.7.1.1 The requirements of the present Chapter are mandatory for ships with the class notation supplemented with one of the following marks in accordance with the requirements of **2.2.26**, Part I “Classification”:

RP-1, RP-1A, RP-1AS, RP-2 or **RP-2S.**

2.7.2 Marks in ship’s class notation for propulsion plant elements redundancy.

2.7.2.1 If ship’s propulsion plant is provided with redundancy of its elements, the main class notation is supplemented with one of the following marks:

.1 RP - 1 — if ship’s propulsion plant has redundancy for all its elements, except of main engine, reduction gear, shafting and propeller; a single failure of any of the elements of the systems and equipment supporting the abovementioned elements shall not result in loss of speed, electric power supply and steerability;

.2 RP - 1A — if ship’s propulsion plant has redundancy for all its elements, except of reduction gear, shafting and propeller; a single failure of any of the elements of the propulsion plant, its auxiliary machinery and systems or monitoring and control systems shall not result in loss of speed and steerability;

.3 RP - 1AS — if ship’s propulsion plant has redundancy for all its elements as required for **RP-1A** mark, and main engines or alternative propulsion plant engines are located in independent machinery spaces, so that the loss of one of the compartments due to fire or flooding shall not result in loss of speed, electric power supply and steerability;

.4 RP - 2 — if ship’s propulsion plant has redundancy for all its elements and consists of several main propulsion plants; a single failure of any of the elements of the propulsion plant and steering gear shall not result in loss of speed, electric power supply and steerability;

.5 RP - 2S — — if ship’s propulsion plant has redundancy for all its elements as required for **RP-2** mark and is located in independent machinery spaces, so that the loss of one of the compartments due to fire or flooding shall not result in loss of speed, electric power supply and steerability.

2.7.2.2 Additional marks **RP-1**, **RP-1A**, **RP-1AS**, **RP-2** o **RP-2S** can be assigned to the ships under construction or in service.

2.7.3 Technical documentation.

2.7.3.1 For assigning additional marks **RP-1**, **RP-1A**, **RP-1AS**, **RP-2** or **RP-2S** in the ship's class notation the following technical documentation shall be submitted to the Register for approval in addition to the requirements of **4**, Part I, "Classification" (as applicable):

.1 calculations indicating that in case of a single failure the ship maintains its speed and steerability in accordance with the requirements of **2.7.5.3** (for ships with additional marks **RP-1**, **RP-1A**, **RP-1AS**, **RP-2** or **RP-2S**).

The results of model or full-scale testing are allowed for submission as an alternative;

.2 qualitative failure analysis for propulsion plant and steering gear (in accordance with Section 12) or Failure Mode and Effect Analysis (FMEA) for propulsion plant elements based on a failure tree, or equivalent risk assessment method coordinated with the Register;

.3 calculation of torsional vibrations, in which the possibility of continuous operation of the alternative propulsion system shall be considered separately;

.4 programs for mooring and sea trials.

2.7.4 Requirements for ships with additional mark RP-1 in class notation.

2.7.4.1 All elements of the following auxiliary machinery and systems of the main propulsion plant are to be redundant:

.1 fuel system, including slop tanks, but except of fuel reception, transfer and separation system;

.2 lubrication system of propulsion machinery, reduction gears, shafting bearings, sternbush bearings, etc., except of oil reception, transfer and separation system;

.3 hydraulic systems that support the operation of propulsion plant couplings, controllable pitch propellers, reverse deflectors of water jet propellers, etc.;

.4 fresh water and sea water cooling systems that support the main propulsion plant;

.5 fuel heating systems in service tanks that support the main propulsion plant;

.6 starting systems (pneumatic, electric, hydraulic) that support the main propulsion plant;

.7 electric power sources;

.8 ventilation installations, if required, e. g. for air supply for cooling the primary engines;

.9 monitoring, alarm and control systems.

2.7.4.2 A single failure of auxiliary machinery and elements of the systems specified in **2.7.4.1**, including damages to stationary pipelines, shall not result in halt of the ship or loss of its steerability. In order to fulfil this requirement, necessary by-passes and equipment redundancy (pumps, heaters, etc.) shall be provided in the systems.

A loss of power output of the main engine is allowed as a result of a single failure by at most 50%.

2.7.4.3 The parts of the systems and pipelines where a failure has occurred shall be able to be disconnected from the operable parts.

2.7.4.4 The ship shall be equipped with main and auxiliary steering gears in accordance with **2.9**, Part III, "Equipment, Arrangements and Outfit".

The main and auxiliary steering gears shall be controlled independently from the navigation bridge and from the steering gear room.

2.7.5 Requirements for ships with additional mark RP-1A in class notation.

2.7.5.1 In addition to the requirements of **2.7.4** the ships with additional mark **RP-1A** shall meet the requirements of **2.7.5**.

2.7.5.2 The main propulsion plant shall consists of at least two propulsion machinery, one reduction gear, one propulsion electric motor, one shafting line and one propeller are sufficient. One of the propulsion machinery may be an alternative propulsion plant. In addition, the independent systems that support the redundant machinery are not subject to the requirements of **2.7.4.2** regarding redundancy of each of the elements of the system.

2.7.5.3 In case of a single failure of the main propulsion plant the operable propulsion machinery or alternative propulsion plant shall ensure the following capabilities in any ship loading condition:

.1 ship propulsion at 6 knots or 50% of specification speed according to **1.1.3**, Part II, "Hull", the lesser of two, at Beaufort 5;

.2 ship steerability sufficient for taking the safest position in respect to stability and maintaining this position at Beaufort 8;

.3 fulfilment of the requirements of **2.7.5.3.1** and **2.7.5.3.2** for at least 72 hours; for ships with the maximum voyage duration less than 72 hours the time specified above may be limited at the maximum voyage duration.

2.7.5.4 The alternative propulsion plant shall be started at most in 5 min after the main propulsion plant fails.

2.7.5.5 A single failure resulting in the loss of at least one generator may be accepted provided that the FMEA performed shows that after failure the ship has enough electric power output to continue propulsion and maintain steerability according to the requirements of 2.7.5.3 without starting the stand-by generator.

After failure the electric power output shall be sufficient for starting the most high-powered consumer without imbalance of the electric loading. Stand-by electric pumps may not be included in electric loading balance during alternative propulsion plant operation.

2.7.5.6 The main switchboard shall consist of two sections. In case one of the sections fails, the remaining section shall be capable of powering the following consumers:

.1 driving motors of the alternative propulsion plant and steering gears, including attached equipment;

.2 equipment for transmission of propulsion thrust;

.3 propulsion electric motor, if any;

.4 propeller;

.5 auxiliary machinery and systems of the propulsion plant;

.6 monitoring, alarm and control systems.

2.7.5.7 The monitoring, alarm and control systems of the alternative propulsion plant shall be independent from the systems of the main propulsion plant.

2.7.6 Requirements for ships with additional mark RP-1AS in class notation.

2.7.6.1 In addition to the requirements of **2.7.5** the ships with additional mark RP-1AS shall meet the requirements of **2.7.6**.

2.7.6.2 The main propulsion plant shall be equipped with at least two main engines located in at least two independent machinery spaces according to the requirements of **2.7.6.3** and **2.7.6.4**.

Non-redundant elements of the main propulsion plant (reduction gear, propeller, shafting line, propulsion electric motor) that are common for several main engines shall be located in a separate room separated with watertight bulkhead of A-0 fire resistance from machinery spaces with the main engines according to **2.7.1.2.1**, Part II, “Hull”.

2.7.6.3 The bulkhead between the machinery spaces mentioned in **2.7.6.2** shall be watertight according to **2.7.1.2.1**, Part II, “Hull” and have fire resistance of A-60.

If the machinery spaces are separated from each other with cofferdams, tanks or other compartments the bulkheads shall have fire resistance at least A-0 but not less than required for adjacent rooms and compartments in accordance with **2**, Part VI, “Fire Protection”.

2.7.6.4 If closures are provided in the bulkheads specified in **2.7.6.3** and **2.7.6.4** they shall meet the requirements of **7.12**, Part III, “Equipment, Arrangements and Outfit”.

This closures may not be considered as emergency exits from machinery spaces.

2.7.7 Requirements for ships with additional mark RP-2 in class notation.

2.7.7.1 In addition to the requirements of **2.7.4** and applicable requirements of **2.7.5**, the ship shall meet the requirements of **2.7.7**.

2.7.7.2 The ship shall be equipped with at least two independent main propulsion plants. In case of a single failure of one of the propulsion plants the propulsion plant shall maintain at least 50% of its power output, which ensures propulsion and steerability in any loading condition.

2.7.7.3 In case of a single failure of one of the propulsion plants the following requirements shall be fulfilled:

.1 the failure shall not affect the operable propulsion plant if it has been in operation when the failure occurred (in particular, no significant change of driving engine power output and rotational speed shall occur);

.2 the operable propulsion plant that has not been in operation when the failure occurred shall be warm stand-by in order to be ready for starting within 45 s after the failure occurs;

.3 safety measures shall be provided for the failed propulsion plant, in particular, shafting block. **2.7.7.4** The ship shall be equipped with at least two independent steering gears in accordance with **2.9**, Part III, “Equipment, Arrangements and Outfit”. In case of any single failure of one of the steering gears the remaining steering gear shall maintain its operability, including synchronization system failure.

Ship steerability shall be maintained in case of external influences specified in **2.7.5.3**, even in case one of the rudders is blocked at the maximum rudder angle, there shall be a possibility of changing the rudder angle in position parallel to the ship's centreline and fixing it in this position.

2.7.7.5 If only steerable propellers are provided as the means of propulsion and steering, at least two propulsion plants with independent steering shall be provided.

Ship steerability shall be maintained in case of external influences specified in **2.7.5.3**, even in case one of the steerable propellers is blocked or disconnected, there shall be a possibility of changing the angle of the failed steerable propeller into position parallel to the ship's centreline and fixing it in this position.

2.7.8 Requirements for ships with additional mark RP-2S in class notation.

2.7.8.1 In addition to the requirements of **2.7.4**, applicable requirements of **2.7.5** and requirements of **2.7.7**, the ship shall meet the requirements of **2.7.8**.

2.7.8.2 The ship shall be equipped with at least two independent propulsion plants (including reduction gear, propeller and shafting line) according to **2.7.7.2** and **2.7.7.3** located in at least two independent machinery spaces.

2.7.8.3 The longitudinal bulkhead between the machinery spaces mentioned in **2.7.8.2** shall be watertight according to **2.7.1.2.1**, Part II, "Hull" and have fire resistance of A-60.

If the machinery spaces are separated from each other with cofferdams, tanks or other compartments the bulkheads shall have fire resistance at least A-0 but not less than required for adjacent rooms and compartments in accordance with **2**, Part VI, "Fire Protection".

2.7.8.4 If closures are provided in the longitudinal bulkhead specified in **2.7.8.4.2** they shall meet the requirements of **7.12**, Part III, "Equipment, Arrangements and Outfit". This closures may not be considered as emergency exits from machinery spaces.

2.7.8.5 The ship shall be equipped with at least two independent steering gears in accordance with the requirements of **2.7.7.4** located in at least two independent steering gear rooms.

2.7.8.6 The longitudinal bulkhead between the steering gear rooms shall be watertight according to **2.7.1.2.1**, Part II, "Hull" and have fire resistance of at least A-0.

2.7.8.7 The main electric power sources shall be located in separate compartments in accordance with **2.7.8.3** and **2.7.8.4** so that in case of fire or flooding in one of the compartments electric power supply to the consumers specified in **2.7.5.6** can be maintained.

2.7.8.8 The main switchboard shall consist of two sections in accordance with **2.7.5.6**. Each of the sections shall be located in separate room.

The bulkhead separating the rooms accommodating the main switchboard shall meet the requirements of **2.7.8.3** and **2.7.8.4**.

2.7.8.9 Automation systems, monitoring and control systems of propulsion plants and steering gears shall be located in such a manner that in case of loss of one of the machinery spaces as a result of fire or flooding only one propulsion plant or steering gear is out of service.

Control stations shall be located so that in case of fire or flooding in one of the machinery spaces or steering gear rooms control functions are maintained.

2.8 MACHINERY REQUIREMENTS FOR POLAR CLASS SHIPS

2.8.1 Application.

2.8.1.1 The requirements of this Chapter apply to main propulsion, steering gear, emergency and essential auxiliary systems essential for the survivability of the crew and the safety of the ships, intended for operation (self-navigation) in polar waters (Arctic waters and/or the Antarctic region) covered with ice, taking into account the provisions of the POLAR Code based on polar classes (refer to **2.2.3**, Part I "Classification")[4].

2.8.2 General.

2.8.2.1 Drawings and particulars to be submitted:

. 1 details of the environmental conditions and the required ice class for the machinery, if different from ship's ice class;

.2 detailed drawings of the main propulsion machinery.

[4] POLAR Code: International Code for Ships Navigating in Polar Waters, 2014, adopted by IMO Resolutions MSC.385 (94) and MERC.264 (68), subject to the provisions of the amendments to the International Convention SOLAS-74, as amended by Resolution MSC.386 (94).

Description of the main propulsion, steering, emergency and essential auxiliaries shall include operational limitations.

Information on essential main propulsion load control functions;

.3 description detailing how main, emergency and auxiliary systems are located and protected to prevent problems from freezing, ice and snow and evidence of their capability to operate in intended environmental conditions;

.4 calculations and documentation indicating compliance with the requirements of this Chapter.

2.8.2.2 System design.

.1 Machinery and supporting auxiliary systems shall be designed, constructed and maintained to comply with the requirements of periodically unmanned machinery spaces with respect to fire safety.

Any automation plant (i.e. control, alarm, safety and indication systems) for essential systems installed shall be maintained to the same standard.

.2 Systems, subject to damage by freezing, shall be drainable.

.3 Single screw vessels classed PC1 to PC5 inclusive shall have means provided to ensure sufficient ship operation in the case of propeller damage including CP-mechanism.

2.8.3 Materials.

2.8.3.1 Materials exposed to sea water.

Materials exposed to sea water, such as propeller blades, propeller hub and blade bolts shall have an elongation not less than 15 % on a test piece the length of which is five times the diameter.

Charpy V-notch impact test (determination of impact energy ***KV*** for sharply-notched specimen) shall be carried out for other than bronze and austenitic steel materials. Test pieces taken from the propeller castings shall be representative of the thickest section of the blade.

An average impact energy ***KV*** value of 20 J taken from three Charpy V-notch tests shall be obtained at -10 ºC.

2.8.3.2 Materials exposed to sea water temperature.

Materials exposed to sea water temperature shall be of steel or other approved ductile material.

An average impact energy ***KV*** value of 20 J taken from three tests shall be obtained at -10ºC.

2.8.3.3 Material exposed to low air temperature.

Materials of essential components exposed to low air temperature shall be of steel or other approved ductile material.

An average impact energy KV value of 20 J taken from three Charpy V-notch tests shall be obtained at 10ºC below the lowest design temperature.

2.8.4 Ice interaction load.

2.8.4.1. Propeller ice interaction.

The present requirements cover open and ducted type propellers situated at the stern of a ship having controllable pitch or fixed pitch blades.

Ice loads on bow propellers and pulling type propellers shall be agreed with the Register.

The given loads are expected, single occurrence, maximum values for the whole ships service life for normal operational conditions.

These loads do not cover off-design operational conditions, for example when a stopped propeller is dragged through ice.

These requirements considering loads due to propeller ice interaction apply also for azimuthing (geared and podded) thrusters.

However, ice loads due to ice impacts on the body of azimuthing thrusters are not covered by this Section.

The loads given in **2.8.4** are total loads (unless otherwise stated) during ice interaction and shall be applied separately (unless otherwise stated) and are intended for component strength calculations only. The different loads given here shall be applied separately.

F_b is a force bending a propeller blade backwards when the propeller mills an ice block while rotating ahead;

F_f is a force bending a propeller blade forwards when a propeller interacts with an ice block while rotating ahead.

2.8.4.2 Ice class factors.

Table 2.8.4.2 below lists the design ice thickness and ice strength index to be used for estimation of the propeller ice loads.

Table 2.8.4.2

Polar class	PC1	PC2	PC3	PC4	PC5	PC6	PC7
H_{ice}, in m	4,0	3,5	3,0	2,5	2,0	1,75	1,5
S_{ice}	1,2	1,1	1,1	1,1	1,1	1,0	1,0
S_{qice}	1,15	1,15	1,15	1,15	1,15	1,0	1,0

H_{ice} — ice thickness for machinery strength design;
S_{ice}— ice strength index for blade ice force;
S_{qice}— = ice strength index for blade ice torque.

2.8.4.3 Design ice loads for open propeller.

2.8.4.3.1 Maximum backward blade force F_b, in kN:

when $D < D_{limit}$:

$$F_b = -27S_{ice}[nD]^{0,7}[EAR/Z]^{0,3}\ [D]^2; \qquad (2.8.4.3.1\text{-}1)$$

when $D \leq D_{limit}$:

$$F_b = -23S_{ice}[nD]^{0,7}[EAR/Z]^{0,3}(H_{ice})^{1,4}[D], \qquad (2.8.4.3.1\text{-}2)$$

where:

D_{limit} - $0,85(H_{ice})^{1,4}$

n- nominal rotational speed (at MCR free running condition) for CP-propeller and 85 % of the nominal rotational speed (at MCR free running condition) for a FP-propeller (regardless driving engine type).

$\boldsymbol{F_b}$ shall be applied as a uniform pressure distribution to an area on the back (suction) side of the blade for the following load cases:

.1 load case **1**: from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length;

.2 load case **2**: a load equal to 50 % of the $\boldsymbol{F_b}$ shall be applied on the propeller tip area outside of 0,9R;

.3 load case **5**: for reversible propellers a load equal to 60 % of the $\boldsymbol{F_b}$ shall be applied from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.

Refer to load cases 1, 2 and 5 in Table 1 of the Appendix.

2.8.4.3.2 Maximum forward blade force $\boldsymbol{F_f}$, in kN:

when $D < D_{limit}$:

$$F_f = 250[EAR/Z][D]^2; \qquad (2.8.4.3.2\text{-}1)$$

when $D \geq D_{limit}$:

$$F_f = 500\frac{1}{(1-\frac{d}{D})}H_{ice}[EAR/Z][D], \qquad (2.8.4.3.2\text{-}2)$$

where:

d - propeller hub diameter, in m;

D - propeller diameter, in m;

EAR- expanded blade area ratio;

Z - number of propeller blades.

$\boldsymbol{F_f}$ shall be applied as a uniform pressure distribution to an area on the face (pressure) side of the blade for the following loads cases:

.1 load case **3**: from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length;

.2 load case **4**: a load equal to 50 % of the $\boldsymbol{F_f}$ shall be applied on the propeller tip area outside of 0,9R;

.3 load case **5**: for reversible propellers a load equal to 60 % $\boldsymbol{F_f}$ shall be applied from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.

Load cases 3, 4 and 5 - refer to Table 1 of the Appendix.

2.8.4.3.3 Maximum blade spindle torque.

Spindle torque Q_{smax}, in kNm, around the spindle axis of the blade fitting shall be calculated both for the load cases described in **2.8.4.3.1** and **2.8.4.3.2** for $\boldsymbol{F_b}$ and $\boldsymbol{F_f}$.

If these spindle torque values are less than the default value given below, the default minimum value shall be used. Default value:

$$Q_{smax}=\boldsymbol{F}\boldsymbol{c}_{0,7}, \qquad (2.8.4.3.3)$$

where:
$c_{0,7}$ - length of the blade chord at 0,7R radius, in m;
F = either F_b or F_f, which ever has the greater absolute value.

2.8.4.3.4 Maximum propeller ice torque applied to the propeller Q_{smax}, in kNm:
when $D < D_{limit}$:

$$Q_{max}= 105(1-d/D)S_{qice}(P_{0,7}/D)^{0,16}(t_{0,7}/D)^{0,6}(nD)^{0,17}D^{3}; \qquad (2.8.4.3.4\text{ -1})$$

when $D \geq D_{limit}$:

$$Q_{max}=202(1-d/D)S_{qice}H_{ice}^{1,1}(P_{0,7}/D)^{0,16}(t_{0,7}/D)^{0,6}(nD)^{0,17}D^{1,9}, \qquad (2.8.4.3.4\text{ -2})$$

where:
D_{limit}= 1,81H_{ice};
S_{qice} - ice strength index for blade ice torque
$P_{0,7}$ - propeller pitch at 0,7R, in m;
$t_{0,7}$ - =max thickness at 0,7R, in m;
n - =the rotational propeller speed, in rps, at bollard condition. If not known, n shall be taken according to Table 2.8.4.3.4.

Table 2.8.4.3.4

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	0,85n_n
n_n - nominal rotational speed at MCR, free running condition.	

For CP propellers, propeller pitch $P_{0,7}$ shall correspond to MCR in bollard condition.

If not known, $P_{0,7}$ shall be taken as 0,7$P_{0,7n}$, where: $P_{0,7}$ is propeller pitch at MCR free running condition.

2.8.4.3.5 Maximum propeller ice thrust (applied to the shaft at the location of the propeller).
Maximum forward propeller ice thrust:

$$T_f=1,1\ \boldsymbol{F_f}. \qquad (2.8.4.3.5\text{-}1)$$

Maximum backward propeller ice thrust (maximum ice axial force acting on the propeller in the opposite direction of the ship):

$$T_b=1,1\ \boldsymbol{F_b}. \qquad (2.8.4.3.5\text{-}2)$$

2.8.4.4 Design ice loads for ducted propeller.
2.8.4.4.1 Maximum backward blade force $\boldsymbol{F_b}$, in kN:
when $D < D_{limit}$:

$$F_b=-9,5S_{ice}(EAR/Z)^{0,3}(nD)^{0,7}D^{2}; \quad (2.8.4.4.1\text{-}1)$$

when $D \geq D_{limit}$:

$$F_b=-66S_{ice}(EAR/Z)^{0,3}(nD)^{0,7}(H_{ice})^{1,4}D^{0,6}; \quad (2.8.4.4.1\text{-}2)$$

where:
D_{limit} = 4 H_{ice};
N shall be taken as in **2.8.4.3.1**

$\boldsymbol{F_b}$ shall be applied as a uniform pressure distribution to an area on the back side for the following load cases (refer to Table 2 of the Appendix):

.1 load case **1**: on the back of the blade from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length;

.2 load case **5**: for reversible rotation propellers a load equal to 60 % of $\boldsymbol{F_b}$ is applied on the blade face from 0,6R to the tip and from the blade trailing edge to a value of 0,2 chord length.

2.8.4.4.2 Maximum forward blade force $\boldsymbol{F_f}$, in kN:

when $D \le D_{limit}$:

$$\boldsymbol{F_f} ,= 250(EAR/Z)\, D^2 ; \qquad (2.8.4.4.2\text{-}1)$$

when $D \ge D_{limit}$:

$$F_f = 500 \frac{1}{(1-\frac{d}{D})} H_{ice}[EAR/Z][D]^2, \qquad (2.8.4.4.2\text{-}2)$$

where: $$D_{limit} = \frac{2}{(1-\frac{d}{D})} H_{ice}, \text{ м.} \qquad (2.8.4.4.2\text{-}2)$$

$\boldsymbol{F_f}$ shall be applied as a uniform pressure distribution to an area on the face (pressure) side for the following load case (refer to Table 2 of the Appendix):

.1 load case **3**: on the blade face from 0,6R to the tip and from the blade leading edge to a value of 0,5 chord length;

.2 load case **5**: load equal to 60 % $\boldsymbol{F_f}$ shall be applied from 0,6R to the tip and from the blade leading edge to a value of 0,2 chord length.

2.8.4.4.3 Maximum propeller ice torque applied to the propeller Q_{max}, in kNm, is the maximum torque on a propeller due to ice-propeller interaction:

when $D \le D_{limit}$:

$$Q_{max} = 74(1-d/D)S_{qice}(P_{0,7}/D)^{0,16}(t_{0,7}/D)^{0,6}(nD)^{0,17}D^3; \qquad (2.8.4.4.2\text{-}1)$$

when $D > D_{limit}$:

$$Q_{max} = 74(1-d/D)S_{qice}(P_{0,7}/D)^{0,16}(t_{0,7}/D)^{0,6}(nD)^{0,17}D^3; \qquad (2.8.4.4.2\text{-}2)$$

where:

D_{limit}= 1,81 H_{ice};

N - rotational propeller speed, in rps, at bollard condition. If not known, n shall be taken according to Table 2.8.4.4.3.

For CP propellers, propeller pitch $P_{0,7}$ shall correspond to MCR in bollard condition.

If not known, $P_{0,7}$ shall be taken as 0,7$P_{0,7n}$, where: $P_{0,7}$ is propeller pitch at MCR free running condition.

Table 2.8.4.4.3

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	0,85n_n
n_n - nominal rotational speed at MCR, free running condition	

2.8.4.4.4 Maximum blade spindle torque for CP-mechanism design Q_{smax}, in kNm.

Spindle torque Q_{smax}, in kNm, around the spindle axis of the blade fitting shall be calculated for the load case described in **2.8.4.1.**

If these spindle torque values are less than the default value given below, the default value shall be used:

$$Q_{smax}=\boldsymbol{Fc_{0,7}}, \qquad (2.8.4.4.4)$$

where:

$c_{0,7}$ - length of the blade section at 0,7R radius;
F = either F_b or F_f, whichever has the greater absolute value.

2.8.4.4.5 Maximum propeller ice thrust (applied to the shaft at the location of the propeller).
Maximum forward propeller ice thrust:

$$T_f=1{,}1\ F_f. \qquad (2.8.4.4.5\text{-}1)$$

Maximum backward propeller ice thrust (maximum ice axial force acting on the propeller in the opposite direction of the ship):

$$T_b=1{,}1\ F_b. \qquad (2.8.4.4.5\text{-}2)$$

2.8.4.5 Design loads on propulsion line.
2.8.4.5.1 Torque..
The propeller ice torque excitation for shaft line dynamic analysis shall be described by a sequence of blade impacts which are of half sine shape and occur at the blade.

The torque due to a single blade ice impact as a function of the propeller rotation angle is then:

$$Q(\varphi) = C_q Q_{\max}\sin(\varphi(180/\alpha_i)) \text{ when } \varphi = 0...\alpha_i;$$

$$Q(\varphi) = 0 \text{ when } \varphi = \alpha_i...360. \qquad (2.8.4.5.1)$$

C_q and α_i parameters are given in Table2.8.4.5.1**.**

The total ice torque is obtained by summing the torque of single blades taking into account the phase shift 360 deg/Z.
The number of propeller revolutions during a milling sequence shall be determined by the formula

$$N_Q=2H_{ice}, \qquad (2.8.4.5.1\text{-}2)$$

The number of impacts is ZN_Q (refer to Fig. 1 in the Appendix)
Milling torque sequence duration is not valid for pulling bow propellers, which shall be agreed with the Register in each particular case.
The response torque at any shaft component shall be analysed considering excitation torque $\boldsymbol{Q}$ (φ) at the propeller, actual engine torque $\boldsymbol{Q_e}$ and mass elastic system.
$\boldsymbol{Q_e}$ actual maximum engine torque at considered speed.
Design torque along propeller shaft line.
The design torqueт $\boldsymbol{Q_r}$ of the shaft component shall be determined by means of torsional vibration analysis of the propulsion line.
Calculations shall be carried out for all excitation cases given above and the response shall be applied on top of the mean hydrodynamic torque in bollard condition at considered propeller rotational speed.

Table 2.8.4.5.1

The process of torque change	Interaction of the propeller and ice	C_q	α_i
Case 1	A single piece of ice	0,5	45
Case 2	A single piece of ice	0,75	90
Case 3	A single piece of ice	1,0	135
Case 4	Two pieces of ice with a phase of rotation angle equal to 45°	0,5	45

2.8.4.5.2 Maximum response thrust (maximum thrust along the propeller shaft line). Maximum thrust along the propeller shaft line shall be calculated with the formulae below. The factors 2,2 and 1,5 take into account the dynamic magnification due to axial vibration. Alternatively the propeller thrust magnification factor may be calculated by dynamic analysis. Maximum shaft thrust forwards, in kN:

$$T_r = T_n + 2{,}2\ T_f. \qquad (2.8.4.5.2\text{-}1)$$

Maximum shaft thrust backwards, in kN:

$$T_r = 1{,}5\ T_b, \qquad (2.8.4.5.2\text{-}2)$$

where

T_n - propeller bollard thrust, in kN;

T_f - maximum forward propeller ice thrust, in kN;

T_b - maximum backward propeller ice thrust, in kN.

If hydrodynamic bollard thrust T_n is not known, T_n shall be taken according to Table 2.8.4.5.2.

Table 2.8.4.5.2

Propeller type	T_n
CP propellers (open)	1,25T
CP propellers (ducted)	1,1T
FP propellers driven by turbine or electric motor	T
FP propellers driven by diesel engine (open)	0,85T
FP propellers driven by diesel engine (ducted)	0,75T
T - nominal propeller thrust at MCR at free running open water conditions.	

2.8.4.5.3 Blade failure load for both open and nozzle propeller. The force is acting at 0,8R in the weakest direction of the blade and at a spindle arm of 2/3 of the distance of axis of blade rotation of leading and trailing edge which ever is the greatest.

The blade failure load F_{ex}, in kN, is determined by formula

$$F_{ex} = \frac{0{,}3ct^2\sigma_{ref}}{0{,}8D-2r}\cdot 10^3, \qquad (2.8.4.5.3)$$

where:

$\sigma_{ref} = 0{,}6\sigma_{0,2} + 0{,}4\sigma_u$;

$\sigma_{0,2}$ and σ_u - representative values for the blade material;

c, t and r - respectively the actual chord length, thickness and radius of the cylindrical root section of the blade at the weakest section outside root fillet, and typically will be at the termination of the fillet into the blade profile;

D - propeller diameter, in m.

2.8.5 Design.

2.8.5.1 Design principle.

The strength of the propulsion line shall be designed: for maximum loads in **2.8.4**;

such that the plastic bending of a propeller blade shall not cause damages in other propulsion line components;

with sufficient fatigue strength.

2.8.5.2 Azimuthing main propulsors. In addition to the above requirements special consideration shall be given to the loading cases which are extraordinary for propulsion units when compared with conventional propellers.

Estimation of the loading cases shall reflect the operational realities of the ship and the thrusters. In this respect, for example, the loads caused by impacts of ice blocks on the propeller hub of a pulling propeller shall be considered.

Also loads due to thrusters operating in an oblique angle to the flow shall be considered.

The steering mechanism, the fitting of the unit and the body of the thruster shall be designed to withstand the loss of a blade without damage.

The plastic bending of a blade shall be considered in the propeller blade position, which causes the maximum load on the studied component.

Azimuth thrusters shall also be designed for estimated loads due to thruster body/ice interaction. The assessment of the relevant ice loads is performed in accordance with the requirements for the protruding parts, where all protruding parts must be designed to perceive the forces corresponding to the place of their attachment to the hull structure or position within the hull area.

2.8.5.3 Blade design.

2.8.5.3.1 Maximum blade stresses.

Blade stresses shall be calculated using the backward and forward loads given in section **2.8.4.3** and **2.8.4.4**.

The stresses shall be calculated with recognised and well-documented FE-analysis or other acceptable alternative method.

The stresses on the blade shall not exceed the allowable stresses σ all for the blade material given below.

Calculated blade stress for maximum ice load shall comply with the following:

$$\sigma_{calc} <= \sigma_{all} = \sigma_{ref}/S, \qquad (2.8.5.3.1\text{-}1)$$

where:

S=1,5

σ_{ref} = reference stress, defined as

$$\sigma_{ref} = 0{,}7\ \sigma_u \quad \text{or} \qquad (2.8.5.3.1\text{-}2)$$

$$\sigma_{ref} = 0{,}6\sigma_{0,2} + 0{,}4\sigma_u \text{ whichever is less} \quad (2.8.5.3.1\text{-}3)$$

$\sigma_{0,2}$ and σ_u —representative values for the blade materia.

2.8.5.3.2 Blade edge thickness.

The blade edge thicknessest_{edge} and t_{tip} thickness tip shall be greater than t_{edge}**,** determined by formula

$$t_{edge} \geqslant xSS_{ice}\sqrt{3p_{ice}/\sigma_{ref}}, \qquad (2.8.5.3.2)$$

where:

x - distance from the blade edge measured along the cylindrical sections from the edge and shall be 2,5 % of chord length, however not to be taken greater than 45 mm.

In the tip area (above 0,975*R*) *x* shall be taken as 2,5 % of 0,975*R* section length and shall be measured perpendicularly to the edge, however not to be taken greater than 45 mm;

S - safety factor;

S = 2,5 for trailing edges;

S = 3,5 for leading edges;

S = 5 for tip;

S_{ice} - according to **2.8.4.2**;

P_{ice} – ice pressure;

P_{ice} = 1 6 MPa for leading edge and tip thickness;

p_{ice} - according to **2.8.5.3.1**.

The requirement for edge thickness shall be applied for leading edge and in case of reversible rotation open propellers also for trailing edge.

Tip thickness refers to the maximum measured thickness in the tip area above 0,975*R*.

The edge thickness in the area between position of maximum tip thickness and edge thickness at 0,975*R* shall be interpolated between edge and tip thickness value and smoothly distributed.

2.8.5.4 Prime movers.

2.8.5.4.1 The main engine shall be capable of being started and running the propeller with the CP in full pitch.

2.8.5.4.2 Provisions shall be made for heating arrangements to ensure ready starting of the cold emergency power units at an ambient temperature applicable to the polar class of the ship.

2.8.5.4.3 Emergency power units shall be equipped with starting devices with a stored energy capability of at least three consecutive starts at the design temperature in **2.8.5.4.2**.

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.

A second source of energy shall be provided for an additional three starts within 30 min, unless manual starting can be demonstrated to be effective.

2.8.6 Machinery fastening loading accelerations.

2.8.6.1 Essential equipment and main propulsion machinery supports shall be suitable for the accelerations as indicated in as follows. Accelerations shall be considered acting independently.

2.8.6.2 Longitudinal impact accelerations a_l.

Maximum longitudinal impact acceleration at any point along the hull girder, in m/s^2, is determined by the formula

$$a_l = (F_{IB}/\Delta)\{[1{,}1\tan(\gamma+\varphi)\ ]+[7H/L]\}, \qquad (2.8.6.2)$$

where:
φ - maximum friction angle between steel and ice, normally taken as 10 deg.;
y - = bow stem angle at waterline, in deg.;
Δ - displacement;
L - length between perpendiculars, in m;
H - distance from the waterline to the point being considered, in m;
F_{IB} - vertical impact force, defined in **3.11.2.13.2.1**, Part II «Hull».

2.8.6.3 Vertical acceleration a_v.

Combined vertical impact acceleration at any point along the hull girder, in m/s^2, is determined by the formula

$$a_v = 2{,}5\ (F_{IB}/\Delta)F_x, \qquad (2.8.6.3)$$

where:
F_x - 1,3 at *FP*;
F_x - 0,2 2 at midships;
F_x - 0,4 at *AP*;
F_x - 1,3 at *AP* for ships conducting ice breaking astern.

Intermediate values to be interpolated linearly.

2.8.6.4 Transverse impact acceleration a_t.

$$a_t = 3\ F_xF_t/\Delta, \qquad (2.8.6.4)$$

where:
F_x - 1,5 at *FP*;
F_x - 0,25 at midships;
F_x - 0,5 at *AP*;
F_x - 1, 5 at *AP* for ships conducting ice breaking astern.
F_t - total impact force, defined in **3.11.2.13.2.1**, Part II «Hull»

Intermediate values to be interpolated linearly.

2.8.7 Auxiliary systems.

2.8.7.1 Machinery shall be protected from the harmful effects of ingestion or accumulation of ice or snow.

Where continuous operation is necessary, means shall be provided to purge the system of accumulated ice or snow.

2.8.7.2 Means shall be provided to prevent damage due to freezing, to tanks containing liquids.

2.8.7.3 Vent pipes, intake and discharge pipes and associated systems shall be designed to prevent blockage due to freezing or ice and snow accumulation.

2.8.8 Sea inlets and cooling water systems.

2.8.8.1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets, shall be designed in accordance with **4.3.3** Part VIII «Systems and Piping».

2.8.9 Ballast tanks.

2.8.9.1 Efficient means shall be provided to prevent freezing in fore and after peak tanks and wing tanks located above the water line and where otherwise found necessary.

2.8.10 Ventilation system.

2.8.10.1 The air intakes for machinery and accommodation ventilation shall be located on both sides of the ship.

2.8.10.2 Accommodation and ventilation air intakes shall be provided with means of heating.

2.8.10.3 The temperature of inlet air provided to machinery from the air intakes shall be suitable for the safe operation of the machinery.

2.8.11 Alternative design[5].

2.8.11.1 As an alternative - a comprehensive design study may be submitted to the Register and may be requested to be validated by an agreed test programme.

[5] Refer to IMO MSC.386(94) of 21.10.2014.

APPENDIX

Table 1. **Load cases for open propeller**

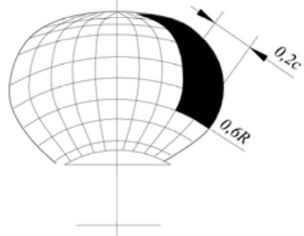
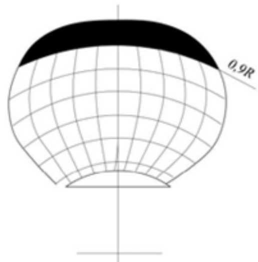
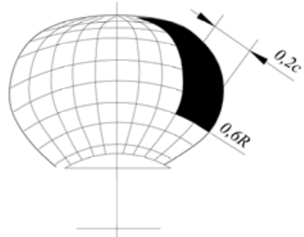
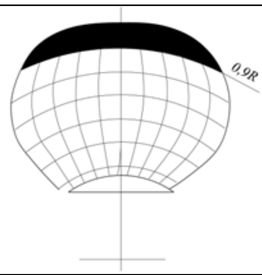
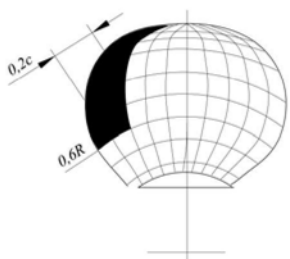
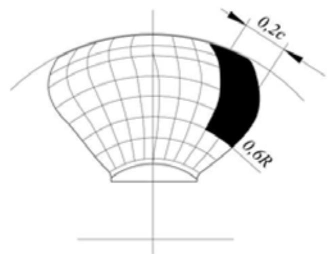
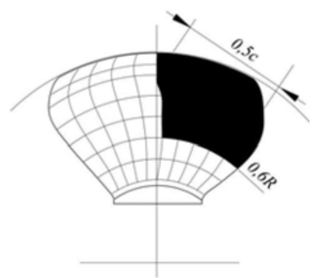
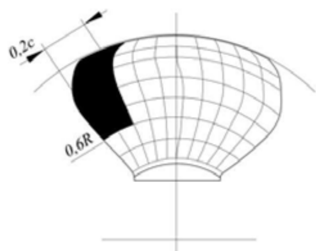
Load	Force	Loaded area	Right handed propeller blade seen from back
Load case **1**	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6*R* to the tip and from the leading edge to 0,2 times the chord length	
Load case **2**	50% of F_b	Uniform pressure applied on the back of the blade (suction side) on the propeller tip area outside of 0,9*R*	
Load case **3**	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6*R* to the tip and fromthe leading edge to 0,2 times the chord length	
Load case **4**	50% of F_f	Uniform pressure applied on propeller face (pressure side) on the propeller tip area outside of 0,9*R*	
Load case **5**	60% of F_b or F_f, which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0,6*R* to the tip and from the trailing edge to 0,2 times the chord length	

Table 2. **Load cases for ducted propeller**

Load	Force	Loaded area	Right handed propeller blade seen from back
Load case **1**	F_b	Uniform pressure applied on the back of the blade (suction side) to an area from 0,6R to the tip and from the leading edge to 0,2 times the chord length	
Load case **3**	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0,6R to the tip and from the leading edge to 0,5 times the chord length	
Load case **5**	60% of F_b or F_f, which one is greater	Uniform pressure applied on propeller face (pressure side) to an area from 0,6R to the tip and from the trailing edge to 0,2 times the chord length	

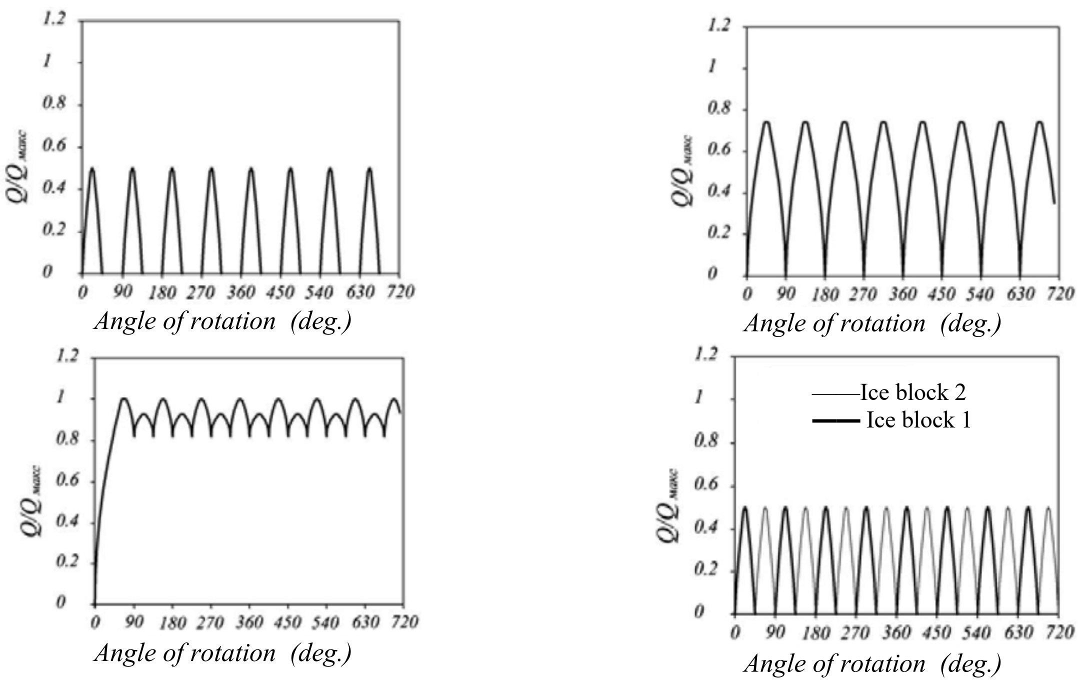


Fig.1. The shape of the propeller ice torque excitation for 45, 90, 135 degrees single blade impact sequences and 45 degrees double blade impact sequence (two ice pieces) on a four bladed propeller

2.9 REQUIREMENTS TO BALTIC CLASS SHIPS MACHINERY INSTALLATIONS

2.9.1 The engine output

2.9.1.1 Definitions and explanations.

.1 *The engine output* P is the maximum output the propulsion machinery can continuously deliver to the propeller(s).

.2 *The dimensions of the ship and some other parameters are defined below* (refer to Fig. 2.1.1.4):

L- length of the ship between the perpendiculars, in m;

L_{BOW} - length of the bow, in m;

L_{PAR} - length of the parallel midship body, in m;

B - maximum breadth of the ship, in m;

T- actual ice class draughts of the ship, in m;

A_{wf} - area of the waterline of the bow, in m ^{2};

A - the angle of the waterline at B/4, in deg.;

φ_1 - the rake of the stem at the centreline, in deg. With bulbous bow φ_1 = 90°;

φ_2 - the rake of the bow at B/4, in deg.;

ψ - ψ = arctan (tan φ/sin α), in deg., using the appropriate to the position angles α and φ. For the purpose of **2.9.1.3** the angle is calculated using equality $\varphi = \varphi_2$;

D_p - diameter of the propeller, in m;

HM - thickness of the brash ice in mid channel;

HF - thickness of the brash ice layer displaced by the bow, in m.

.3 Upper and lower ice waterlines.

The upper ice waterline (UIWL) shall be the envelope of the highest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

The lower ice waterline (LIWL) shall be the envelope of the lowest points of the waterlines at which the ship is intended to operate in ice. The line may be a broken line.

2.9.1.2 The engine output shall not be less than, determined in **2.9.1.3**.

The engine output shall not be less than that determined by the formula (2.9.1.3-1), and in no case less than 1000 kW for ice class **IA**, **IB** and **IC**, and not less than 2800 kW for **IA Super**.

2.9.1.3 The engine output requirement shall be calculated for two draughts.

The engine output shall not be less than the greater of these two outputs.

In the calculations the ship's parameters, specified in **2.9.1.1**, which depend on the draught are to be determined at the appropriate draught, but L and B are to be determined only at the LWL.

$$P = K_e\,(R_{CH}\ /1000)^{3/2}/D_P,\ \text{кВт} \qquad (2.9.1.3\text{-}1)$$

where:

K_e - shall be taken from Table 2.9.1.3;

R_{CH} - is the resistance, in N, of the ship in a channel with brash ice and a consolidated layer.

$$R_{CH} = C_1+C_2+C_3C_\mu(H_F+H_M)^2(B + C_\psi H_F) + C_4L_{PAR}H_F+C_5(LT/B^2)^3(A_{wf}/L), \qquad (2.9.1.3\text{-}2)$$

Table 2.9.1.3 **Factor K_e with conventional propulsion plants**

Propeller type or machinery	CP or electric or hydraulic propulsion machinery	FP propeller
1	2,03	2,26
2	1,44	1,60
3	1,18	1,31

where:

C_μ = 0,15cos φ_2 + sinψsinα is to be taken equal or larger than 0,45;

C_ψ = 0,047ψ -2,115 i C_ψ = 0, if ψ< 45°;

H_F =0,26 + $(H_MB)^{0,5}$;

H_M = 1,0 m for ice classes **IA** and **IA Super**;

H_M = 0,8 m for ice class **IB**;

H_M = 0,6 m for ice class **IC**;

C_1 = 0 for ice classes **IA**, **IB** and **IC**;

for ice class **IA Super**;
f_1 = 23 N/m^2;
f_2 = 45,8 N/m;
f_3 = 14,7 N/m;
f_4 = 29 N/m^2;
C_2 = 0 for ice classes **IA**, **IB** and **IC**;

for ice class **IA Super**;
g_1 = 1530N;
g_2 = 170 N/m;
g_3 = (400 N/m)^{1,5}.

$$C_1 = f_1 \frac{BL_{PAR}}{2(T/B)+1} + (1 + 0{,}021\varphi_1)(f_2 B + f_3 L_{BOW} + f_4 L_{BOW})$$

$$C_2 = (1 + 0{,}063\varphi_1)(g_1 + g_2 B) + g_3\left(1 + 1{,}2\frac{T}{B}\right)\frac{B^2}{\sqrt{L}}$$

C_3 = 845;
C_4 = 42;
C_5 = 825.

The value $(L \cdot T/B^2)^3$ in Formula (2.9.1.3-2) shall be taken not less than 5 and not greater than 20.

If the value $(L \cdot T/B^2)^3$ is less than 5, then the value equal to 5 shall be used; if the value is greater than 20, the value of 20 shall be used.

2.9.1.4 Formula (2.9.1.3-2) can be used under the conditions specified in Table 2.9.1.4.

Table 2.9.1.4 **Conditions of application of the formula 2.9.1.3-2**

Parameter	α, in deg.	φ_1, in deg.	φ_2, in deg.	L, in m	B, in m	T, in m	L_{BOW}/L	L_{PAR}/L	D_p/T	$A_{wf}/(L \cdot B)$
Minimum value	15	25	10	65,0	11,0	4,0	0,15	0,25	0,45	0,09
Maximum value	55	90	90	250,0	40,0	15,0	0,40	0,75	0,75	0,27

The use of K_e or R_{CH} values based on more exact calculations or values based on model tests may be approved. Such an approval will be given on the understanding that it can be revoked if experience of the ship's performance in practice motivates this.

The design requirement for ice classes is a minimum speed of 5 knots in the following brash ice channels:

H_M = 0,6 m for ice class **IC**;
H_M = 0,8 m for ice class **IB**;
H_M = 1,0 m for ice class **IA**;
H_M = 1,0м m and a 0.1 m thick consolidated layer of ice for ice class **IA Super**.

2.9.2 Propulsion machinery.

2.9.2.1 Application.

These regulations apply to propulsion machinery covering open- and ducted-type propellers with a controllable pitch or fixed pitch design for ice classes **IA Super**, **IA**, **IB** and **IC**.

The given propeller loads are the expected ice loads for the entire ship's service life under normal operational conditions, including loads resulting from the changing rotational direction of FP propellers. However, these loads do not cover offdesign operational conditions, for example when a stopped propeller is dragged through ice.

The regulations also apply to azimuthing and fixed thrusters for main propulsion. However, the load models of the regulations do not include propeller/ice interaction loads when ice enters the propeller of a turned azimuthing thruster from the side (radially).

The loads arising at interaction of ice with the AMSS casing shall be defined separately.

2.9.2.2 Definitions and explanations.

D - propeller diameter, in m.
R - propeller radius, in m.
c - chord length of blade section, in m.
$c_{0,7}$ - chord length of blade section at 0.7R propeller radius, in m.
d - external diameter of propeller hub (at propeller plane), in m.
D_{limit} - limit value for propeller diameter, in m.
F_b - maximum backward blade force for the ship's service life, in kN.

F_{ex} - ultimate blade load resulting from blade loss through plastic bending, in kN.

F_f - maximum forward blade force during the ship's service life, in kN.

F_{ice} - ice load, kN.

$(F_{ice})_{\max}$ - maximum ice load during the ship's service life, in kN.

h_0 - depth of the propeller centreline from the lower ice waterline, in m.

H_{ice} - thickness of the maximum design ice block entering the propeller, in m.

I_e - equivalent mass moment of inertia of all parts on the engine side of the component under consideration, kgm^2.

I_t - equivalent mass moment of inertia of the whole propulsion system, kgm^2.

k - shape parameter for Weibull distribution.

m - slope for SN curve in log/log scale.

M_{BL} - blade bending moment, kNm.

N - propeller rotational speed, rev/s.

n_n - nominal propeller rotational speed at MCR in free running condition, rev/s.

N_{class} - reference number of impacts per nominal propeller rotational speed per ice class.

N_{ice} - total number of ice loads on the propeller blade for the ship's service life.

N_R - reference number of load for the equivalent fatigue stress (10^8 cycles).

N_Q - number of propeller revolutions during a milling sequence.

$P_{0,7}$ - propeller pitch at 0.7R radius, in m.

$P_{0,7n}$ - propeller pitch at 0.7R radius at MCR in free running condition, in m.

$P_{0,7b}$ - propeller pitch at 0.7R radius at MCR in bollard condition, in m.

Q - torque, kNm.

$Q_{e\max}$ - maximum engine torque, kNm.

$Q_{\max}$ - maximum torque on the propeller resulting from propeller/ice interaction, kNm.

Q_{motor} - electric motor peak torque, kNm.

Q_n - nominal torque at MCR in free running condition, kNm.

Q_r - response torque along the propeller shaft line, kNm.

$Q_{s\max}$ - maximum spindle torque of the blade for the ship's service life, kNm.

Q_{sex} - maximum spindle torque due to blade failure caused by plastic bending, kNm.

Q_{vib} - vibratory torque at considered component, taken from frequency domain open water torque vibration calculation (TVC), kNm.

r - blade section radius, in m.

T - propeller thrust, kN.

T_b - maximum backward propeller ice thrust during the ship's service life, kN.

T_f - maximum forward propeller ice thrust during the ship's service life, kN.

T_n - propeller thrust at MCR in free running condition, kN.

T_r - maximum response thrust along the shaft line, kN.

t - maximum blade section thickness, in m.

Z - number of propeller blades.

a_i - duration of propeller blade/ice interaction expressed in rotation angle, in deg.

α_1 - phase angle of propeller ice torque for blade order excitation component, in deg.

α_2 - phase angle of propeller ice torque for twice the blade order excitation component, in deg.

γ_v - the reduction factor for fatigue; variable amplitude loading effect.

γ_m - the reduction factor for fatigue; mean stress effect.

ρ - a reduction factor for fatigue correlating the maximum stress amplitude.

$\sigma_{0,2}$ - proof yield strength (at 0.2% offset) of blade material, in MPa.

σ_{exp} - mean fatigue strength of blade material at 10^8 cycles to failure in sea water.

σ_{fat} - equivalent fatigue ice load stress amplitude for 10^8 stress cycles, in MPa.

σ_{fl} - characteristic fatigue strength for blade material, in MPa.

σ_u - ultimate tensile strength of blade material, in MPa.

σ_{ref} - $\sigma_{ref} = 0,6\sigma_{0,2} + 0,4\sigma_u$, in MPa.

σ_{ref2} - $\sigma_{ref2} = 0,7\sigma_u$ or

σ_{ref2} - $\sigma_{ref2} = 0,6\sigma_{0,2} + 0,4\sigma_u$, whichever is less, in MPa.

σ_{st} - maximum stress resulting from F_b or F_f, in MPa.

$(\sigma_{ice})_{bmax}$ - principal stress caused by the maximum backward propeller ice load, in MPa.

$(\sigma_{\text{ice}})_{fmax}$ - principal stress caused by the maximum forward propeller ice load, in MPa.

$(\sigma_{ice})_{max}$ - maximum ice load stress amplitudȩ, in MPa.

Table 2.9.2.2

	Definition	Use of the load in design process
1	**2**	**3**
F_b	The maximum lifetime backward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to the 0.7*R* chord line. Refer to Figure. 2.9.2.2.	Design force for strength calculation of the propeller blade.
F_f	The maximum lifetime forward force on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade. The direction of the force is perpendicular to the 0.7R chord line.	Design force for calculation of strength of the propeller blade.
Q_{smax}	The maximum lifetime spindle torque on a propeller blade resulting from propeller/ice interaction, including hydrodynamic loads on that blade.	When designing the propeller strength, the spindle torque is automatically taken into account because the propeller load is acting on the blade in the form of distributed pressure on the leading edge or tip area.
T_b	The maximum lifetime thrust on a propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction and the force is opposite to the hydrodynamic thrust	Is used for estimating the response thrust T_r. T_b can be used as an estimate of excitation in axial vibration calculations.
T_f	The maximum lifetime thrust on a propeller (all blades) resulting from propeller/ice interaction. The direction of the thrust is the propeller shaft direction acting in the direction of hydrodynamic thrust.	Is used for estimating the response thrust T_r. T_f *c*an be used as an estimate of excitation in axial vibration calculations.
Q_{max}	The maximum ice-induced torque resulting from propeller/ice interaction on one propeller blade, including hydrodynamic loads on that blade.	Is used for estimating the response torque (Q_r) along the propulsion shaft line and as excitation for torsional vibration calculations.
F_{ex}	Ultimate blade load resulting from blade loss through plastic bending. The force that is needed to cause total failure of the blade so that a plastic hinge appears in the root area. The force is acting on 0.8R. The spindle arm is 2/3 of the distance between the axis of blade rotation and the leading/trailing edge (whichever is the greater) at the 0.8R radius.	Blade failure load is used to dimension the blade bolts, pitch control mechanism, propellershaft, propeller shaft bearing and trust bearing. The objective is to guarantee that total propeller blade failure does not lead to damage to other components
Q_r	Maximum response torque along the propeller shaft line, taking account of the dynamic behaviour of the shaft line for ice excitation (torsional vibration) and the hydrodynamic mean torque on the propeller.	Design torque for propeller shaft line components.
T_r	Maximum response thrust along the shaft line, taking account of the dynamic behaviour of the shaft line for ice excitation (axial vibration) and the hydrodynamic mean thrust on the propeller.	Design thrust for propeller shaft line components.
F_{ti}	Maximum response force caused by ice block impacts on the thruster body or the propeller hub.	Design load for thruster body and slewing bearings.
F_{tr}	Maximum response force on the thruster body caused by ice ridge/thruster body interaction.	Design load for thruster body and slewing bearings.

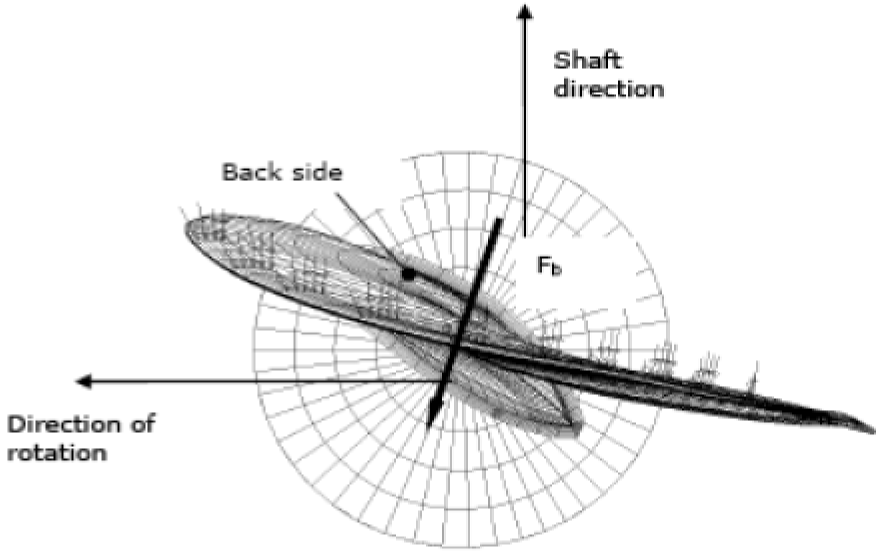


Fig. 2.9.2.2 Direction of the resultant backward blade force taken perpendicular to the chord line at radius 0.7R. The ice contact pressure at the leading edge is indicated with small arrows

2.9.2.3 Design ice conditions.

In estimating the ice loads of the propeller for various ice classes, account was taken of different types of operation as shown in Table 2.9.2.3-1. For the estimation of design ice loads, a maxi- mum ice block size must be determined. The maximum design ice block entering the propeller is a rectangular ice block with the dimensions $H_{ice} \times 2H_{ice} \times 3H_{ice}$

The thickness of the ice block H_{ice} is given in Table 2.9.2.3-2.

Table 2.9.2.3-1 **Types of operation for different ice classes**

Ice class	Operation of the ship
IA Super	Operation in ice channels and in level ice The ship may proceed by ramming
IA, **IB** and **IC**	Operation in ice channels

Table 2.9.2.3-2 **Thickness of design ice block**

Ice class	**IA Super**	**IA**	**IB**	**IC**
Thickness of the design maximum ice block entering the propeller H_{ice}	1,75 m	1,5 m	1,2 m	1,0 m

2.9.2.4 Materials.

2.9.2.4.1 Materials exposed to sea water.

The materials of components exposed to sea water, such as propeller blades, propeller hubs, and thruster body, shall have an elongation of no less than 15% in a test specimen, the gauge length of which is five times the diameter.

A Charpy V impact test shall be carried out for materials other than bronze and austenitic steel.

An average impact energy value of 20 J based on three tests must be obtained at minus 10ºC.

For nodular cast iron, average impact energy of 10 J at minus 10ºC is required accordingly.

2.9.2.4.2 Materials exposed to sea water temperature.

Materials exposed to sea water temperature shall be made of steel or another ductile material. An average impact energy value of 20 J, based on three tests, must be obtained at minus 10 ºC.

The nodular cast iron of a ferrite structure type may be used for relevant parts other than bolts.

The average impact energy for nodular cast iron shall be a minimum of 10 J at minus 10 ºC.

This requirement applies to the propeller shaft, blade bolts, CP mechanisms, shaft bolts, strut-pod connecting bolts etc. It does not apply to surface-hardened components, such as bearings and gear teeth.

2.9.2.5 Design loads.

The given loads are intended for component strength calculations only and are total loads, including iceinduced loads and hydrodynamic loads, during propeller/ice interaction.

The values of the parameters in the formulae given in this section are provided in the units shown in the symbol list in **2.9.2.2**.

If the highest point of the propeller of **IB** and **IC** class ships is not below the water surface when the ship is in ballast condition, the propulsion system shall be designed according to ice class **IA**.

2.9.2.5.1 Design loads on propeller blades.

F_b is the maximum force experienced during the lifetime of a ship that bends a propeller blade backwards when the propeller mills an ice block while rotating ahead.,

F_f is the maximum force experienced during the lifetime of a ship that bends a propeller blade forwards when the propeller mills an ice block while rotating ahead.

F_b and F_f originate from different propeller/ice interaction phenomena, and do not occur simultaneously. Hence, they are to be applied to one blade separately.

2.9.2.5.1.1 Maximum backward blade force F_b for open propellers.

$$F_b = 27(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} D^2$$ in kN when $D \le D_{limit}$; (2.9.2.5.1.1 -1)

$$F_b = 23(nD)^{0.7}\left(\frac{EAR}{Z}\right)^{0.3} DH_{ice}^{1.4}$$ in kN when $D > D_{limit}$, (2.9.2.5.1.1-2)

where:

$D_{limit} = 0{,}85H_{ice}^{1,4}$

n - is the nominal rotational speed:

$n = n_n$ – for CP propeller;

$n = 0{,}85n_n$ - for FP propeller.

2.9.2.5.1.2 Maximum forward blade force F_f for open propellers

$$F_f = 250\left(\frac{EAR}{Z}\right)D^2$$ in kN when $D \le D_{limit}$; (2.9.2.5.1.2 -1)

$$F_f = 500\left(\frac{EAR}{Z}\right)D\frac{1}{1-d/D}H_{ice}$$ in kN when $D > D_{limit}$, (2.9.2.5.1.2 -2)

where:

$$D_{limit} = \frac{2}{1-d/D}H_{ice}$$

2.9.2.5.1.3 Loaded area on the blade for open propellers.

Load cases 1-4 must be covered, as given in Table 2.9.2.5.1.3 below, for CP and FP propellers.

To obtain blade ice loads for a reversing propeller, load case 5 must also be covered for FP propellers.

2.9.2.5.1.4 Maximum backward blade ice force F_b for ducted propellers.

$$F_b = 9{,}5(nD)^{0{,}7}\left(\frac{EAR}{Z}\right)^{0{,}3} D^2$$ in kN when $D \le D_{limit}$; (2.9.2.5.1.4 -1)

$$F_b = 66(nD)^{0{,}7}\left(\frac{EAR}{Z}\right)^{0{,}3} D^{0{,}6}H_{ice}^{1{,}4}$$ in kN when $D > D_{limit}$, (2.9.2.5.1.4 -2)

where:

$D_{limit} = 4\ H_{ice}$, in m

n - is the nominal rotational speed:

$n = n_n$ – for CP propeller;

$n = 0{,}85n_n$ - for FP propeller.

2.9.2.5.1.5 Maximum forward blade ice force F_f for ducted propellers.

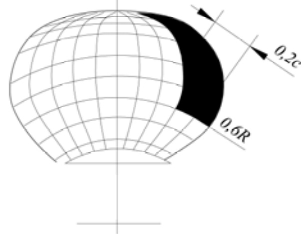
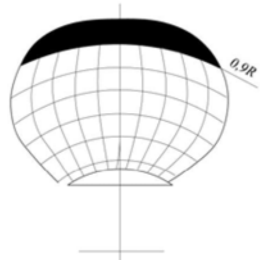
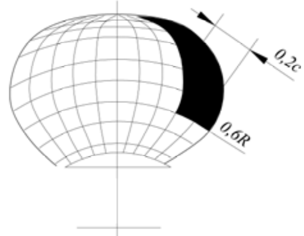
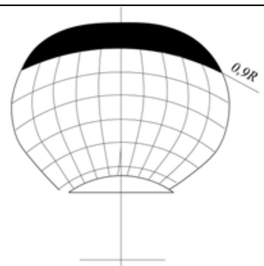
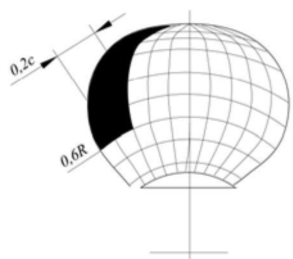
$$F_f = 250\left(\frac{EAR}{Z}\right)D^2$$ in kN when $D \le D_{limit}$; (2.9.2.5.1.5 -1)

$$F_f = 500\left(\frac{EAR}{Z}\right)D\frac{1}{1-d/D}H_{ice}$$ in kN when $D > D_{limit}$, (2.9.2.5.1.5 -2)

where:

$$D_{limit} = \frac{2}{1-d/D} H_{ice}$$

Table 2.9.2.5.1.3 **Load cases for open propellers**

Load case	Force	Loaded area	Right-handed propeller blade seen from behind
Load case 1	F_b	Uniform pressure applied on the blade back (suction side) to an area from 0.6*R* to the tip and from the leading edge to 0.2 times the chord length.	
Load case **2**	50% of F_b	Uniform pressure applied on the blade back (suction side) on the blade tip area outside 0.9R radius.	
Load case **3**	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord lengt	
Load case **4**	50% of F_f	Uniform pressure applied on the blade face (pressure side) of the blade tip area outside 0.9*R* radius	
Load case **5**	60% of F_b or F_f, whichever is greater	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the trailing edge to 0.2 times the chord length	

2.9.2.5.1.6 Loaded area on the blade for ducted propellers.

Load cases 1 and 3 have to be covered as given in Table 2.9.2.5.1.6 for all propellers, and an additional load case (load case 5) for an FP propeller, to cover ice loads when the propeller is reversed.

2.9.2.5.1.7 Maximum blade spindle torque Q_{smax} for open and ducted propellers.

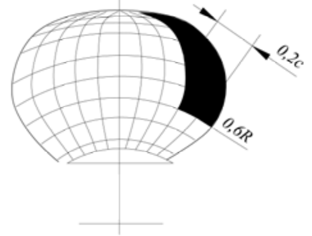
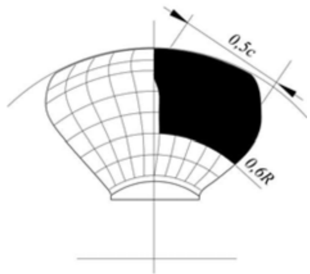
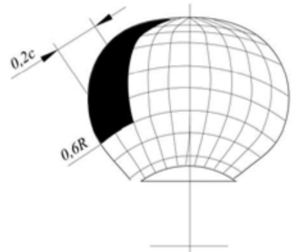
The spindle torque Qsmax around the axis of the blade fitting shall be determined both for the maximum backward blade force F_b and forward blade force Ff, which are applied as in Tables 2.9.2.5.1.3 and 2.9.2.5.1.6.

If the above method gives a value which is less than the default value given by the formula below, the default value shall be used

$$Q_{s\max} = 0{,}25Fc_{0,7}, \qquad (2.9.2.5.1.7)$$

where: F is either F_b or F_f whichever has the greater absolute value.

Table 2.9.2.5.1.6 **Load cases for ducted propellers**

Load case	Force	Loaded area	Right handed propeller blade seen from behind
Load case **1**	F_b	Uniform pressure applied on the blade back (suction side) to an area from 0.6R to the tip and from the leading edge to 0.2 times the chord length	
Load case **3**	F_f	Uniform pressure applied on the blade face (pressure side) to an area from 0.6R to the tip and from the leading edge to 0.5 times the chord length	
Load case **5**	60% of F_b or F_f, whichever is greater	Uniform pressure applied on the face (pressure side) to an area from 0.6R to the tip and from blade the trailing edge to 0.2 times the chord length	

2.9.2.5.1.8 Load distributions for blade loads.

The Weibull-type distribution (probability that F_{ice} exceeds $(F_{ice})_{\max}$), is used for the fatigue design of the blade.

$$P\left(\frac{F_{ice}}{(F_{ice})_{\max}} \geq \frac{F}{(F_{ice})_{\max}}\right) = \exp\left(-\left(\frac{F_{ice}}{(F_{ice})_{\max}}\right)^k \ln N_{ice}\right), \qquad (2.9.2.5.1.8)$$

where:
k = 0,75 shall be used for the ice force distribution of an open propeller and the shape parameter;
k = 1, 0 for that of a ducted propeller blade;
F_{ice} is the random variable for ice loads on the blade; $0 < F_{ice} < (F_{ice})_{\max}$.

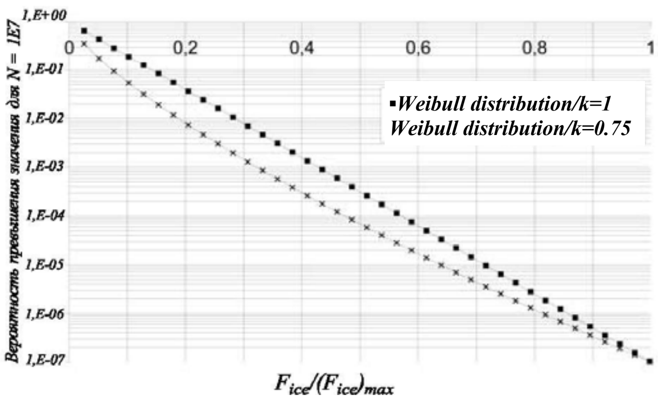


Fig. 2.9.2.5.1.8 The Weibull-type distribution

2.9.2.5.1.9 Number of ice loads.

The number of load cycles per propeller blade in the load spectrum shall be determined according to the formula:

$$N_{ice} = k_1 k_2 k_3 k_4 N_{class} n, \qquad (2.9.2.5.1.9)$$

where:

Ice class	**IA Super**	**IA**	**IB**	**IC**
impacts in life/n_n	$9{\cdot}10^6$	$6{\cdot}10^6$	$3,4{\cdot}10^6$	$2,1{\cdot}10^6$

	Centre propeller Bow first operation	Wing propeller Bow first operation	Pulling propeller (wing and centre) Bow propeller or Stern first operation
k_1	1	2	3

Ducted propeller	no	no
k_2	1	1,1

Type	Fixed	Turning
k_3	1	1,1

The submersion factor k_4 is determined from the equation:

$k4 = 0,8 — f$ when $f < 0$;

$k4 = 0,8 — 0,4f$ when $0 \le f \le 1$;

$k4 = 0,6 — 0,2f$ when $1 < f \le 2,5$;

$k4 = 0,1$ when $f > 2,5$,

where the immersion function f is $f = \dfrac{h_0 - H_{ice}}{D/2} - 1.$

For components that are subject to loads resulting from propeller/ice interaction with all the propeller blades, the number of load cycles (N_{ice}) must be multiplied by the number of propeller blades (Z).

2.9.2.5.2 Axial design loads for open and ducted propellers.

2.9.2.5.2.1 Maximum ice thrust on propeller T_f and T_b for open and ducted propellers:

$$T_f = 1,1\ F_f, \text{ in kN}; \qquad (2.9.2.5.2.1\text{-}1)$$

$$T_b = 1,1\ F_b, \text{ in kN}. \qquad (2.9.2.5.2.1\text{-}2)$$

2.9.2.5.2.2 Design thrust along the propulsion shaft line for open and ducted propellers.

The design thrust along the propeller shaft line must be calculated using the formulae below. The greater value of the forward and backward direction loads shall be taken as the design load for both directions.

Factors 2.2 and 1.5 take account of the dynamic magnification resulting from axial vibration. In a forward direction.

$$T_r = T + 2,2\ T_f, \text{ in kN}; \qquad (2.9.2.5.2.2\text{-}1)$$

$$T_r = 1,5\ T_b, \text{ in kN}. \qquad (2.9.2.5.2.2\text{-}2)$$

If the hydrodynamic bollard thrust, T, is not known, it must be taken as given in Table *2.9.2.5.2.2-2*:

Table 2.9.2.5.2.2-2

Propeller type	T
CP propellers(open)	1,25 T_n
CP propellers(ducted)	1,1 T_n
FP propellers driven by turbine or electric motor	T_n
FP propellers driven by diesel engine (open)	0,85 T_n
FP propellers driven by diesel engine (ducted)	0,75 T_n
T_n is the nominal propeller thrust at MCR in the free running open water condition.	

2.9.2.5.3 Torsional design loads.

2.9.2.5.3.1 Design ice torque on propeller Q_{max} for open propellers.

$$Q_{max} = 10.9\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{3} \text{ in kNm when } D \le D_{limit}; \quad (2.9.2.5.3.1\text{-}1)$$

$$Q_{max} = 20.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}^{1.1} \text{ in kNm when } D > D_{limit}, \quad (2.9.2.5.3.1\text{-}2)$$

where:

D_{limit} = 1,8H_{ice}, in m;

n is the rotational propeller speed at MCR in bollard condition. If unknown, n must be attributed a value in accordance with Table 2.9.2.5.3.1:

Table 2.9.2.5.3.1

Propeller type	n
CP propellers	n_n
FP propellers driven by turbine or electric motor	n_n
FP propellers driven by diesel engine	0,85n_n
n_n is the nominal rotational speed at MCR in the free running open water condition	

For CP propellers, the propeller pitch, $P_{0,7}$ ond to MCR in bollard condition.

If known, $P_{0,7}$ shall have a value equal to 0,7$P_{0,7n}$, where: $P_{0,7}$ is the propeller pitch at MCR in free running condition.

2.9.2.5.3.2 Design ice torque on propeller Q_{max} for ducted propellers.

$$Q_{max} = 7.7\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17} \text{ in kNm when } D \le D_{limit}; \quad (2.9.2.5.3.2\text{-}1)$$

$$Q_{max} = 14.6\left(1-\frac{d}{D}\right)\left(\frac{P_{0.7}}{D}\right)^{0.16}(nD)^{0.17}D^{1.9}H_{ice}^{1.1} \text{ in kNm when } D > D_{limit}, \quad (2.9.2.5.3.2\text{-}1)$$

where:

D_{limit} =1,8H_{ice}, in m;

n and $P_{0,7}$ — refer to 2.9.2.5.3.1.

2.9.5.3.3 Design torque for non-resonant shaft lines.

If there is no relevant first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speed (bollard condition), the following estimation of the maximum torque can be used.

Directly coupled two stroke diesel engines without flexible coupling

$$Q_{peak} = Q_{emax} + Q_{vib} + Q_{max}\, I_e / I_t, \text{ in kNm}; \quad (2.9.2.5.3.3\text{-}1)$$

and other plants

$$Q_{peak} = Q_{emax} + Q_{max}\, I_e / I_t, \text{ in kNm}. \quad (2.9.2.5.3.3\text{-}1)$$

All the torques and the inertia moments shall be reduced to the rotation speed of the component being examined.

If the maximum torque, Q_{emax}, is unknown, it shall be accorded the value given in Table 2.9.2.5.3.3.

Table 2.9.2.5.3.3

Propellertype	Q_{emax}
Propellers driven by electric motor	*Q_{motor}
CP propellers not driven by electric motor	Q_n
FP propellers driven by turbine	Q_n
FP propellers driven by diesel engine	0,75 Q_n
*Q_{motor} is the electric motor peak torque	

2.9.2.5.3.4 Design torque for shaft lines having resonance.

If there is first blade order torsional resonance in the operational speed range or in the range 20% above and 20% below the maximum operating speed (bollard condition), the design torque (Q_{peak}) of the shaft component shall be determined by means of torsional vibration analysis of the propulsion line.

There are two alternative ways of performing the dynamic analysis.

Time domain calculation for estimated milling sequence excitation.

Frequency domain calculation for blade orders sinusoidal excitation.

The frequency domain analysis is generally considered conservative compared to the time domain simulation, provided that there is a first blade order resonance in the considered speed range.

2.9.2.5.3.4.1 Time domain calculation of torsional response.

Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for blade order resonant rotational speeds so that the resonant vibration responses can be obtained.

The load sequence given in this chapter, for a case where a propeller is milling an ice block, shall be used for the strength evaluation of the propulsion line. The given load sequence is not intended for propulsion system stalling analyses.

The following load cases are intended to reflect the operational loads on the propulsion system, when the propeller interacts with ice, and the respective reaction of the complete system. The ice impact and system response causes loads in the individual shaft line components.

The ice torque Q_{max} may be taken as a constant value in the complete speed range. When considerations at specific shaft speeds are performed, a relevant Q_{max} may be calculated using the relevant speed according to section **2.9.2.5.3**.

Diesel engine plants without an elastic coupling shall be calculated at the least favourable phase angle for ice versus engine excitation, when calculated in the time domain. The engine firing pulses shall be included in the calculations and their standard steady state harmonics can be used.

If there is a blade order resonance just above the MCR speed, calculations shall cover rotation- al speeds up to 105% of the MCR speed.

The propeller ice torque excitation for shaft line transient dynamic analysis in the time domain is defined as a sequence of blade impacts which are of half sine shape.

The excitation frequency shall follow the propeller rotational speed during the ice interaction sequence.

The torque due to a single blade ice impact as a function of the propeller rotation angle is then defined using the formula:

$Q(\varphi) = C_q\, Q_{\max} \sin(\varphi\, (180/\, \alpha_i))$ when φ rotates from 0 to α_i plus integer revolutions;

$Q(\varphi) = 0$ when φ rotates from α_i to 360 plus integer revolutions.

φ is the rotation angle from when the first impact occurs and parameters C_q and α_i are given in Table 2.9.2.5.3.4.1.

α_i is the duration of propeller blade/ice interaction expressed in terms of the propeller rotation angle. See Figure 2.9.2.5.3.4.1-1.

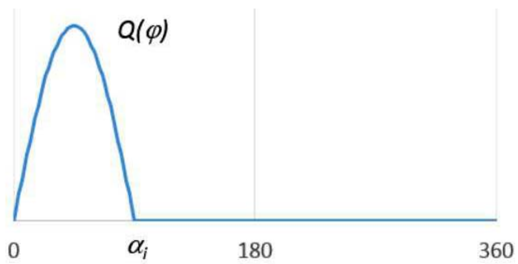


Fig. 2.9.2.5.3.4.1-1 Schematic ice torque due to a single blade ice impact as a function of the propeller rotation angle

The total ice torque is obtained by summing the torque of single blades, while taking account of the phase shift 360 deg./Z, see Figure 2.9.2.5.3.4.1-2.

At the beginning and end of the milling sequence (within the calculated duration) linear ramp functions shall be used to increase C_q to its maximum value within one propeller revolution and vice versa to decrease it to zero (see the examples of different Z numbers in Figure 2.9.2.5.3.4.1-2 and 2.9.2.5.3.4.1-3.

Table 2.9.2.5.3.4.1

Torque excitation	Propeller/ ice interaction	C_q	α_i, in deg. Z=3	Z=4	Z=5	Z=6
Excitation case 1	Single ice block	0,75	90	90	72	60
Excitation case 2	Single ice block	1,0	135	135	135	135

Excitation case 3	Two ice blocks (phase shift 360/(2·Z) deg.)	0,5	45	45	45	30
Excitation case 4	Single ice block	0,5	45	45	45	30

The number of propeller revolutions during a milling sequence shall be obtained from the formula:

$$N_Q = 2H_{ice}. \qquad (2.9.2.5.3.4.1\text{-}1)$$

The number of impacts is $Z{\cdot}N_Q$ for blade order excitation.

A dynamic simulation must be performed for all excitation cases at the operational rotational speed range.

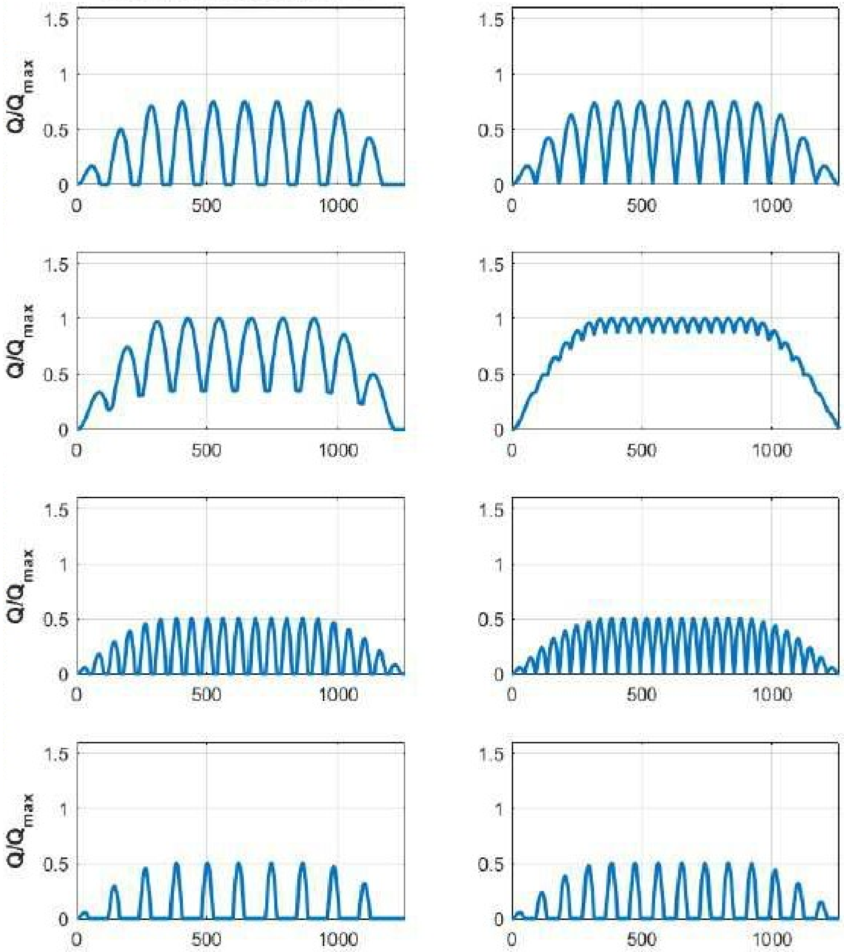
Number of blades Z= 3 Number of blades Z= 4

Excitation case **1**

Excitation case **2**

Excitation case **3**

Excitation case **4**



Rotation angle, in deg. Rotation angle, in deg.

Fig. 2.9.2.5.3.4.1-2 The shape of the propeller ice torque excitation sequences for propellers with 3 and 4 blades

For a fixed pitch propeller propulsion plant, a dynamic simulation must also cover the bollard pull condition with a corresponding rotational speed assuming the maximum possible output of the engine.

If a speed drop occurs until the main engine is at a standstill, this indicates that the engine may not be sufficiently powered for the intended service task.

For the consideration of loads, the maximum occurring torque during the speed drop process must be used.

For the time domain calculation, the simulated response torque typically includes the engine mean torque and the propeller mean torque. If this is not the case, the response torques must be obtained using the formula:

$$Q_{peak} = Q_{emax} + Q_{rtd}, \text{ in kNm.} \qquad (2.9.2.5.3.4.1\text{-}2)$$

where: Q_{rtd} — is the maximum simulated torque obtained from the time domain analysis.

Excitation case	Number of blades Z= 5	Number of blades Z= 6
Excitation case 1		
Excitation case 2		
Excitation case 3		
Excitation case 4		

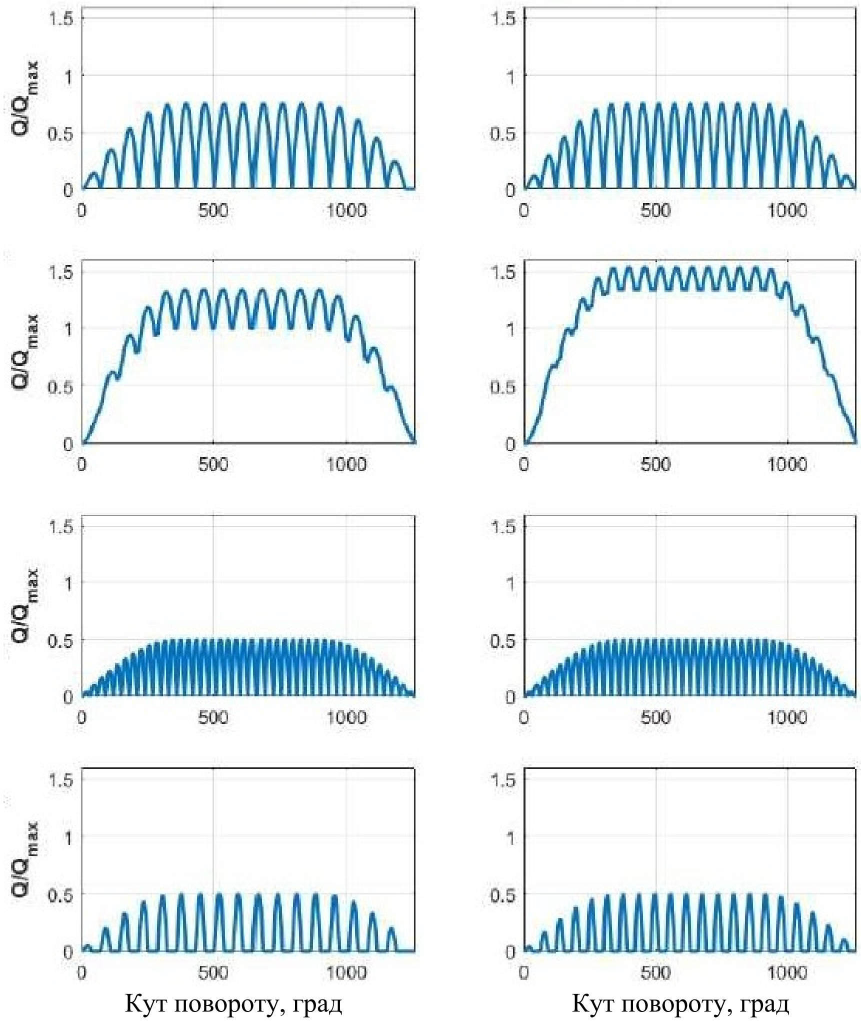


Fig. 2.9.2.5.3.4.1-3 The shape of the propeller ice torque excitation sequences for propellers with 5 or 6 blades

2.9.2.5.3.4.2 Frequency domain calculation of torsional response.

For frequency domain calculations, blade order and twice-the-blade-order excitation may be used.

The amplitudes for the blade order and twice-the-blade-order sinusoidal excitation have been derived based on the assumption that the time domain half sine impact sequences were continuous, and the Fourier series components for blade order and twice-the-blade-order components have been derived.

The propeller ice torque is then:

$$Q_F(\varphi) = Q_{max}(C_{q0} + C_{q1}\sin(ZE_0\,\varphi + \alpha_1) + C_{q2}\sin(ZE_0\,\varphi + \alpha_2)), \quad \text{in kNm} \quad (2.9.2.5.3.4.2\text{-}1)$$

Where E_0 is the number of ice blocks in contact.

The values of the parameters are given in Table2.9.2.5.3.4.2.

Table 2.9.2.5.3.4.2

Torque excitation (Z=3)	C_{q0}	C_{q1}	α_1	C_{q2}	α_2	E_0
Excitation case **1**	0,375	0,36	-90	0	0	1
Excitation case **2**	0,7	0,33	-90	0,05	-45	1
Excitation case **3**	0,25	0,25	-90	0	0	2
Excitation case **4**	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=4)						
Excitation case **1**	0,45	0,36	-90	0,06	-90	1
Excitation case **2**	0,9375	0	-90	0,0625	-90	1

Excitation case **3**	0,25	0,25	-90	0	0	2
Excitation case **4**	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=5)						
Excitation case **1**	0,45	0,36	-90	0,06	-90	1
Excitation case **2**	1,19	0,17	-90	0,02	-90	1
Excitation case **3**	0,3	0,25	-90	0,048	-90	2
Excitation case **4**	0,2	0,25	0	0,05	-90	1
Torque excitation (Z=6)						
Excitation case **1**	0,45	0,36	-90	0,05	-90	1
Excitation case **2**	1,435	0,1	-90	0	0	1
Excitation case **3**	0,3	0,25	-90	0,048	-90	2
Excitation case **4**	0,2	0,25	0	0,05	-90	1

The design torque for the frequency domain excitation case must be obtained using the formula

$Q_{peak}=Q_{emax}+ Q_{vib}+(Q^{n}_{max}\ C_{q0})I_e/I_t + Q_{rf1} + Q_{rf2}$, in kNm (2.9.2.5.3.4.2-2)

where:

$Q_{\max}$ – is the maximum propeller ice torque at the operation speed in consideration;

C_{q0} – is the mean static torque coefficient from Table 2.9.2.3.4.2;

Q_{rf1} – is the blade order torsional response from the frequency domain analysis;

Q_{rf2} – is the second order blade torsional response from the frequency domain analysis.

If the prime mover maximum torque, Q_{emax} is not known, it shall be taken as given in 2.9.2.5.3.3.

2.9.2.5.3.4.3 Guidance for torsional vibration calculation.

The aim of time domain torsional vibration simulations is to estimate the extreme torsional load for the ship's lifespan. The simulation model can be taken from the normal lumped mass elastic torsional vibration model, including damping. For a time domain analysis, the model should include the ice excitation at the propeller, other relevant excitations and the mean torques provided by the prime mover and hydrodynamic mean torque in the propeller.

The calculations should cover variation of phase between the ice excitation and prime mover excitation. This is extremely relevant to propulsion lines with directly driven combustion engines.

Time domain calculations shall be calculated for the MCR condition, MCR bollard conditions and for resonant speed, so that the resonant vibration responses can be obtained.

For frequency domain calculations, the load should be estimated as a Fourier component analysis of the continuous sequence of half sine load sequences. First and second order blade components should be used for excitation.

The calculation should cover the entire relevant rpm range and the simulation of responses at torsional vibration resonances.

2.9.2.5.4 Blade failure load.

10.7.5.4.1 Bending force, F_{ex}.

The ultimate load resulting from blade failure as a result of plastic bending around the blade root shall be calculated using formula (2.9.2.5.4.1), or alternatively by means of an appropriate stress analysis, reflecting the nonlinear plastic material behaviour of the actual blade. In such a case, the blade failure area may be outside the root section.

The ultimate load is assumed to be acting on the blade at the 0.8R radius in the weakest direction of the blade.

$$F_{ex} = 300ct^2\sigma_{ref}/(0{,}8D\text{-}2r),\ \text{in kN}, \qquad (2.9.2.5.4.1)$$

where: c, t and r are, respectively, the actual chord length, maximum thickness and radius of the cylindrical root section of the blade, which is the weakest section out-side the root fillet typically located at the point where the fillet terminates at the blade profile.

2.9.2.5.4.2 Spindle torque, Q_{sex}.

The maximum spindle torque due to a blade failure load acting at 0.8R shall be determined. The force that causes blade failure typically reduces when moving from the propeller centre towards the leading and trailing edges.

At a certain distance from the blade centre of rotation, the maximum spindle torque will occur. This maximum spindle torque shall be defined by an appropriate stress analysis or using the equation given below:

$$Q_{sex}=\max(C_{LE0,8};\ 0{,}8C_{TE0,8})C_{spex}F_{ex},\ \text{in kNm};$$

$$C_{spex} = 0,7(1-(4EAR/Z)^3),$$

where:
EAR – expanded blade area ratio.
If C_{spex} is below 0,3, a value of 0.3 shall to be used for C_{spex}.
$C_{LE0,8}$ is the leading edge portion of the chord length at 0.8R;
$C_{TE0,8}$ – is the trailing edge portion of the chord length at0.8R.

Figure 2.9.2.5.4.2 illustrates the spindle torque values due to blade failure loads across the entire chord length.

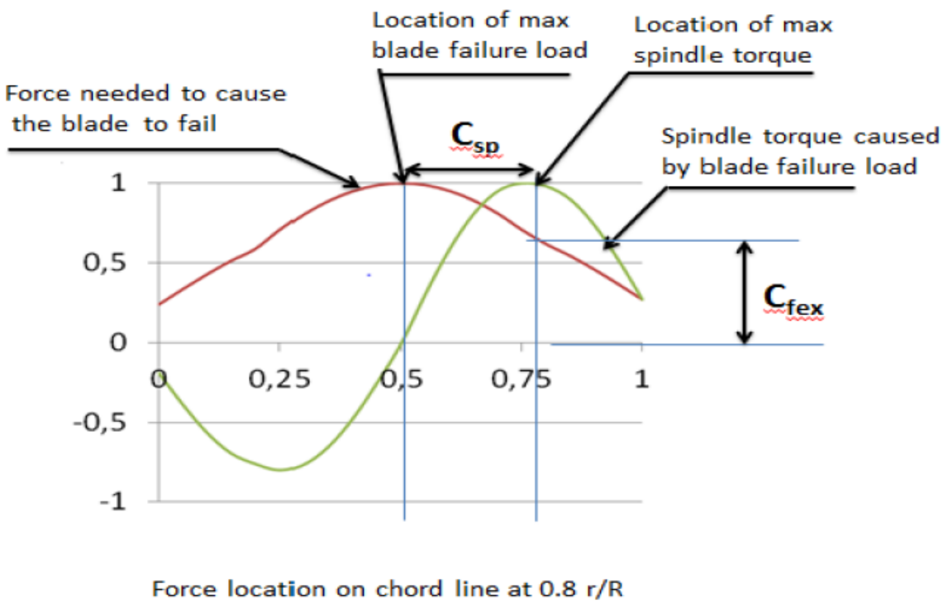


Fig. 2.9.2.5.4.2 Schematic figure showing a blade failure load and the related spindle torque when the force acts at a different location on the chord line at radius0,8R

2.9.2.6 Design.

2.9.2.6.1 Design principle.

The strength of the propulsion line shall be designed according to the pyramid strength principle. This means that the loss of the propeller blade shall not cause any significant damage to other propeller shaft line components.

2.9.2.6.2 Propeller blade.

2.9.2.6.2.1 Calculation of blade stresses.

The blade stresses shall be calculated for the design loads given in **2.9.2.5.1**.

Finite element analysis shall be used for stress analysis for the final approval of all propellers. The following simplified formulae can be used for estimating the blade stresses for all propellers at the root area ($r/R < 0,5$).

Root area dimensions based on formula (2.9.2.6.2.1), can be accepted, even if the FEM analysis would show greater stresses at the root area.

$$\sigma_{st} = C_1 M_{BL}/100ct^2, \text{ in MPa}, \qquad (2.9.2.6.2.1)$$

where:
constant C_1 is the actual stress/stress obtained from the beam equation. If the actual value is not available, C_1 should have a value of 1.6;
$M_{BL} = (0,75-r/R)\cdot R\cdot F$,
where: $F = F_b$ or F_f, whichever has greater absolute value.

2.9.2.6.2.2 Acceptability criterion.

The following criterion for calculated blade stresses must be fulfilled:

$$\sigma_{ref2}/\sigma_{st} \geq 1,3$$

If FEM analysis is used for estimating the stresses, von Mises stresses shall be used.

2.9.2.6.2.3 Fatigue design of propeller blade.

The fatigue design of the propeller blade is based on an estimated load distribution for the service life of the ship and the S-N curve for the blade material. An equivalent stress that produces the same fatigue damage as the expected load distribution shall be calculated and the acceptability criterion for fatigue should be fulfilled. The equivalent stress is normalised for 10^8 cycles

For materials with a two-slope SN curve, fatigue calculations in accordance with this chapter are not required if the following criterion is fulfilled.

$$\sigma_{exp} \geq B_1\ \sigma_{ref2}\ B_2\ \log(N_{ice})\ B_3$$

where: B_1, B_2 and B_3 coefficients for open and ducted propellers are given in Table 2.9.2.6.2.3-1.

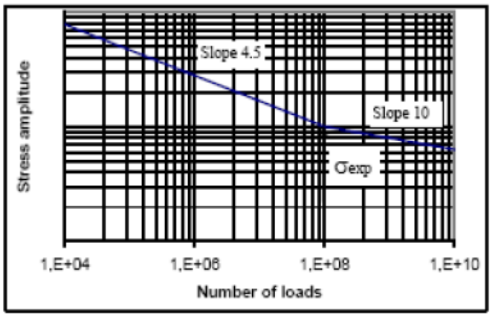


Fig. 2.9.2.6.2.3-1 Two-slope S-N curve

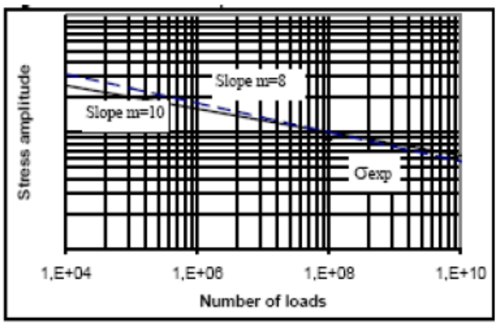


Fig. 2.9.2.6.2.3-2 Constant-slope S-N curve. Equivalent fatigue stress

Table 2.9.2.6.2.3-1

	Open propeller	Ducted propeller
B_1	0,00246	0,00167
B_2	0,947	0,956
B_3	2,101	2,470

For the calculation of equivalent stress, two types of SN curves are available.

Two slope SN curve (slopes 4.5 and 10), see Figure 2.9.2.6.2.3-1;

One slope SN curve (the slope can be chosen), see Figure 2.9.2.6.2.3-2.

The type of the SN-curve shall be selected to correspond with the material properties of the blade.

If the SN-curve is unknown, the two slope SN curve shall be used.

2.9.2.6.2.3.1 The equivalent fatigue stress.

The equivalent fatigue stress for 10^8 stress cycles, which produces the same fatigue damage as the load distribution for the service life of the ship, is:

$$\sigma_{fat} = \rho(\sigma_{ice})_{\max}, \qquad (2.9.2.6.2.3.1)$$

where $(\sigma_{ice})_{\max} = 0{,}5((\sigma_{ice})_{f\max} - (\sigma_{ice})_{b\max})$.

In the calculation of $(\sigma_{ice})_{\max}$ case 1 and case 3 (or case 2 and case 4), specified in **2.9.2.5.1**, are considered a pair for $(\sigma_{ice})_{f\max}$ and $(\sigma_{ice})_{b\max}$ calculations. Case 5 is excluded from the fatigue analysis

.

2.9.2.6.2.3.2 Calculation of parameter ρ for two-slope S-N curve.

The parameter ρ relates the maximum ice load to the distribution of ice loads according to the regression formula

$$\rho = C_1(\sigma_{ice})_{\max} C_2 \sigma_{fl} C_3 \log(N_{ice}) C_4\ , \qquad (2.9.2.6.2.3.2)$$

where $\sigma_{ft} = \gamma_\varepsilon\ \gamma_v\ \gamma_m\ \sigma_{exp}$.

The following values should be used for the reduction factors if actual values are unavailable $\gamma_\varepsilon = 0{,}67$, $\gamma_v = 0{,}75$ and $\gamma_m = 0{,}75$.

The coefficients$C1$, $C2$, $C3$ and $C4$ are given in Table2.9.2.6.2.3.2.

Table 2.9.2.6.2.3.2

	Open propeller	Ducted propeller
C_1	0,000711	0,000534
C_2	0,0645	0,0533
C_3	-0,0565	-0,0459
C_4	2,22	2,584

2.9.2.6.2.3.3 Calculation of parameterρ for constant-slope S-N curve.

For materials with a constant-slope S-N curve, the factor ρ shall be calculated using the following formula

$$\rho = \left(G\,\frac{N_{ice}}{N_R}\right)^{1/m}(\ln(N_{ice}))^{-1/k}, \qquad (2.9.2.6.2.3.2)$$

where: k = 1,0 for ducted propellers;

k = 0,75 for open propellers.

Values for the parameter G are given in Table 2.9.6.2.2.3.3, Linear interpolation may be used to calculate the value of m/k ratios other than those given in Table 2.9.6.2.2.3.3.

Table 2.9.2.6.2.3.3 **Value of the parameter *G* for different *m/k* ratios**

m/k	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5	10
G	6	11,6	24	52,3	120	287,9	720	1871	5040	14034	40320	119292	362880	$1{,}133\cdot10^6$	$3{,}623\cdot10^6$

2.9.2.6.2.4 Acceptability criterion for fatigue.

The equivalent fatigue stress at all locations on the blade must fulfil the following acceptability criterion:

$$(\sigma_{fð} / \sigma_{fat}) \geq 1{,}5$$

where: $\sigma_{fl} = \gamma_{\varepsilon1}\gamma_{\varepsilon2}\gamma_v\gamma_m\,\sigma_{exp}$.

The following values should be used for the reduction factors if actual values are unavailable: $\gamma_\varepsilon = \gamma_{\varepsilon1}$ = 0,67, γ_v = 0,75 and γ_m = 0,75.

2.9.6.2.3 Propeller bossing and CP mechanism.

The blade bolts, the CP mechanism, the propeller boss, and the fitting of the propeller to the propeller shaft shall be designed to withstand the maximum and fatigue design loads, as defined in **2.9.2.5**.

The safety factor against yielding shall be greater than 1.3 and that against fatigue greater than 1.5. In addition, the safety factor for loads resulting from loss of the propeller blade through plastic bending, as defined in**2.9.2.5**, shall be greater than 1.0 against yielding.

2.9.2.6.4 Propulsion shaft line.

The shafts and shafting components, such as the thrust and stern tube bearings, couplings, flanges and sealings, shall be designed to withstand the propeller/ice interaction loads as given in **2.9.2.5**.

The safety factor must be at least 1.3.

2.9.2.6.4.1 Shafts and shafting components.

The ultimate load resulting from total blade failure, as defined in **2.9.2.5.4.1**, shall not cause yielding in shafts and shaft components.

The loading shall consist of the combined axial, bending, and torsion loads, wherever this is significant. The minimum safety factor against yielding must be 1.0 for bending and torsional stresses.

2.9.2.6.5 Azimuthing main propulsors.

2.9.2.6.5.1 Design principle.

In addition to the above requirements for propeller blade dimensioning, azimuthing thrusters must be designed for thruster body/ice interaction loads.

Load formulae are given for estimating once in a lifetime extreme loads on the thruster body, based on the estimated ice condition and ship operational parameters.

Two main ice load scenarios have been selected for defining the extreme ice loads. Examples of loads are illustrated in Figure2.9.2.6.5.1.

In addition, blade order thruster body vibration responses may be estimated for propeller excitation.

The following load scenario types are considered:

.1 Ice block impact on the thruster body or propeller hub;

.2 Thruster penetration into an ice ridge that has a thick consolidated layer;

.3 Vibratory response of the thruster at blade order frequency.

The steering mechanism, the fitting of the unit, and the body of the thruster shall be designed to withstand the plastic bending of a blade without damage.

The loss of a blade must be taken into account for the propeller blade orientation causing the maximum load on the component being studied. Top-down blade orientation typically places the maximum bending loads on the thruster body.

2.9.2.6.5.2 Extreme ice impact loads.

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub.

Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster.

The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster must withstand the loads occurring when the design ice block defined in 2.9.2.3-2, impacts on the thruster body when the ship is sailing at a typical ice operating speed.

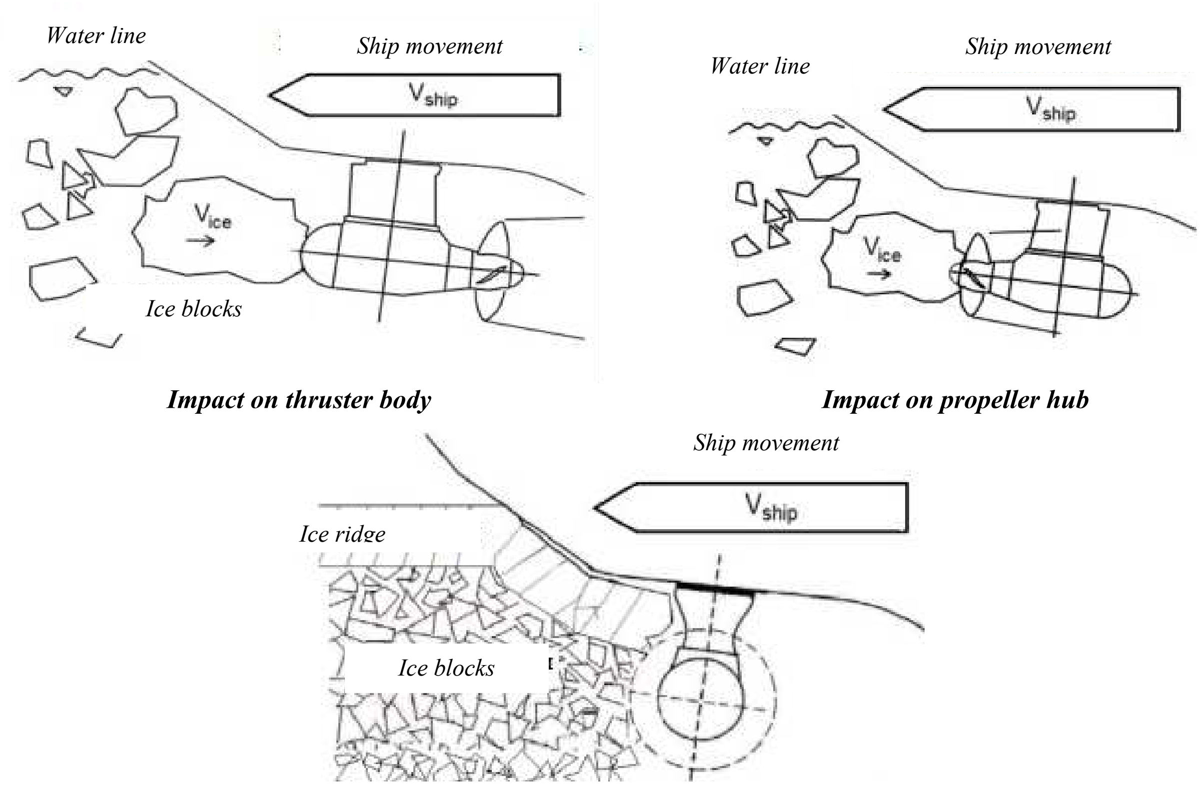
Load cases for impact loads are given in Table 2.9.2.6.5.2-1.

The contact geometry is estimated to be hemispherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius must be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

The ice impact contact load must be calculated using formula (2.9.2.6.5.2).

The related parameter values are given in Table 2.9.2.6.5.2-2.

The design operation speed in ice can be derived from Tables 2.9.2.6.5.2-3 i 2.9.2.6.5.2-4 or the ship in question's actual design operation speed in ice can be used.



Thruster penetration into the ice ridge

Fig. 2.9.2.6.5.1 Examples of load scenario types

2.9.2.6.5.2 Extreme ice impact loads.

When the ship is operated in ice conditions, ice blocks formed in channel side walls or from the ridge consolidated layer may impact on the thruster body and the propeller hub.

Exposure to ice impact is very much dependent on the ship size and ship hull design, as well as the location of the thruster. The contact force will grow in terms of thruster/ice contact until the ice block reaches the ship speed.

The thruster must withstand the loads occurring when the design ice block defined in Table2.9.2.3-2, impacts on the thruster body when the ship is sailing at a typical ice operating speed.

Load cases for impact loads are given in Table 2.9.2.6.5.2-1.

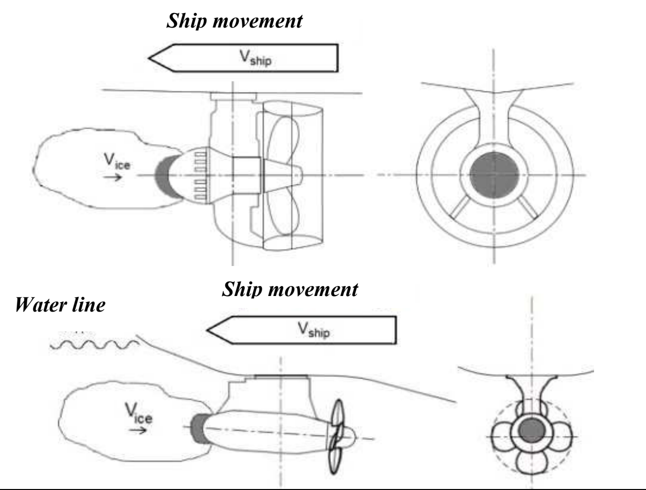
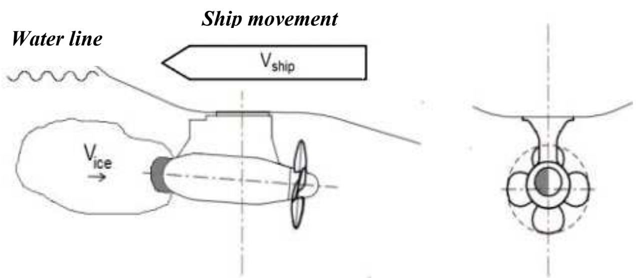
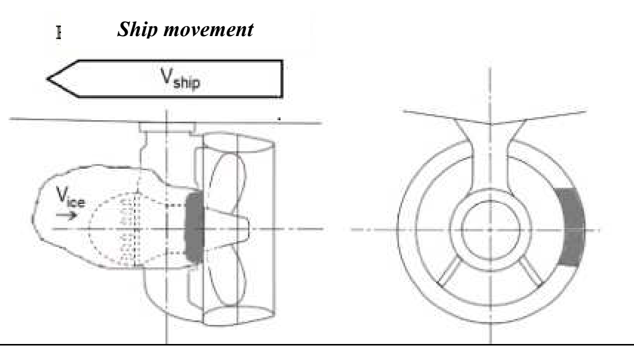
The contact geometry is estimated to be hemispherical in shape. If the actual contact geometry differs from the shape of the hemisphere, a sphere radius must be estimated so that the growth of the contact area as a function of penetration of ice corresponds as closely as possible to the actual geometrical shape penetration.

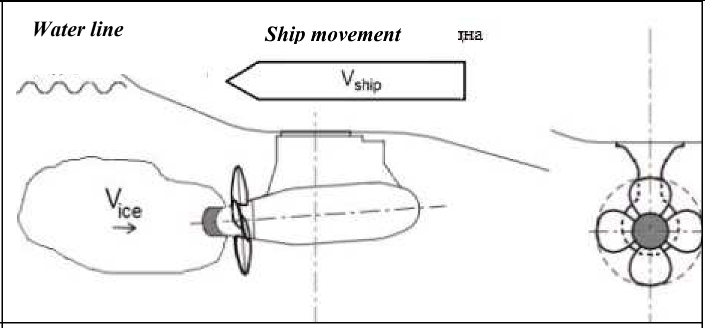
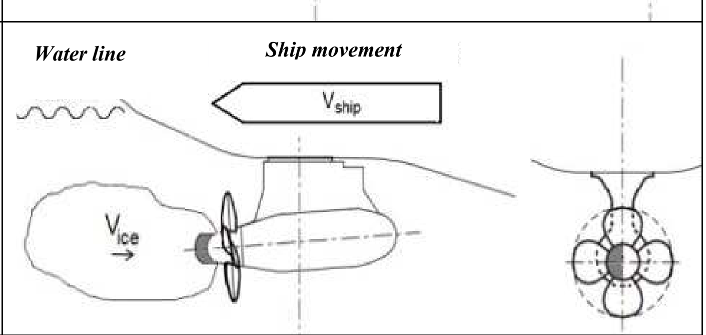
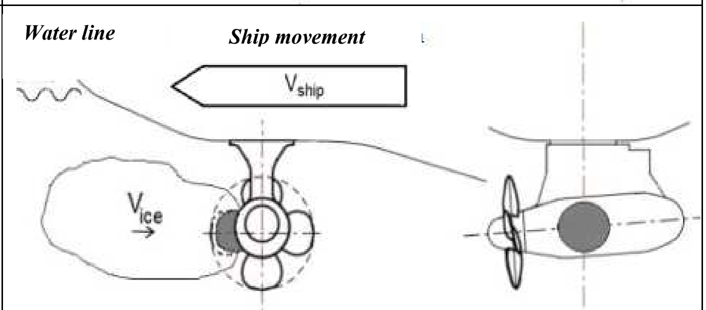
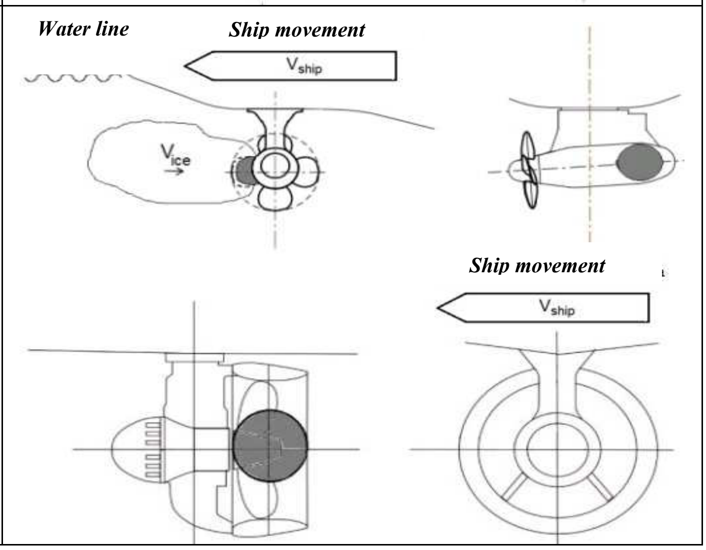
The ice impact contact load must be calculated using formula (2.9.2.6.5.2).

The related parameter values are given in Table 2.9.2.6.5.2-2.

The design operation speed in ice can be derived from Tables2.9.2.6.5.2-3 i 2.9.2.6.5.2-4 or the ship in question's actual design operation speed in ice can be used.

Table 2.9.2.6.5.2-1 **Load cases for impact loads**

Load case	Force	Loaded area	Interaction
1	**2**	**3**	**4**
Load case T1a Symmetric longitudinal ice impact on thruster	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T1b Non-symmetric longitudinal ice impact on thruster	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area	
Load case T1c Non-symmetric longitudinal ice impact on nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Contact area is equal to the nozzle thickness (H_{nz}) the contact height H_{ice}	

Load case T2a Symmetric longitudinal ice impact on propeller hub	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T2b Non-symmetric longitudinal ice impact on propeller hub	50% of F_{ti}	Uniform distributed load or uniform pressure, which are applied on the other half of the impact area.	
Load case T3a Symmetric lateral ice impact on thruster body	F_{ti}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T3b Non-symmetric lateral ice impact on thruster body or nozzle	F_{ti}	Uniform distributed load or uniform pressure, which are applied on the impact area. Nozzle contact radius *R* to be taken from the nozzle length (L_{nz})	

The longitudinal impact speed in Tables 2.9.2.6.5.2-3 i 2.9.2.6.5.2-4, refers to the impact in the thruster's main operational direction.

For the pulling propeller configuration, the longitudinal impact speed is used for load case T2, impact on hub; and for the pushing propeller unit, the longitudinal impact speed is used for load case T1, impact on thruster end cap. For the opposite direction, the impact speed for transversal impact is applied.

$$F_{ti}=C_{DMI}\,34{,}5R_c^{0{,}5}(m_{ice}v_s^2)^{0{,}333}, \text{ in kN} \qquad (2.9.2.6.5.2\text{-}1)$$

where:
R_c is the impacting part sphere radius, see Figure (10.7.6.5.2), in m;
m_{ice} is the ice block mass, in kg;
v_s is the ship speed at the time of contact, im m/s;
C_{DMI} is the dynamic magnification factor for impact loads.

C_{DMI} shall be taken from Table 2.9.2.6.5.2-2 if unknown.

For impacts on non-hemispherical areas, such as the impact on the nozzle, the equivalent impact sphere radius must be estimated using the equation below:

$$R_{ceq} = (A/\pi)^{1/2}, \text{ in m.} \quad (2.9.2.6.5.2\text{-}2)$$

If the $2R_{ceq}$ is greater than the ice block thickness, the radius is set to half of the ice block thickness.

For the impact on the thruster side, the pod body diameter can be used as a basis for determining the radius.

For the impact on the propeller hub, the hub diameter can be used as a basis for the radius.

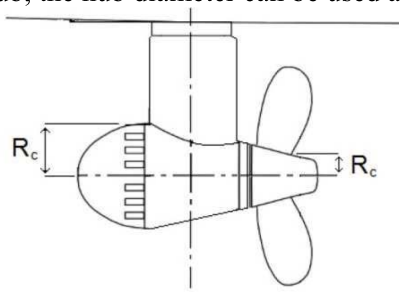


Fig. 2.9.2.6.5.2 Dimensions used for R_c

Table 2.9.2.6.5.2-2 **Parameter values for ice dimensions and dynamic magnification**

Baltic ice class	**IA Super**	**IA**	**IB**	**IC**
Thickness of the design ice block impacting thruster (2/3 of H_{ice}), in m	1.17	1,0	0,8	0,67
Extreme ice block mass m_{ice}, in k	8670	5460	2800	1600
C_{DMI} (if not known)	1,3	1,2	1,1	1,0

Table 2.9.2.6.5.2-3 **Impact speeds for aft centerline thruster**

Baltic ice class	**IA Super**	**IA**	**IB**	**IC**
Longitudinal impact in main operational direction	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4	3	3	3
Transversal impact in bow first operation	3	2	2	2
Transversal impact in stern first operation (double acting ship)	4	3	3	3

Таблиця 2.9.2.6.5.2-4 **Impact speeds for aft wing, bow centerline and bow wing thrusters**

Baltic ice class	**IA Super**	**IA**	**IB**	**IC**
Longitudinal impact in main operational direction	6	5	5	5
Longitudinal impact in reversing direction (pushing unit propeller hub or pulling unit cover end cap impact)	4	3	3	3
Transversal impact	4	3	3	3

2.9.2.6.5.3 Extreme ice loads on thruster hull when penetrating an ice ridge.

In icy conditions, ships typically operate in ice channels.

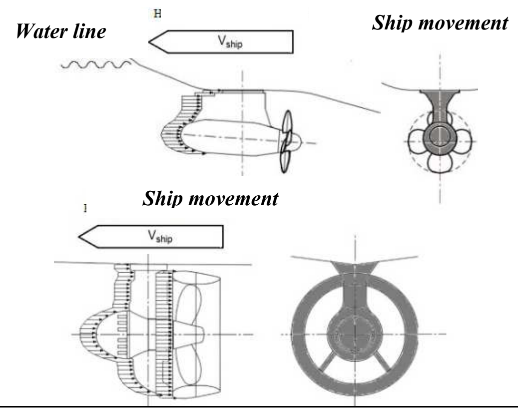
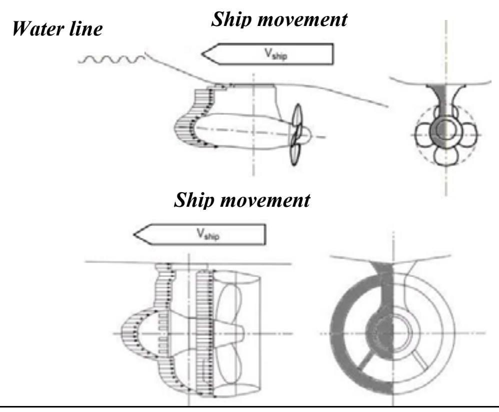
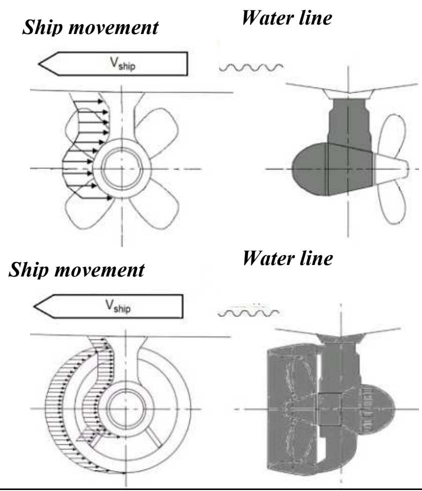
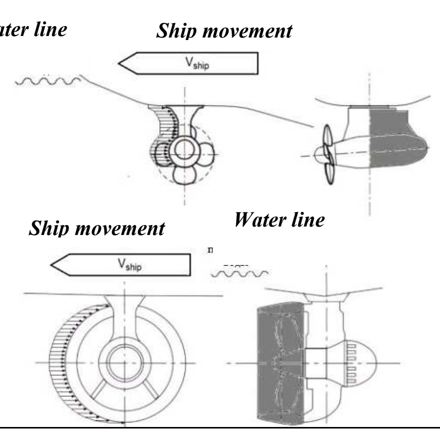
When passing other ships, ships may be subject to loads caused by their thrusters penetrating ice channel walls. There is usually a consolidated layer at the ice surface, below which the ice blocks are loose. In addition, the thruster may penetrate ice ridges when backing. Such a situation is likely in the case of ships with notation **IA Super**, in particular, because they may operate independently in difficult ice conditions. However, the thrusters in ships with lower ice classes may also have to withstand such a situation, but at a remarkably lower ship speed.

In this load scenario, the ship is penetrating a ridge in thruster first mode with an initial speed. This situation occurs when a ship with a thruster at the bow moves forward, or a ship with a thruster astern moves in backing mode. The maximum load during such an event is considered the extreme load. An event of this kind typically lasts several seconds, due to which the dynamic magnification is considered negligible and is not taken into account.

The load magnitude must be estimated for the load cases shown in Table 2.9.2.6.5.3-1, using formula (2.9.2.6.5.3).

The parameter values for calculations are given in Tables 2.9.2.6.5.3-2 and 2.9.2.6.5.3-3.

Table 2.9.2.6.5.3-1 **Load cases for ridge ice loads**

Load case	Force	Loaded area	Interaction
Load case T4a Symmetric longitudinal ridge penetration loads	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the impact area.	
Load case T4b Nonsymmetric longitudinal ridge penetration loads	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area.	
Load case T5a Symmetric lateral ridge penetration loads for ducted azimuthing unit and pushing open propeller unit	F_{tr}	Uniform distributed load or uniform pressure, which are applied symmetrically on the contact area.	
Load case T5b Nonsymmetric lateral ridge penetration loads for all azimuthing units	50% of F_{tr}	Uniform distributed load or uniform pressure, which are applied on the other half of the contact area	

The loads must be applied as uniform distributed load or uniform pressure over the thruster surface.

The design operation speed in ice can be derived from Table 2.9.2.6.5.3-2 or Table 2.9.2.6.5.3-3. Alternatively, the actual design operation speed in ice of the ship in question can be used.

$$F_{tr}=32v_s^{0,66}\,H_r^{0,9}A_t^{0,74}, \quad \text{in kN}, \ (2.9.2.6.5.3)$$

where:

v_s – ship speed, in m/s;

H_r – ice ridge design thickness (the thickness of the frozen ice layer is 18% of the total thickness of the ice ridge), in m;

A_t – CP design area , in m^2.

When calculating the loaded area of the CP interaction with ice ridge, the loaded area in vertical direction is restricted by the maximum ridge thickness, as is shown in Figure 2.9.2.6.5.3.

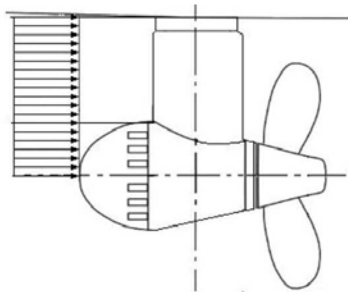


Fig. 2.9.2.6.5.3 Schematic figure showing the reduction of the contact area by the maximum ridge thickness

Table 2.9.2.6.5.3-2 **Parameters for calculating maximum loads when the thruster penetrates an ice ridge. Aft thrusters. Bow first operation**

Baltic ice class	**IA Super**	**IA**	**IB**	**IC**
Thickness of the design ridge consolidated layer, in m	1,5	1,5	1,2	1,0
Total thickness of the design ridge *Hr*, in m	8	8	6,5	5
Initial ridge penetration speed (longitudinal loads)	4	2	2	2
Initial ridge penetration speed (transversal loads)	2	1	1	1

Таблиця 2.9.2.6.5.3-3 **Parameters for calculating maximum loads when the thruster penetrates an ice ridge. Thruster first mode such as double acting ships.**

Baltic ice class	**IA Super**	**IA**	**IB**	**IC**
Thickness of the design ridge consolidated layer	1,5	1,5	1,2	1,0
Total thickness of the design ridge *Hr*, in m	8	8	6,5	5
Initial ridge penetration speed (longitudinal loads)	6	4	4	4
Initial ridge penetration speed (transversal loads)	3	2	2	2

2.9.2.6.5.4 Acceptability criterion for static loads.

The stresses on the thruster must be calculated for the extreme once-in-a-lifetime loads described in **2.9.2.6.5**.

The nominal von Mises stresses on the thruster body must have a safety margin of 1.3 against the yielding strength of the material. At areas of local stress concentrations, stresses must have a safety margin of 1.0 against yielding. The slewing bearing, bolt connections and other components must be able to maintain operability without incurring damage that requires repair when subject to the loads given in **2.9.2.6.5.2** and **2.9.2.6.5.3**, multiplied by a safety factor of 1.3.

2.9.2.6.5.5 Thruster body global vibration.

Evaluating the global vibratory behavior of the thruster body is important, if the first blade order excitations are in the same frequency range with the thruster global modes of vibration, which occur when the propeller rotational speeds are in the high power range of the propulsion line.

This evaluation is mandatory and it must be shown that there is either no global first blade order resonance at high operational propeller speeds (above 50% of maximum power) or that the structure is designed to withstand vibratory loads during resonance above 50% of maximum power.

When estimating thruster global natural frequencies in the longitudinal and transverse direction, the damping and added mass due to water must be taken into account. In addition to this, the effect of ship attachment stiffness must be modelled.

2.9.2.7 Alternative design procedure.

2.9.2.7.7.1 Scope.

As an alternative to **2.9.2.5** and **2.9.2.6**, a comprehensive design study may be performed to the satisfaction of the Register. The study must be based on the ice conditions given for different ice classes in **2.9.2.3**. It must include both fatigue and maximum load design calculations and fulfil the pyramid strength principle, as given in **2.9.2.6.1**.

2.9.2.7.2 Loading.

Loads on the propeller blade and propulsion system shall be based on an acceptable estimation of hydrodynamic and ice loads.

2.9.2.7.3 Design levels.

The analysis must confirm that all components transmitting random (occasional) forces, excluding propeller blade, are not subjected to stress levels in excess of the yield stress of the component material, with a reasonable safety margin. Cumulative fatigue damage calculations must give a reasonable safety factor. Due account must be taken of material properties, stress raisers, and fatigue enhancements.

A vibration analysis must be performed and demonstrate that the overall dynamic system is free of the harmful torsional resonances resulting from propeller/ice interaction.

2.9.3 MISCELLANEOUS MACHINERY REQUIREMENTS.

2.9.3.1 Starting arrangements.

The capacity of the air receivers must be sufficient to provide no less than 12 consecutive starts of the propulsion engine without reloading, if it has to be reversed for moving astern, or 6 consecutive starts if the propulsion engine does not have to be reversed for moving astern.

If the air receivers serve any purposes other than starting the propulsion engine, they must have additional capacity sufficient for such purposes.

The capacity of the air compressors must be sufficient for charging the air receivers from atmospheric to full pressure in one (1) hour, except for a ship with ice class **IA Super**, if its propulsion engine has to be reversed for going astern, in which case the compressor must be able to charge the receivers in half an hour.

2.9.3.2 Sea inlet and cooling water systems.

The cooling water system shall be designed to secure the supply of cooling water when navigating in ice (refer also to **4.3.3**, Part VIII «Systems and piping»).

For this purpose, at least one cooling water inlet chest shall be arranged as follows:

.1 The sea inlet shall be situated near the centreline of the ship and well aft, if possibl;

.2 The volume of the chest shall be around one cubic metre for every 750 kW in engine output of the ship, including the output of auxiliary engines necessary for the operation of the ship;

.3 The chest shall be sufficiently high to allow ice to accumulate above the inlet pipe;

.4 A pipe for discharge cooling water, allowing full capacity discharge, shall be connected to the chest;

.5 The open area of the strainer plates shall be no less than four (4) times the inlet pipe sectional area.

If there are difficulties in meeting the requirements of **2.9.3.2.2** and **2.9.3.2.3** above, two smaller chests may be arranged for alternating the intake and discharge of cooling water. The requirements of **2.9.3.2.1**, **2.9.3.2.4** and **2.9.3.2.5** shall be met.

Heating coils may be installed in the upper part of the sea chest.

Arrangements for using ballast water for cooling purposes may be useful as a reserve in terms of ballast, but cannot be accepted as a substitute for an inlet chest as described above.

2.10 REQUIREMENTS FOR SHIPS EQUIPPED FOR USING GASES OR LOW-FLASHPOINT FUELS

2.10.1 GENERAL.

2.10.1.1 All dimensions of hull construction elements, except those specifically stipulated in this subsection, shall be determined in accordance with the requirements of Part II "Hull" depending on the purpose and design of the ship.

2.10.1.2 Definitions and explanations relating to the general terminology of this part are given in **1.2**.

For the purpose of this Chapter definitions and explanations, which are also valid for Parts VIII "Systems and piping" and IX "Machinery" havew been adopted.

Multi-fuel engine means an engine capable of using two or more different fuels that are separate from each other.

Non-hazardous atmosphere means air environment where gas concentration is lower than the level corresponding to activating an alarm on high gas concentration in the air.

Open space means a space open from one or several sides in all parts of which effective natural ventilation is arranged via permanently open openings in the side partitions and in the above located deck.

Secondary barrier means the liquid-resisting outer element of a fuel containment system designed to afford temporary containment of any envisaged leakage of liquid fuel through the primary barrier and to prevent the lowering of the temperature of the ship's structure to an unsafe level.

High pressure means maximum operating pressure over 1.0 MPa.

Gas means a fluid having a vapour pressure exceeding 0,28 MPa absolute at a temperature of 37,8 °C.

Gas area means an area where gas-containing systems and equipment are located, including the weather deck spaces above them.

Gas fuel means any hydrocarbon fuel having at the temperature of 37,8 8C the absolute pressure of saturated vapours according to Reid equal to 0,28 MPa and above.

Gas-safe machinery space means closed gas-safe space with gas fuel consumers, explosion safety of which is ensured by installation of gas-containing equipment in gastight enclosures (piping, ducting, partitions) for gas fuel bleed-off, and the inner space of partitions and ducting shall be considered gas-dangerous.

Gas-safe space means a space other than a gas-dangerous space.

Gas-dangerous space means a space in the gas area which is not equipped with approved device to ensure that its atmosphere is at all times maintained in a gas-safe condition. It is subdivided into explosion hazardous zones 0, 1, 2 the boundaries of which are specified in **19.12** Part XI «Electrical Equipment».

Gas-dangerous machinery space means enclosed gas-dangerous space with gas fuel consumers, explosion safety of which in case of gas fuel leakage is ensured by emergency shutdown (ESD) of all machinery and equipment which may be an ignition source.

Gas-containing systems mean systems intended for storage, feed, supply and discharge of gas to ship consumers.

Gas engine means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

Dual fuel engine means a heat engine so designed that both gas and fuel oil may be used as fuel, simultaneously or separately.

Source of release means a point or location from which a gas, vapour, mist or liquid may be released into the atmosphere so that an explosive atmosphere could be formed.

Master gas fuel valve means an automatic valve installed at gas supply pipeline to each engine located outside machinery space where the equipment for gas fuel combustion is used.

Fuel storage tank means a tank designed as an initial gas fuel tank for storage on board the ship in liquid or compressed gaseous form.

CNG tank means compressed gas fuel storage tank.

LNG tank means liquefied gas fuel storage tank.

A , B and C type tanks mean independent fuel storage tanks complying with the requirements for A, B and C type independent tanks specified in the IGF Code.

ESD (*ESD/emergency shutdown*) – система аварійного відключення, завданням якої є зупинка потоку або витоку вантажу в надзвичайній ситуації, коли здійснюється передача рідкого вантажу або пари.

Enclosed space means any space inside of which, in the absence of mechanical ventilation, natural ventilation is restricted in such a way that any explosive atmosphere is not subject to natural dispersion.

Double block and bleed valve means a set of two valves in series in a pipe and a third valve enabling the pressure release from the pipe between those two valves. The arrangement may also consist of a two-way valve and a closing valve instead of three separate valves.

LNG means liquefied natural gas, consisting mainly of methane.

LPG eans liquefied petroleum gas consisting mainly of hydrocarbons (mixtures of propane and butane in any combination), which may contain small amounts of other components, such as hydrogen sulfide or alkyl lead.

CNG means compressed natural gas, consisting mainly of methane.

PRV/Pressure relief valve means pressure relief valve.

MARVS means maximum allowable releife valve setting of the cargo tank.

MAWP means the maximum allowable working pressure.

Filling Limit (Fl) means the maximum liquid volume in a fuel tank relative to the total tank volume when the liquid fuel has reached the reference temperature.

Membrane tanks are non-self-supporting tanks that consist of a thin liquid and gas tight layer (membrane) supported through insulation by the adjacent hull structure.

Semi-enclosed space means a space restricted by decks and bulkheads where natural ventilation is available but its efficiency sufficiently differs from normal at the weather deck.

Hazardous area means an area in which an explosive gas atmosphere or a flammable gas is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus.

Unacceptable loss of power means that it is not possible to sustain or restore normal operation of the propulsion machinery in the event of one of the essential auxiliaries becoming inoperative, in accordance with SOLAS regulation II-1/26.3.

Low-flashpoint fuel - gaseous or liquid fuel with a flash point lower than otherwise permitted by 2.1.1 Reg II-2/4 SOLAS 74 , as amended.

Gas fuel storage room means a room where gas fuel storage tanks are located.

Tank connection space means a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

Fuel preparation room means any space containing pumps, compressors or vaporizers for fuel preparation purposes.

Fuel oil means liquid hydrocarbon petroleum-derived fuel which complies with the requirements specified in **1.1.2**.

Design temperature for selection of materials s the minimum temperature at which liquefied gas fuel may be loaded or transported in the liquefied gas fuel tanks.

Vapour pressure means the equilibrium pressure of the saturated vapour above the liquid, in MPa, absolute at a specified temperature.

Fuel containment system means the arrangement for the storage of fuel including tank connection spaces.

The fuel containment system includes a primary and, where fitted, a secondary barriers, associated insulation and any intervening spaces, and adjacent structures, if necessary for the support of these elements. If the secondary barrier is part of the hull structure, it may be a boundary of the fuel storage hold space.

The spaces around the fuel tank are defined as follows:

.1 fuel storage hold space means a space enclosed by the ship's structures in which a fuel containment system is situated. If tank connection spaces are located in the fuel storage hold space, it will also be a tank connection space;

.2 interbarrier space means the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

.3 fuel storage tank connection space means a space surrounding all fuel storage tank connections and tank valves that are required for such tanks in enclosed spaces.

Gas consumer means any ship equipment using gas as a fuel.

Vapour pressure means the equilibrium pressure of the saturated vapour above the liquid, in MPa, absolute at a specified temperature.

Reference temperature means the temperature corresponding to the vapour pressure of the fuel in a fuel tank at the set pressure of the pressure relief valves (PRVs).

2.10.2 Onboard location of fuel storage tanks.

2.10.2.1 Fuel storage tanks both in liquefied (LNG) and compressed (CNG) condition may be located directly on the open deck of the ship or in special enclosed spaces in the ship's hull.

In the enclosed spaces, liquefied gas fuel shall be stored at the pressure not exceeding 1 MPa.

Where a fuel storage tank is located on the weather deck or in a special enclosure designed as a semienclosed space, provision shall be made for sufficient natural ventilation to prevent accumulation of escaped gas.

Membranes ensuring a seal between a deck and fuel storage tank shall be provided where the fuel storage tank gets through the upper weather deck. Therewith, the space located below the membranes may be considered as an enclosed gas-dangerous space, and the space above the membranes may be considered as an open space.

Gas fuel storage tanks shall not be installed under the survival craft except for the liferafts in compliance with **4.1.1.4**, Part II "Live-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

2.10.2.2 Fuel storage tanks shall be protected against mechanical damage.

When fuel is carried in a fuel containment system requiring a complete or partial secondary barrier:

.1 fuel storage hold spaces shall be segregated from the sea by a double bottom/inner bottom; and

.2 ship shall have longitudinal bulkheads forming side tanks.

2.10.2.3 The fuel storage tanks shall be protected from external damage caused by collision or grounding in the following way:

.1 fuel tanks shall be located at a minimum distance of B/5 or 11,5 m, whichever is less, measured inboard from the ship side at right angles to the centreline at the level of the summer load line draught. where B = the greatest moulded breadth of the ship at the summer load line draught) (refer to SOLAS regulation II-1/2.8). As an alternative, the calculation method specified in **5.3.4** of the IGF Code may be used to determine the acceptable location of fuel tanks;

.2 boundaries of each fuel tank shall be taken as the extreme outer longitudinal, transverse and vertical limits of the tank structure including its valves;

.3 for independent tanks the protective distance shall be measured to the tank shell (the primary barrier of the tank containment system). For membrane tanks, such distance shall be measured to the bulkheads surrounding the tank insulation;

.4 in no case shall the boundary of the fuel tank be located closer to the shell plating or aft terminal of the ship than as follows:

.4.1 for passenger ships: $B/10$ but in no case less than 0,8 m. However, this distance shall not be greater than $B/15$ or 2 m, whichever is less, where the shell plating is located inboard for $B/5$ or 11,5 m, whichever is less, as specified in **2.10.3.1**;

.4.2 for cargo ship:

.4.1.1 for $V_c \le 1000$ m^3- 0,8 m;

.4.2.2 for 1000м^3 < V_c < 5000 m^3- 0,75 + $V_c \times 0{,}2/4000$ m;

.4.2.3 for 5000м^3 ≤ V_c < 30000 m^3- 0,8 + V_c /25000 m; and

.4.2.4 for $V_c \ge 30000$ m^3 - 2 m,

where: V_c corresponds to 100 % of the gross design volume of the individual fuel storage tank at 20°C, including domes and appendages;

.4.5 the lowermost boundary of the fuel storage tank shall be located above the minimum distance of B/15 or 2,0 m, whichever is less, measured from the moulded line of the bottom shell plating at the centreline;

.4.6 for multi-hull ships, the value B may be specially considered;

.4.7 fuel storage tanks shall be located abaft a transverse plane at 0,08L measured from the forward perpendicular in accordance with SOLAS regulation II-1/8.1 for passenger ships, and abaft the collision bulkhead for cargo ships.

where: L - length as defined in the International Convention on Load Lines (refer to SOLAS regulation II-1/2.5).

2.10.3 Drip trays.

2.10.3.1 Drip trays for spilled liquefied gas shall be fitted where liquefied gas leakage may occur which can cause damage to the ship structure or where limitation of the area, which is effected from a spill, is necessary.

Drip trays for collection of leaks are necessary in the following cases:

.1 when the tank is located on the open deck, drip trays shall be provided to protect the deck from leakages from tank connections and other sources of leakage;

.2 when the tank is located below the open deck but the tank connections are on the open deck, drip trays shall be provided to protect the deck from leakages from tank connections and other sources of leakage;

.3 when the tank and the tank connections are located below the deck, all tank connections shall be located in a tank connection space. Drip trays in this case are not required.

2.10.3.2 Drip trays shall be made of suitable material.

2.10.3.3 The drip tray shall be thermally insulated from the ship's structure so that the surrounding hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid fuel.

2.10.3.4 Each drip tray shall be fitted with a drain valve to enable rain water to be discharged overboard.

2.10.3.5 Each drip tray shall have sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled.

2.10.4 Machinery spaces.

2.10.4.1 In order to minimize the probability of gas explosion in a machinery space containing gasfuelled machinery one of the following two alternatives of machinery space arrangement may be applied:

.1 **gas-safe machinery spaces**: arrangements in machinery spaces are such that the spaces are considered gas safe under all conditions, normal as well as unplanned conditions, i.e. inherently gas safe. In a gas-safe machinery space a single failure cannot lead to release of fuel gas into the machinery space;

.2 ESD protected machinery spaces: arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-safe equipment (ignition sources) and machinery shall be automatically executed while equipment or machinery in use or active during these conditions shall be of a certified safe type and have relevant certificates.

In an ESD protected machinery space, a single failure resulting in gas release into the space is allowable provided that the gas is removed by venting.

Failures leading to dangerous gas concentrations, e.g. gas pipe or gasket ruptures are covered by explosion pressure relief devices and ESD arrangements.

2.10.4.2 Requirements for gas-safe machinery spaces.

.1 single failure within the fuel system shall not lead to gas release into the machinery space;

.2 all gas piping within machinery space boundaries shall be enclosed in a gas tight enclosure.

2.10.4.3 Requirements for ESD protected machinery spaces.

.1 ESD protection shall be limited to machinery spaces that are intended for periodically unmanned operation.

.2 measures shall be applied to protect against explosion and damage of areas outside the machinery space and ensure redundancy of power supply.

At least the following measures and arrangements shall be provided:

gas detector;

shut-off valve;

redundancy;

efficient ventilation.

2.10.4.4 Gas supply piping without a gastight external enclosure within machinery spaces may be accepted under the following conditions:

.1 engines for generating propulsion power and electric power shall be located in two or more machinery spaces not having any common boundaries unless it can be documented that a single failure will not affect both spaces;

.2 gas machinery space shall contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function;

.3 fixed gas detection system arranged to automatically shutdown the gas supply, and disconnect all electrical equipment or installations not of a certified safe type, shall be fitted.

2.10.4.5 Distribution of engines between the different machinery spaces shall be such that shutdown of fuel supply to any one machinery space does not lead to an unacceptable loss of power.

2.10.4.6 ESD protected machinery spaces separated by a single adjacent bulkhead shall have sufficient strength to withstand the effects of local gas explosion in either space, without affecting the integrity of the adjacent space and equipment within that space.

2.10.4.7 ESD protected machinery spaces shall have a geometrical shape that will minimize the accumulation of gases or formation of gas pockets.

2.10.4.8 The ventilation system of ESD protected machinery spaces shall be arranged in accordance with **12.14**, Part VIII «Systems and piping».

2.10.4.9 Requirements for location and protection of fuel piping:

.1 fuel piping shall not be located less than 800 mm from the ship's side;

.2 fuel piping shall not pass directly through accommodation spaces, service spaces, electrical equipment rooms or control stations;

.3 fuel piping passing through ro-ro cargo spaces, special category spaces and on weather decks shall be protected against mechanical damage.

.4 gas fuel piping in ESD protected machinery spaces shall be located, as far as practicable, from the electrical installations and tanks containing flammable liquid.

2.10.4.10 Gas fuel piping in ESD protected machinery spaces shall be protected against mechanical damage.

2.10.4.11 Requirements for fuel preparation room design. Fuel preparation rooms shall be located on the open deck or within an open space unless those rooms are arranged and fitted in accordance with the requirements for tank connection spaces.

In such case, regardless of the room location the following requirements shall be complied with:

.1 fuel preparation room, regardless of location, shall be arranged to safely contain cryogenic leakages;

.2 material of the boundaries of the fuel preparation room shall have a design temperature corresponding with the lowest temperature it can be subjected to in a probable maximum leakage scenario unless the structures forming the boundaries of the space, i.e. bulkheads and decks, are provided with suitable thermal protection;

.3 a fuel preparation room shall be arranged to prevent surrounding hull structure from being exposed to unacceptable cooling, in case of leakage of cryogenic liquids;

.4 a fuel preparation room shall be designed to withstand the maximum pressure build up during such a leakage.

Alternatively, pressure relief venting to a safe location (mast) may be provided.

2.10.5 Requirements for bilge systems.

2.10.5.1 Bilge systems installed in areas where gas or other low-flashpoint fuels may be present shall comply woth the requirements of **7.15**, Part VIII «Systems and piping».

2.10.6 Requirements for arrangement of entrances and other openings in enclosed spaces.

2.10.6.1 Direct access shall not be permitted from a gas-safe area to a gas-dangerous area. Where such openings are necessary for operational reasons, an airlock, which complies with **2.10.7**, shall be provided.

2.10.6.2 If a fuel preparation room is approved to be located below deck, the room shall, as far as practicable, have an independent access directly from the open deck. Where a separate access from deck is not practicable, an airlock, which complies with the requirements of **2.10.7**, shall be provided.

2.10.6.3 Unless access to the tank connection space is independent and directly from the open deck, it shall be arranged as a bolted hatch. The space containing the bolted hatch is a hazardous space.

2.10.6.4 If access to an ESD protected machinery space is from another enclosed space of the ship, the entrances shall be arranged with an airlock, which complies with the requirements of **2.10.7**.

2.10.6.5 For inerted spaces, access arrangements shall be such that unintended entry by personnel shall be prevented. If access to such spaces is not from the open deck, sealing arrangements shall prevent leakages of inert gas to adjacent spaces.

2.10.7 Requirements for airlocks.

4.7.7.1 An airlock is a space enclosed by gastight bulkheads with two substantially gastight doors spaced at least 1,5 m and not more than 2,5 m apart.

Unless subject to the requirements of the International Convention on Load Lines, the door coaming shall not be less than 300 mm in height. The doors shall be self-closing without any holding back arrangements.

2.10.7.2 Airlocks shall be mechanically ventilated at overpressure relative to the adjacent hazardous area or space.

2.10.7.3 The airlock shall be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas-dangerous space separated by the airlock. The events shall be evaluated in the risk analysis according to **4.2.2.15**, Part I «Classification».

2.10.7.4 Airlocks shall have a simple geometrical form. They shall provide free and easy passage, and shall have a deck area not less than 1,5 m^2.

Airlocks shall not be used for other purposes, e.g. as store rooms.

2.10.7.5 An audible and visual alarm system to give a warning on both sides of the airlock shall be provided to indicate if more than one door is moved from the closed position.

2.10.7.6 For gas-safe spaces with access from hazardous spaces below deck where the access is protected by an airlock, upon loss of underpressure in the hazardous space access to the space shall be restricted until the ventilation is reinstated.

Audible and visual alarms shall be given at a manned location to indicate both loss of pressure and opening of the airlock doors when pressure is lost.

2.10.7.7 Essential equipment required for safety shall not be de-energized and shall be of a certified safe type. This may include lighting, fire detection, public address and general alarms systems.

2.10.8 Crew protection.

2.10.8.1 At least two sets of protective outfit, which ensures the safety of personnel when entering and working in spaces filled with natural gas, shall be provided on ships with gas containment system equipment installed in enclosed spaces of the hull.

2.10.8.2 Protective outfit, specified in **2.10.8.1**, shall include:

.1 air-breathing isolating apparatus with cylinders with a capacity of at least 1200l of free air;

.2 tightly fitted safety goggles, gloves, protective clothing and footwear made of spark-proof materials;

.3 steel core rescue line with intrinsically safe braid;

.4 explosion prof torch.

2.10.8.3 Breathing apparatus, specified in **2.10.8.2.1**, shall be fitted with filled air cylinders with a total capacity of at least 3600 liters of free air for each device.

2.10.8.4 The ship shall be provided with medicines and medical devices needed to provide first aid to victims of burns, frostbite (including cryogenic) and poisoning by natural gas or incomplete combustion products.

2.10.8.5 The ship shall be provided with the following operating documentation:

.1 instructions for gas fuel bunkering;

.2 instructions for inertization and degassing;

.3 instructions for the use of gaseous fuels;

.4 instructions describing the actions of the crew in emergencies that may occur during gas fuel operations.

2.10.8.6 The ship shall be provided with athe plan for periodic verifications and maintenance of equipment related to the use of gas as a fuel.

2.10.9 Design of gas fuel tanks.

2.10.9.1 General requirements for gas fuel storage.

2.10.9.1.1 Natural gas in a liquid state may be stored with a maximum allowable relief valve setting (MARVS) of up to 1,0 MPa.

2.10.9.1.2 The maximum allowable working pressure (MAWP) of the gas fuel tank shall not exceed 90 % of the maximum allowable relief valve setting (MARVS).

2.10.9.1.3 A fuel containment system located below deck shall be gastight towards adjacent spaces.

2.10.9.1.4 All tank connections, fittings, flanges and tank valves shall be enclosed in gastight tank connection spaces, unless the tank connections are on the open deck.

The space shall be able to contain leakage from the tank without overpressure in case of leakage from the tank connections.

A tank connection space may be required also for tanks on open deck for ships where restriction of hazardous areas is safety critical. A tank connection space may also be necessary in order to provide environmental protection for essential safety equipment related to the gas fuel system (tank valves, safety valves and instrumentation).

A tank connection space may also contain equipment such as vaporizers or heat exchangers. Such equipment is considered to only contain potential sources of release, but not sources of ignition. In such case, such a tank connection space shall not be considered as a fuel preparation room.

2.10.9.1.5 Pipe connections to the fuel storage tank shall be mounted above the highest liquid level in the tanks, except for fuel storage tanks of type C. Connections below the highest liquid level may, however, also be accepted for other tank types after special consideration.

2.10.9.1.6 Each gas fuel storage tank (LNG or CNG) shall be equipped with a remote operated isolation shutoff valve located at any piping connected to the tank or directly on the tank. A branch pipe between the tank and the isolation valve which release LNG in case of pipe failure shall have equivalent safety to the type

C tank, with permissible stress not exceeding the least of values $R_m/2,5$ or $R_e/1,2$, where R_e is a minimum yield stress at room temperature, and R_m is a minimum tensile strength at room temperature.

2.10.9.1.7 The material of the structures of the tank connection space shall have a design temperature corresponding to the lowest temperature that can be subject to in a probable maximum leakage scenario. The tank connection space shall be designed to withstand the maximum pressure build up during such a leakage. Alternatively, pressure relief venting to a safe location (mast) may be provided.

2.10.9.1.8 The probable maximum leakage into the tank connection space shall be determined based on design calculations using the operating parameters of detection and shutdown systems.

2.10.9.1.9 If connected below the liquid level of the tank, piping shall be protected by a secondary barrier up to the first valve.

2.10.9.1.10 If LNG tanks are located on the open deck, steel structures shall be protected against potential leakages from tank connections and other sources of leakage by use of drip trays.

The material shall have a design temperature corresponding to the temperature of fuel carried at atmospheric pressure.

The normal operation pressure of tanks shall be taken into consideration for protecting the steel structures of the ship.

2.10.9.1.11 Means shall be provided to safely empty liquefied gas storage tanks.

2.10.9.1.12 It shall be possible to empty, purge and vent fuel storage tanks with fuel piping systems. Instructions for carrying out these procedures shall be available on board.

Inerting shall be performed with inert gas prior to venting with dry air to avoid an explosion hazardous atmosphere in tanks and fuel pipelines. Requirements to the inerting system are specified in **12.15**, Part VIII «Systems and piping».

2.10.9.1.13 For single fuel (gas only) main engines at least two gas fuel storage tanks of approximately equal capacity shall be provided and they shall be located in separate spaces.

2.10.9.1.14 All fuel storage tanks shall be provided with a pressure relief system appropriate to the design of the fuel containment system and the fuel being carried.

Fuel storage hold spaces, interbarrier spaces, tank connection spaces and tank cofferdams, which may be subject to pressures beyond their design capabilities, shall also be provided with a suitable pressure relief system.

Pressure relief system shall be independent of the pressure control systems specified in **2.10.10**.

2.10.9.2 Liquefied gas storage tanks (LNG tanks).

2.10.9.2.1 LNG tanks shall be designed in compliance with the requirements of Section **6.4** of the IGF Code and manufactured by the firms having a Recognition Certificate for Manufacturer.

2.10.9.2.2 All LNG tanks shall be fitted with safety valves in compliance with the requirements specified in **6.7** of the IGF Code (refer also to **3.3.4**, Part VI "Systems and Piping" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk).

2.10.9.2.3 The outlets of vent pipes from the pressure relief valves shall be located at least $B/3$ or 6 m, whichever is greater, above the weather deck and 6 m above the working area and forward and aft gangways.

Gas outlet piping system shall be designed so that the outgoing gas shall be directed upwards and the possibility of water and snow ingress into the system shall be kept to minimum.

2.10.9.2.4 All gas outlets shall be located at a distance of at least 10 m from:

the nearest air inlet or openings in the accommodation and service spaces and control stations or from other gas-safe spaces;

outlets in the machinery space.

2.10.9.2.5 LNG tanks shall be provided with the pressure control system specified in **2.10.10**.

2.10.9.3 Compressed gas storage tanks (CNG tanks).

2.10.9.3.1 CNG tanks shall be designed in compliance with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels" or other applicable standards for design of gas storage pressure vessels agreed upon with the Administration.

Standard cylinders, for which it is necessary to make calculation of permitted pressure, and specially designed pressure vessels may be used as CNG tanks.

2.10.9.3.2 Each compressed gas storage tank shall be equipped with safety valves with cracking pressure less than design pressure of the tank.

Safety valves of CNG tanks located in the hull or on the open deck shall be connected with gas outlet pipes.

The outlets of vent pipes from the pressure relief valves shall comply with requirements specified in **2.10.9.2.3** and **2.10.9.2.4**.

2.10.9.3.3 Adequate means shall be provided to depressurize the tank in case of fire, which can affect the tank.

2.10.9.3.4 Storage of CNG in enclosed spaces is generally not acceptable, but may be permitted provided the following is fulfilled in addition to **2.10.9.1.4** and **2.10.9.1.6**:

.1 adequate means are provided to depressurize and inert the tank in case of fire which can affect the tank;

.2 all surfaces within such enclosed spaces containing the CNG storage are provided with suitable thermal protection against any high-pressure gas leakages and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

.3 a fixed fire-extinguishing system is installed in the enclosed spaces containing the CNG storage. In addition, special arrangements for extinguishing of jet-fires shall be provided.

2.10.9.3.5 CNG tanks shall be secured on the hull in a manner which will prevent their movement under static or dynamic loads. Tanks with supports shall be designed for a static angle of heel of 30°. The supports and fittings shall be designed with due regard to loads determined in accordance with **6.4.9.4** of the IGF Code.

2.10.9.4 Regulations for portable liquefied gas fuel tanks.

2.10.9.4.1 The design of the tank shall comply with the requirements of IGF Code for type C independent tanks. The tank support (container frame or truck chassis) shall be designed for the intended purpose.

2.10.9.4.2 Portable fuel tanks shall be located in dedicated areas fitted with:

.1 mechanical protection of the tanks depending on location and damage hazard during cargo operations;

.2 if located on open deck: spill protection and water spray and cooling systems; and

.3 if located in an enclosed space: the space shall be considered as a tank connection space.

2.10.9.4.3 Portable fuel tanks shall be secured to the deck when connected to the ship systems.

The arrangement for supporting and fixing the tanks shall be designed for the maximum expected static and dynamic inclinations, as well as the maximum expected values of acceleration, taking into account the ship characteristics and the position of the tanks.

2.10.9.4.4 Consideration shall be given to the strength and the effect of the portable fuel tanks on the ship's stability.

2.10.9.4.5 Connections to the ship's fuel piping systems shall be made by means of approved flexible hoses or other suitable means designed to provide sufficient flexibility.

2.10.9.4.6 Arrangements shall be provided to limit the quantity of fuel spilled in case of inadvertent disconnection or rupture of the non-permanent connections.

2.10.9.4.7 The pressure relief system of portable tanks shall be connected to a fixed venting system.

2.10.9.4.8 Control and monitoring systems for portable fuel tanks shall be integrated in the ship's control and monitoring system.

A safety system for portable fuel tanks shall be integrated in the ship's safety system (e.g. shutdown systems for tank valves, gas detection systems).

2.10.9.4.9 Safe access to tank connections for the purpose of inspection and maintenance shall be ensured.

2.10.10 Stored fuel pressure and temperature control system.

2.10.10.1 With the exception of liquefied gas fuel tanks designed to withstand the full gauge vapour pressure of the fuel under conditions of the upper ambient design temperature, liquefied gas fuel tanks' pressure and temperature shall be maintained at all times within their design range by one of the following methods:

.1 reliquefaction of vapours;

.2 thermal oxidation of vapours;

.3 pressure accumulation;

.4 liquefied gas fuel cooling.

The method chosen shall ensure maintaining tank pressure below the set pressure of the tank pressure relief valves for a period of 15 days assuming the full tank at normal service pressure and the ship in nonworking condition, i.e. only power for domestic load is generated.

2.10.10.2 The overall capacity of the system shall be such that it can control the pressure within the design conditions without venting to atmosphere. The system shall be sized in a sufficient way also in case of no or low consumption. Venting of fuel vapour for controlling the tank pressure is not acceptable except in emergencies.

LNG tanks' pressure and temperature shall be controlled and maintained within the design range at all times including after activation of the safety system required in **7.23.3** Part XI «Electrical Equipment» for a period of minimum 15 days.

The activation of the safety system alone is not deemed as an emergency situation.

2.10.10.3 For worldwide service, the upper ambient design temperature shall be 32°C for sea water and 45°C for air.

For service in particularly hot or cold zones, these design temperatures shall be increased or decreased as agreed upon with the Register.

2.10.10.4 The reliquefaction system shall be designed and calculated in one of the following ways:

.1 a direct system where evaporated fuel is compressed, condensed and returned to the fuel tanks;

.2 an indirect system where fuel or evaporated fuel is cooled or condensed by refrigerant without being compressed;

.3 a combined system where evaporated fuel is compressed and condensed in a fuel/refrigerant heat exchanger and returned to the fuel tanks; or

.4 if the reliquefaction system produces a waste stream containing methane during pressure control operations within the design conditions, these waste gases shall, as far as reasonably practicable, be disposed of without venting to atmosphere.

2.10.10.5 Thermal oxidation can be done by either consumption of the vapours according to the regulations for consumers specified in**2.10.10**, or in a dedicated gas combustion unit (GCU).

It shall be demonstrated that the capacity of the oxidation system is sufficient to consume the required quantity of vapours. In this regard, periods of slow steaming and no consumption from propulsion plant or other consumers of the ship shall be considered.

2.10.10.6 Refrigerants or auxiliary agents used for cooling of fuel shall be compatible with the fuel they may come in contact with (not causing any hazardous reaction or excessively corrosive products). In addition, when several refrigerants or agents are used, these shall be compatible with each other.

2.10.10.7 The redundancy of the system and its supporting auxiliary services shall be such that in case of a single failure (of mechanical non-static component or a component of the control system) the fuel tank pressure and temperature can be maintained by another system or service.

2.10.10.8 Heat exchangers that are necessary for maintaining the pressure and temperature of the fuel tanks within their design ranges shall have redundancy unless they have a capacity in excess of 25 % of the largest required capacity for pressure control and they can be repaired on board without external sources.

2.11 REQUIREMENTS FOR SHIP EQUIPMENT TO ENSURE LONG-TERM OPERATION AT LOW TEMPERATURE

2.11.1 Application.

2.11.1.1 The requirements of this Section apply to the main propulsion plants, responsible emergency and auxiliary machinery and systems ensuring safety of the crew and the ship intended for long-term operation at low temperatures.

For ships complying with the requirements of this Section a distinguishing mark **WINTERIZATION(DAT)** may be added to the character of classification at the shipowner's request. Design ambient temperature shall be indicated in brackets, for example: **WINTERIZATION(-40)** (refer to **2.2.30**, Part I «Classification»).

2.11.1.2 Definitions and explanations related to the general terminology of this part are given **1.2**.

For the purpose of this Section the following definitions, explanations and abbreviations have been adopted, which are also valid for Parts VIII «Systems and Piping» and IX «Machinery».

Open space is a space with a direct access to the open deck which is not fitted with closure or shall be kept open for long periods as regards operational conditions of equipment installed in this space.

Enclosed space is a space with a direct access to the open deck which is fitted with an appropriate closure.

Working liquids mean fuel and lubricating materials, and hydraulic oils, except for marine fuel, necessary for normal operation of a ship and its equipment.

Design ambient temperature (DAT) is the outside air temperature, in °C, used as the criterion for selection and testing of materials and equipment subject to low temperatures.

Design temperature of the structure is the temperature, in °C, assumed for choosing of construction material. When the Rules or this Section contain no additional provisions, the design ambient temperature is assumed as a design temperature of the structure.

2.11.1.3 Design temperatures.

.1 Design ambient temperature value is established by the shipowner according to the ship purpose and service conditions.

.2 The following standard values of design ambient temperature are stipulated by this Section:

-30°C (the distinguishing mark **WINTERIZATION(-30)**);

- 40°C (the distinguishing mark **WINTERIZATION(-40)**);

-50°C (the distinguishing mark **WINTERIZATION(-50)**).

Application of this requirements for design ambient temperatures above -30°C and intermediate values shall be determined by the Register upon agreement with the shipowner.

.3 Design ambient temperature shall not be assumed above the temperature specified in 1.2.3.3 of Part II "Hull" for the appropriate ice class.

.4 For equipment and machinery installed on the open decks, as well as in the open spaces, the design ambient temperature shall be assumed as design temperature of structures.

For equipment and machinery installed in unheated enclosed spaces exposed to the environment and adjoining unheated adjacent enclosed spaces the design ambient temperature shall be assumed as the design temperature.

For equipment and machinery installed in unheated enclosed spaces exposed to the environment and adjoining heated adjacent enclosed spaces the temperature of 20°C above the design ambient temperature shall be assumed as the design temperature of structure.

2.11.2 Machinery installations.

2.11.2.1 Propulsion plants of ice class ships with distinguishing marks **WINTERI-ZATION(-30)**, **WINTERIZATION(-40)** and **WINTERIZATION(-50)** shall be capable of maintaining rated power and required rated torque at propeller shafts in a range of rotation speed corresponding to the appropriate operating conditions and modes in accordance with the assigned ice class.

2.11.2.2 Means shall be provided to ensure that machinery may be brought into operation from the dead ship condition without external aid, as well as storage and supply of fuel to the emergency diesel-generator with pour point temperature being 5°C lower than design ambient temperature indicated in brackets of the distinguishing mark **WINTERIZATION(DAT)**.

As an alternative, self-contained portable arrangements may be provided on board to ensure that machinery may be brought into operation from the dead ship condition.

2.11.2.3 Based on their design, the machinery, shafting, boilers and other pressure vessels, as well as pipelines of systems and fittings, shall remain operative during the ship stay at design ambient temperature.

2.11.2.4 Onboard the ships with distinguishing marks **WINTERIZATION(-40)** and **WINTERIZATION(-50)** air supply to main engines shall not lead to overcooling of machinery space.

Technical means shall be provided to exclude increase of mechanical load on cylinders and pistons and bearings of main engines due to the harmful effect of reduced temperatures of scavenging air.

2.11.2.5 When environmentally hazardous refrigerants are used, the sterntube seals shall be so designed as to prevent leakage out of the seal housing when operated within the specified modes. Permissible leakage of non-toxic and biologically neutral refrigerants are not considered as pollution from ships.

2.11.2.6 Technical means shall be provided for complete shaft line turning during the ship stay in close floating ice.

2.11.2.7 In general, at least two auxiliary boilers shall be provided onboard the ships with distinguishing marks **WINTERIZATION(-40)** and **WINTERIZATION(-50)**.

2.11.2.8 In general, steel four-bladed propellers with detachable blades shall be used.

2.11.2.9 Ships shall be provided with technical means for replacing defective blades afloat.

3. CONTROL DEVICES AND STATIONS. MEANS OF COMMUNICATION

3.1 CONTROL DEVICES

3.1.1 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.

control systems essential for the propulsion, control and safety of the ship shall be independent or so designed that failure of one of them does not degrade the performance of another.

3.1.2 The starting and reversing arrangements shall be so designed and placed that each engine can be started or reversed by one operator.

3.1.3 Proper working direction of control handles or handwheels shall be clearly indicated by arrows and relevant inscriptions.

3.1.4 The setting of manoeuvring handle in the direction from, or to the right of, the operator, or turning the handwheel clockwise, when controlling the main engines from the navigation bridge, shall correspond to the ahead speed direction of the ship.

In the case of control stations, from which only the stern is visible, such a setting shall correspond to the direction of astern speed of the ship.

3.1.5 Control arrangements shall be so designed as to eliminate the possibility of spontaneously changing the positions prescribed..

3.1.6 The control devices of main engines shall have an interlocking system to preclude starting of the main engine, with a mechanical shaft-turning gear engaged.

3.1.7 It is recommended to provide an interlocking system between the engine-room telegraph and the reversing and starting arrangements so as to prevent the engine from running in the direction opposite to the prescribed one.

3.1.8 The main engine remote control system, with control from the bridge, shall be designed so as to provide an alarm in the event of failure.

As far as practicable, the present propeller speed and thrust direction shall remain unchanged until control is transferred to a local station.

Among other factors, the loss of power supply (electric, pneumatic or hydraulic power) shall not substantially affect the power of main engines or change the direction of propeller rotation.

3.1.9 The propulsion machinery remote control system with control from the wheel house shall be independent from the other order transmission system; however, one manoeuvring handle for systems may be accepted.

3.1.10 It shall be possible to control the propulsion machinery from the local control station, in the event of a failure of any unit of the remote control system.

3.1.11 For ships of river-sea navigation the duration of reversing (a period of time from the reversing of a steering control to the beginning of propeller operation with a thrust opposite in direction) shall not exceed:

25 s at full speed;

15 s at slow speed;

depending on the ship's speed.

3.1.12 Operation of auxiliary machinery required for the movement and safety of the ship, by means located on/or near such machinery shall be provided.

3.2 CONTROL STATIONS

3.2.1 The bridge control stations of main engines and propellers, as well as the main machinery control room, with any type of remote control, shall be equipped with:

.1 controls for the operation of main engines and propellers.

For installations comprising CP-propellers, vertical axis and similar type propellers, the navigation bridge may be equipped with means for remote control of propellers only. In such case, the alarm for low pressure of starting air, prescribed by 3.2.1.10, need not be provided;

.2 shaft speed and direction indicators if a fixed pitch propeller is installed; shaft speed and blade position indicators if the controllable pitch propeller is installed; main engines speed indicator if the disengaging coupling is provided;

.3 indicating means to show that the main machinery and remote control systems are ready for operation;

.4 indicating means to show which station is in control of the main propulsion machinery;

.5 means of communication (refer to **3.3**);

.6 main engine emergency stop device, independent of the control system. If disengaging couplings are provided for disconnection of main machinery from propellers, it is permissible that emergency shut-off of these couplings only is effected from the navigation bridge;

.7 device to override the automatic protection covering full range of parameters except those parameters which being exceeded, may result in serious damage, complete failure or explosion;

.8 indication for the override operation, alarms for activation of protection devices and the emergency stop;

.9 alarm for minimum oil pressure in pitch control system; overload alarm where the main engine operates with a CP-propeller, unless the recommendation of **6.5.3** is fulfilled;

.10 alarm for low starting air pressure, set at a level which still permits three starting attempts of reversible main engines duly prepared for operation;

.11 device to remote shut-off fuel oil supply to each engine for multi-engine installations in case where the fuel oil is supplied to all the engines from a single supply source (refer to **13.8.3.2**, Part VIII "Systems and Piping");

.12 speed repeater (with due regard to **3.7.3.6**, Part V "Navigational Equipment" of the Rules for the Equipment of Sea-Going Ships).

3.2.2 The control stations on the wings of navigation bridge shall be equipped with devices of waterproof construction with controlled illumination.

The control stations provided on the wings of the navigation bridge need not meet the requirements of **3.2.1.3**, **3.2.1.5**, **3.2.1.7 – 3.2.1.10**.

3.2.3 The emergency stop devices of main engine and the overrides of automatic controls shall be so constructed that inadvertent operation of such devices is not possible.

3.2.4 For the installations which consist of several main engines driving a single shafting, there shall be provided a common control station.

3.2.5 With a remote control system in use, provision shall also be made for local control stations of main machinery and propellers.

Where, however, mechnaical linkage is fitted for remote-controlling the main engine, the local control stations may be dispensed with on agreement with the Register.

3.2.6 Remote control of main machinery and propellers shall be performed only from one location.

The transfer of control between the navigation bridge and engine room shall be possible only in the engine room and the main machinery control room.

The means of transfer shall be so designed as to prevent the propelling thrust from altering significantly.

Where the control stations are arranged on the wings of navigation bridge, the remote control of the main machinery shall be possible from one control station only. Such control stations may be equipped with interconnected controls.

3.2.7 Main engines shall be remotely operated from the wheelhouse by means of a single control element per propeller. In installations with CP-propellers, systems with two control elements may be used.

3.2.8 The sequence of the main engine operation modes assigned from the wheelhouse, including reversal from the full ahead speed in case of emergency, shall be controlled with the time intervals admissible for main engines. The modes assigned shall be indicated at the main machinery control room and at the local control stations of the main machinery.

3.2.9 Main machinery control rooms of floating docks shall comprise the following equipment:

.1 controls of the pumps, including the suction and overboard discharge valves of ballast system;

.2 recording devices for heel, trim and deflection control of the dock;

.3 signals indicating the operation of pumps and the position ("open", "closed") of suction and discharge valves of the ballast system;

.4 alarms on limit values of list and trim;

.5 water level indicators of ballast compartments;

.6 dock's communication facilities.

3.2.10 CCR shall be located as far from the machinery spaces as practicable. Onboard the tankers the CCR shall be arranged according to **2.4.9**, Part VI "Fire Protection".

Furthermore, arrangement of CCR onboard chemical tankers shall comply with the requirements of Section 3, Part II "Structure of Chemical Tanker" of the Rules for the Classification and Construction of Chemical Tankers, and for gas carriers - the requirements of Section **9**, Part VI "Systems and Pipelines" of the Rules for the Classification and Construction of Gas Carriers.

3.2.11 If CCR is provided on board the ship with assigning the distinguishing mark CCO (refer to **2.2.19**, Part I "Classification") added to the character of classification, besides compliance with the requirements of **3.2.10**, CCR shall be equipped with:

.1 means of communication according to **3.3.2**;

.2 control means of:

.2.1 cargo, stripping and ballast pumps;

.2.2 fans servicing cargo area spaces or cargo holds;

.2.3 remotely controlled valves of cargo and ballast systems;

.2.4 hydraulic system pumps (if provided);

.2.5 inert gas system;

.2.6 pumps and valves of heeling system (if provided);

.3 means for monitoring of:

.3.1 pressure in cargo manifolds;

.3.2 pressure in the manifold for vapour emission system (if provided);

.3.3 temperature in cargo and settling tanks;

.3.4 temperature and pressure of warming medium in the cargo heating system;

.3.5 actual value of ship's heel, trim and draught;

.3.6 actual value of level in the cargo and ballast tanks;

.4 larm devices on:

.4.1 fire alarm;

.4.2 exceeding of cargo temperature in cargo holds;

.4.3 high and low levels in cargo, ballast and settling tanks;

.4.4 extreme high level in cargo tanks;

.4.5 exceeding of permissible pressure in cargo manifolds of vapour emission system (80 per cent of pressure for actuating of high-velocity devices);

.4.6 exceeding the permissible fuel oil content in the discharge ballast and flushing water;

.4.7 exceeding the permissible temperature of pump casing according to **5.2.6**, Part IX "Machinery";

.4.8 increasing of gland and bearing temperature at bulkhead penetrations of pump shafts as per **4.2.5**;

.4.9 availability of cargo in segregated ballast tanks (for chemical tankers);

.4.10 increasing of level in the bilgeways of cargo pump rooms;

.4.11 parameters of inert gas system in compliance with **9.16.7.6**, Part VIII "Systems and Piping";

.4.12 status of technical aids stipulated in **3.2.10**;

.4.13 low water level in deck water seal (refer to **9.16.5**, Part VIII "Systems and Piping");

3.2.12 In ships carrying liquid gas in bulk, means for monitoring and alarm shall be additionally provided in CCR to meet the requirement of Part VIII "Instrumentation" of the Rules for the Classification and Construction of Gas Carriers.

3.2.13 In ships carrying dangerous chemical cargo in bulk, the signalling shall be additionally provided in CCR to meet the requirements of **6.6**, Part VIII "Instrumentation" of the Rules for the Classification and Construction of Chemical Tankers.

3.2.14 If the main and other related machinery, including the main sources of power supply, have different degrees of automatic or remote control and are constantly supervised from the central control room, then the arrangements and controls shall be designed, fitted and installed so that the operation of the machinery was as safe and reliable as with direct control.

Particular attention shall be paid to protecting such spaces from fire and flooding.

3.3 MEANS OF COMMUNICATION

3.3.1 At least two independent means shall be provided for communicating orders from the navigation bridge to the position in the machinery space or in the control room, from which the speed and direction of thrust of the propellers are normally controlled.

One of these shall be an engine-room telegraph, which provides visual indication of the orders and responses both in the machinery spaces and on the navigation bridge and which is fitted with a sound signal clearly audible in any part of the engine room while the machinery is at work, and distinct in tone from all other signals in the machinery space (refer also to **7.1**, Part XI "Electrical Equipment").

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

A single voice-communication device serving two control stations located in close proximity is permissible.

3.3.2 Two-way communication shall be provided between the engine room, auxiliary machinery spaces and boiler room. Onboard the ships equipped with CCR, two-way communication between CCR and navigation bridge, between CCR and the spaces, where cargo and ballast pumps are located, shall be additionally provided.

3.3.3 When installing a voice-communication device, measures shall be taken to ensure clear audibility, with the machinery at work.

3.3.4 Main machinery control rooms of floating docks shall have means of communication in accordance with 19.8, Part XI "Electrical Equipment".

3.3.5 In the case of ships with twin hulls, provision shall be made for voice communication between local control stations of the hulls in addition to communication between local control stations and the common control station in the wheelhouse and the main machinery control room.

4. MACHINERY SPACES, ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.1 GENERAL

4.1.1 Ventilation of machinery spaces shall comply with the requirements of 12.5, Part VIII "Systems and Piping".

4.1.2 Machinery spaces with gas engines shall be fitted with gas concentration sensors and the ultimate concentration level alarm system (refer to **7.23**, Part XI «Electrical equipment».

4.1.3 The ventilation of machinery spaces shall be sufficient under normal conditions of ship operation to prevent accumulation of oil product vapour.

4.1.4 All moving parts of machinery, units, equipment and drives that can cause harm to service personnel and other persons onboard shall be fenced with handrails or enclosures.

Internal combustion engines equipped with safety valves of appropriate type for prevention of explosion in crankcase shall be equipped with appropriate means that direct the exhaust through the valves, which ensures minimum possibility of injuries to personnel.

4.1.5 Appropriate means shall be provided in ships for reducing noise down to the acceptable level in accordance with **8.9**, Part III, “Equipment, Arrangements and Outfit”.

4.2 ARRANGEMENT OF MACHINERY AND EQUIPMENT

4.2.1 Engines, boilers, equipment, pipes and valves shall be so arranged as to provide easy access for servicing and repair; the requirements stated in **4.5.3** shall also be met.

4.2.2 The arrangement of boilers shall be such that the distance between boilers and fuel tanks is sufficient for a free circulation of air necessary to keep the temperature of the fuel in the tanks below its flash point except as mentioned in **13.3.5**, Part VIII "Systems and Piping".

4.2.3 Where auxiliary boilers design installed in the same space with the internal combustion engines will not initiate sparks if flame is accidentally blown out from the furnace, their furnaces shall have metallic screens or other arrangements to protect the equipment of that space if flame is accidentally blown out from the furnace.

4.2.4 The auxiliary oil-fired boilers installed on platforms or on ’tween decks in non-watertight enclosures shall be protected by oil-tight coamings at least 200 mm in height.

4.2.5 Driving machinery of the pumps and fans in the cargo pump rooms of oil tankers, combination carriers designed for the carriage of oil products with a flash point 60 8C or less and of oil recovery vessels shall be installed in spaces fitted with mechanical ventilation and having no exits leading to the cargo pump rooms.

Driving machinery of the submerged pumps are allowed to be installed in the open deck, provided their design and location comply with the applicable requirements of **19.2.4.1.4** and **19.2.4.9** Part XI "Electrical Equipment".

Steam engines with working temperatures not exceeding 220°C and hydraulic motors may be installed in cargo pump rooms.

Drive shafts of pumps and fans shall be carried through bulkheads or decks in gastight sealing glands supplied with effective lubrication from outside the pump room. As far as practicable, the construction of sealing gland shall protect it against being overheated.

Those parts of gland, which may come in contact in case of eventual disalignment of drive shaft, or damage to the bearings, shall be made of such materials, which will not initiate sparks.

If bellows are incorporated in the design, they shall be subjected to test pressure before fitting.

Cargo pumps, ballast pumps and stripping pumps, installed in cargo pump-rooms, as well as in ballast pump-rooms where cargo containing equipment is fitted, and driven by shafts passing through pump-room bulkheads shall be fitted with temperature sensing devices for bulkhead shaft glands, bearings and pump cassings.

Alarm shall be initiated in the cargo control room or the pump control station.

4.2.6 Air compressors shall be installed in such places where air is least contaminated by vapours of combustible liquids.

4.2.7 Fuel oil units (refer to **1.2**) as well as hydraulic units containing flammable liquids with working pressure above 1,5 MPa and not being a part of main and auxiliary engines, boilers, etc., shall be placed in a separate rooms with self-closing steel doors.

If it is impracticable to locate the main components of such units and systems in a separate space, special consideration shall be given with regard to shielding of the components and location, containment of possible leakages.

4.2.8 Requirements for the arrangement of emergency diesel-generators are outlined in **9.2**, Part XI "Electrical Equipment".

4.2.9 In oil recovery ships, the internal combustion engines, boilers and equipment containing sources of ignition as well as relevant air inlets shall be installed in intrinsically safe spaces (refer to **19.2**, Part XI "Electrical Equipment").

4.2.10 A blowdown gas caps fitted with gas fuel leakage detectors shall be installed above the dualfuel internal combustion engines (refer to **9.1**, Part IX "Machinery").

4.3 ARRANGEMENT OF FUEL OIL TANKS

4.3.1 In general, fuel oil tanks shall be part of the ship's structure and shall 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, their surfaces in machinery spaces shall be kept to a minimum and shall preferably have a common boundary with the double bottom tanks.

Where such tanks are situated within the boundaries of machinery spaces of category A, they shall not contain fuel oil having flash point less than 60°C. In general, the use of free standing fuel oil tanks shall be avoided.

Service fuel oil tanks shall comply with the requirements of **13.8.1**, Part VIII "Systems and Piping".

4.3.2 Where the use of free standing fuel oil tanks is permitted by the Register, they shall be placed in oil-tight spill trays, and on passenger ships and special purpose ships carrying more than 50 special personnel, outside machinery spaces of category A as well.

4.3.3 Fuel oil tanks located in the machinery space shall not be located immediately above the machinery and equipment with surface temperature under insulation over 220°C, boilers, internal combustion engines, electrical equipment and, as far as practicable, shall be arranged far apart therefrom.

4.3.4 The arrangement of fuel oil and oil tanks of tankers in way of accommodation, service and refrigerated spaces is permitted, provided they are separated by cofferdams (dimensions and structure of cofferdams - refer to **2.7.5.2**, Part II "Hull") or subject to the adoption of other special measures aimed at preventing fuel, oils and their vapours from reaching the specified spaces.

When tanks of fuel and oils of other types of ships are located in way of accommodation, service and refrigerated spaces, the cofferdams are recommended for separating them.

The manholes of the cofferdams and tanks for fuel and oils, as well as detachable joints of the fuel and oil tanks piping in accommodation and service spaces are not allowed.

4.4 INSTALLATION OF MACHINERY AND EQUIPMENT

4.4.1 The machinery and equipment constituting the propulsion plant shall be installed on strong and rigid seatings and securely attached thereto.

The construction of the seatings shall comply with the requirements of **2.11**, Part II "Hull".

4.4.2 Boilers shall be installed on bearers in such a way that their welded joints do not rest on the bearer supports.

4.4.3 To prevent shifting of boilers, provision shall be made for efficient stops and securing for rough sea; thermal expansion of boiler structures shall be taken into account.

4.4.4 The main engines, their gears, thrust bearings of shafts shall be secured to seatings with fitted bolts throughout or in part. The bolts may be omitted, if appropriate stops or other means providing reliable protection of equipment from displacement are provided. Where necessary, fitted bolts shall be used to fasten auxiliary machinery to seatings.

4.4.5 The bolts securing the main and auxiliary machinery and shaft bearings to their seatings, end nuts of shafts as well as bolts connecting the lengths of shafting shall be fitted with appropriate lockers against spontaneous loosening.

4.4.6 Where the machinery shall be mounted on shock absorbers, the design of the latter shall be approved by the Register.

Shock absorbing fastenings of the machinery and equipment shall:

maintain vibration-proof insulation properties when the absorbed machinery and equipment are operated in the environmental conditions as per the requirement of **2.3.1**;

be resistant to the corrosive mediums, temperature and various kinds of radiation;

be equipped with the yielding grounding jumper of sufficient length to prevent radio reception interference and comply with the requirements of safety engineering;

eliminate the interference for operation of other equipment, devices and systems.

4.4.7 In case of installation of machinery, mechanical equipment, ship arrangements and their components on plastic pads or their assembly with the use of polymeric materials, their technology shall be submitted to the Register for approval. Polymeric materials used for the pads and assembly shall be agreed with the Register (refer to Section **6**, Part XIII "Materials").

4.4.8 The machinery with horizontal arrangement of the shaft shall be installed parallel to the centre line of the ship. Installing such machinery in any other direction is permitted if the construction of machinery provides for operation under the conditions specified in **2.3**.

4.4.9 The machinery for driving generators shall be mounted on the same seatings as the generators

4.5 MEANS OF ESCAPE FROM MACHINERY SPACES

4.5.1 Means of escape from machinery spaces, including ladders, corridors, doors and hatches, shall, if not expressly provided otherwise, provide safe escape to the lifeboat and liferaft embarkation decks.

4.5.2 All the doors as well as the covers of companionways and skylights, which may serve as means of escape from machinery spaces, shall permit of opening and closing both from inside and outside. The covers of companionways and skylights shall be marked, as appropriate, and bear a clear inscription prohibiting to stow any loads on them.

Lifts shall not be considered as forming one of the means of escape.

4.5.3 The main and auxiliary machinery shall be so arranged as to provide passageways from the control stations and servicing flats to the means of escape from the machinery spaces. The width of passageways shall not be less than 600 mm over the whole length. In ships of less than 1000 gross tonnage the width of passageways may be reduced to 500 mm. The width of passageways along the switchboards shall comply with the requirements of 4.6.7, Part XI "Electrical Equipment".

4.5.4 The width of ladders serving as escape routes and the width of doors providing access to embarkation decks shall be at least 600 mm. The width of ladders in ships of less than 1000 gross tonnage may be reduced to 500 mm.

4.5.5 In a passenger ship, each machinery space located below the bulkhead deck shall be provided with at least two means of escape, which shall comply with the requirements of either **4.5.5.1** or **4.5.5.2**, as follows:

.1 the means of escape shall consist of two sets of steel ladders as widely separated as possible, leading to doors (hatches) in the upper part of the space similarly separated and satisfying the requirements of **4.5.1**. One of these ladders shall be located within a protected enclosure that satisfies the requirements of 2.1.4.5, Part VI "Fire Protection", from the lower part of the space 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 the heat is not transferred into the enclosure through non-insulated fixing points. The protected enclosure shall have minimum internal dimensions of at least 800x800 mm, and shall have emergency lighting provisions, and a vertical ladder, complying with requirements of **8.5.4.4** Part III «Equipment, arrangements and outfit».

Notes: 1. A "safe position" can be any space, excluding lockers and storerooms irrespective of their area, cargo spaces and spaces where flammable liquids are stowed, but including special category spaces and ro-ro spaces, from which access is provided and maintained clear of obstacles to the decks according to **4.5.1** (categories of ship's spaces (refer to Chapter **1.5**, Part VI "Fire protection")).

2. Machinery spaces may include working platforms and passageways, or intermediate decks at more than one deck level. In such case, the lower part of the space shall be regarded as the lowest deck level, platform or passageway within the space. At deck levels, other than the lowest one, where only one means of escape other than the protected enclosure is provided, selfclosing fire doors shall be fitted in the protected enclosure at that deck level. Smaller working platforms in-between deck levels, or only for access to equipment or components, need not be provided with two means of escape.

3. A protected enclosure providing escape from machinery spaces to an open deck may be fitted with a hatch as means of egress from the enclosure to the open deck. The hatch shall have minimum internal dimensions of 800 mm x 800 mm.

4. Internal dimensions (refer to Note 3) shall be interpreted as clear width, so that a passage having diameter of 800 mm is available throughout the vertical enclosure, as shown in Fig. 4.5.5, clear of ship's structure, with insulation and equipment, if any. The ladder within the enclosure can be included in the internal dimensions of the enclosure. When protected enclosures include horizontal portions their clear width shall not be less than 600 mm (refer to Fig. 4.5.5).

.2 the means of escape shall consist of one steel ladder leading to a door (hatch) in the upper part of the space and satisfying the requirements of **4.5.1** and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space in accordance with **4.5.1**.

.3 all inclined ladders/stairways with open treads fitted to comply with **4.5.5.1** and **4.5.5.2** in machinery spaces being part of or providing access to escape routes but not located within a protected enclosure shall be made of steel.

Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

Note. Inclined ladders/stairways in machinery spaces being part of, or providing access to, escape routes but not located within a protected enclosure shall not have an inclination greater than 608 and shall not be less than 600 mm in clear width.

Such requirement need not be applied to ladders/stairways not forming part of an escape route, only provided for access to equipment or components, or similar areas, from one of the main platforms or deck levels within the spaces subject to requirements **4.5.5**.

4.5.6 Where the machinery spaces in passenger ships are above the bulkhead deck, two means of escape shall be provided, which shall be as widely separated as possible, and the doors (hatches) leading from such means of escape shall be in a position satisfying the requirements of **4.5.1**. Where such means of escape require the use of ladders, these shall be of steel.

4.5.7 In passenger ships of less than 1000 gross tonnage, the Register may dispense with one of the means of escape from the spaces specified in **4.5.5** and **4.5.6**, due regard being paid to the width and disposition of the upper part of the space. In ships of 1000 gross tonnage and above, the Register may dispense with one means of escape from the above mentioned spaces, including a normally unattended auxiliary machinery space, so long as the provisions of **4.5.1** are satisfied, due regard being paid to the nature of the space and whether persons are normally absent in that space.

In ships of restricted navigation areas **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, D-R3-RS The Rregister may allow only one way of escape route from machinery space in such cases:

in ships of less than 24 meters in length, taking into account the width and location of the upper part of the space;

in ships of 24 meters in length and over, provided that the door or steel ladder provides a safe escape route to the lifeboat deck, and taking into account the number of people normally working in the space.

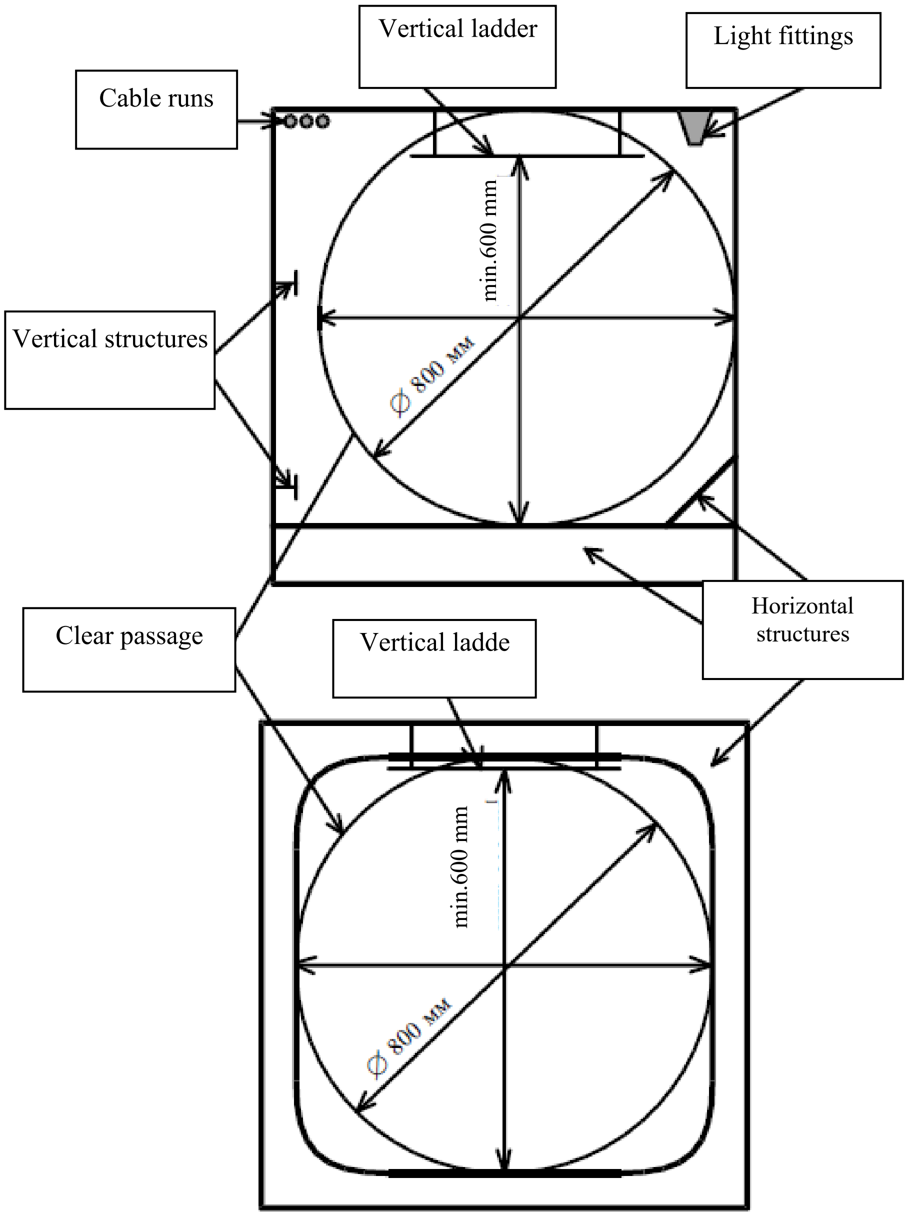


Fig. 4.5.5 An example of a possible exit through the hatch, taking into account the minimum internal clear dimensions

4.5.8 The second means of escape shall be provided from the steering gear space when the emergency steering position is located in this space unless there is a direct access to the open deck.

Note: The local steering position located in the steering gear space is considered to be an emergency steering position if a separate emergency steering position is not provided outside steering gear.

4.5.9 On passenger ships two means of escape shall be provided from the main machinery control room and 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.

4.5.10 In a cargo ship, at least two means of escape shall be provided from each machinery space of category A, which shall comply with the requirements of either **4.5.10.1**, or **4.5.10.2**, as follows:

.1 the means of escape shall consist of two sets of steel ladders as widely separated as possible leading to doors (hatches), from which access is provided to the open deck. One of these means of escape shall be located within a protected enclosure that satisfies the requirements of **2.1.4.5**, Part VI "Fire Protection", from the lower part of the space 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 800x800 mm, and shall have emergency lighting provisions, and a vertical ladder, complying with requirements of **8.5.4.4** Part III «Equipment, arrangements and outfit».

Notes: 1. A "safe position" can be any space, excluding cargo spaces, lockers and storerooms irrespective of their area, cargo pump-rooms and spaces where flammable liquids are stowed, but including vehicle and ro-ro spaces, from which access is provided and maintained clear of obstacles to the open deck in accordance with **4.5.1** (categories of ship's spaces (refer to **1.5.4.3** and **1.5.4.4**, Part VI "Fire Protection")).

2. Machinery spaces of category A may include working platforms and passageways, or intermediate decks at more than one deck level. In such case, the lower part of the space shall be regarded as the lowest deck level, platform or passageway within the space.

At deck levels, other than the lowest one, where only one means of escape other than the protected enclosure is provided, self-closing fire doors shall be fitted in the protected enclosure at that deck level.

Smaller working platforms in-between deck levels, or only for access to equipment or components, need not be provided with two means of escape.

3. A protected enclosure providing escape from machinery spaces to an open deck may be fitted with a hatch as means of egress from the enclosure to the open deck. The hatch shall have minimum internal dimensions of 800 mm x 800 mm.

4. Internal dimensions (refer to Note 3) shall be interpreted as clear width, so that a passage having diameter of 800 mm is available throughout the vertical enclosure, as shown in Fig. 4.5.5, clear of ship's structure, with insulation and equipment, if any. The ladder within the enclosure can be included in the internal dimensions of the enclosure. When protected enclosures include horizontal portions their clear width shall not be less than 600 mm (refer to Fig. 4.5.5).

.2 the means of escape shall consist of one steel ladder leading to a door (hatch) in the upper part of the space, from which access is provided to the open deck and, additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

.3 all inclined ladders/stairways with open treads fitted to comply with **4.5.10.1** and **4.5.10.2** in machinery spaces of category A being part of or providing access to means of escape but not located within a protected enclosure shall be made of steel. Such ladders/stairways shall be fitted with steel shields attached to their undersides, such as to provide escaping personnel protection against heat and flame from beneath.

Note. Inclined ladders/stairways in machinery spaces being part of, or providing access to, escape routes but not located within a protected enclosure shall not have an inclination greater than 608 and shall not be less than 600 mm in clear width. Such requirement need not be applied to ladders/stairways not forming part of an escape route, only provided for access to equipment or components, or similar areas, from one of the main platforms or deck levels within the spaces (refer to requirements of **4.5.10**;

.4 two means of escape shall be provided from the main machinery control room and 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.

4.5.11 In fishing vessels of more than 1000 gross tonnage one means of escape from machinery spaces of category A may be provided on the condition that it leads directly onto the open deck, the spaces are entered only periodically and the maximum travel distance to the door (hatch) leading directly onto open deck from the control stations of the equipment located in the space is 5 m or less.

In cargo ships of less than 1000 gross tonnage, the Register may dispense with one of the means of escape from machinery spaces of category A, due regard being paid to the dimension and disposition of the upper part of the space. In addition, the means of escape in these ships need not comply with the requirements for an enclosure listed in paragraph **4.5.10.1**.

4.5.12 From each machinery space other than that of category A, at least two escape routes shall be provided except for spaces that are entered only occasionally, and for spaces where the maximum travel distance to the door (hatch) is 5 m or less.

Note: The travel distance shall be measured from any point normally accessible to the crew, taking into account machinery and equipment within the space.

4.5.13 In addition to the requirements of **4.5.12**, the steering gear space of a cargo ship shall comply with the following requirements:

.1 steering gear spaces which do not contain the emergency steering position need only have one means of escape;

Note: The local steering position is considered to be an emergency steering position if a separate emergency steering position is not provided.

.2 steering gear spaces containing the emergency steering position can have one means of escape provided it leads directly onto the open deck.

Otherwise, two means of escape shall be provided but they do not need to lead directly onto the open deck;

.3 escape routes that pass only through stairways and/or corridors are considered as providing "direct access to the open deck" if outside the steering gear spaces they have continuous fire shelter equivalent to steering gear spaces or stairways and corridors, whichever is greater.

4.5.14 The escape routes from shaft tunnels and pipe ducts shall be enclosed in watertight trunks carried to above the bulkhead deck or the uppermost waterline.

Doors from shaft tunnels and pipe ducts leading in the machinery spaces and cargo pump rooms shall comply with the requirements of **7.12**, Part III "Equipment, Arrangements and Outfit".

4.5.15 In oil tankers and combination carriers, one of the escape routes from pipe ducts situated below the cargo tanks may lead in the cargo pump room.

Exit in the machinery space is not permitted.

4.5.16 The doors and hatch covers of cargo pump rooms in oil tankers shall be capable of being opened and closed both from inside and from outside; their design shall preclude the possibility of sparking.

4.5.17 Escape routes from cargo pump rooms shall lead directly to the open deck. Exit to other machinery spaces is not permitted.

4.5.18 If two adjacent machinery spaces communicate through a door and each of them has only one means of escape through the casing, these means of escape shall be located at the opposite sides.

4.6 INSULATION OF HEATED SURFACES

4.6.1 Surfaces of machinery, equipment and piping with temperatures above 220°C, which may be impinged as a result of a fuel system failure, shall be properly insulated.

4.6.2 The insulating materials and surface of insulation shall be in accordance with the requirements of **2.1.1.5**, Part VI "Fire Protection".

4.6.3 Structural measures shall be taken to prevent any oil that may escape under pressure from any pump, filter or heater from coming into contact with heated surfaces.

5. SHAFTING

5.1 GENERAL

5.1.1 Shafting is a solid unit connecting the engine with the propeller.

Optimum location of the shafting within the ship space shall be provided to ensure rational combination of loads of the shafting components, its supports and the engine.

For this a number of design, scientific, technical and engineering measures shall be taken which are unified by a concept "Shafting alignment" and approved by the Register.

5.1.2 The minimum shaft diameters without allowance for subsequent turning on lathe during service life shall be determined by formulae given in this Section. It is assumed that additional stresses from torsional vibration will not exceed permissible values stipulated in Section **8**.

Tensile strength of the shaft material shall be not less than 400 MPa and for shafts which may experience vibratory stresses close to the permissible stresses for transient operation _ not less than 500 MPa.

Alternative calculation methods are permitted. These methods shall take into account criteria of static and fatigue strength and include all the relevant loads under all permissible operating conditions.

The shaft diameters determined for ships of restricted navigation areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** and **A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS, D-R3-S**, and **D-R3-RS** according to **5.2.1** - 5.2.3 may be reduced by 5 per cent.

5.1.3 In icebreakers and ice class ships, the propeller shafts shall be protected from ice effects.

5.1.4 In ships with no obstruction for the propeller shaft to slip out of the sterntube, means shall be provided which, in the event of the propeller shaft breaking, will prevent its slipping out of the sterntube; alternative arrangements shall be made to preclude flooding of the engine room, should the propeller shaft be lost.

5.1.5 The areas between the sterntube, strut bearing (if any) and propeller boss shall be protected by a strong casing.

5.1.6 Arrangement of stern tubes shall comply with the requirements of **1.1.6.1.8**, **1.1.6.2.8** or **1.1.6.3.11**, depending on the case, Part II «Hull».

5.2 CONSTRUCTION AND DIAMETERS OF SHAFTS

5.2.1 The design diameter of the intermediate shaft d_{int}, in mm, shall not be less than

$$d_{int} = F\sqrt[3]{P/n}, \qquad (5.2.1)$$

where:

F – factor taken depending on the type of machinery installation as follows:

95 for installations with main machinery of rotary type or main internal combustion engines fitted with hydraulic or electromagnetic couplings;

100 for other machinery installations with internal combustion engines;

P – rated power of intermediate shaft, kW;

n – rated speed of intermediate shaft, rpm.

5.2.2 The diameter of thrust shaft in external bearing on a length equal to thrust shaft diameter on either side of the thrust collar and, where roller thrust bearings are used, on a length inside the housing of thrust bearing, shall not be less than 1,1 times the intermediate shaft diameter determined by Formulas (5.2.1), (5.2.4). Beyond the said lengths the diameter of the thrust shaft may be tapered to that of the intermediate shaft.

5.2.3 The design diameter of the propeller shaft, in mm, shall not be less than that determined by the following formula

$$d_{\text{rp}} = 100k\sqrt[3]{P/n}, \qquad (5.2.3)$$

where:

k – factor assumed as follows proceeding from the shaft design features: for the portion of propeller shaft between the propeller shaft cone base or the aft face of the propeller shaft flange and the forward edge of the aftermost shaft bearing, subject to a minimum of2,5d_{p}:

1,22 – where the propeller is keyless fitted onto the propeller shaft taper or is attached to an integral propeller shaft flange;

1,26 – where the propeller is keyed onto the propeller shaft taper;

for the portion of propeller shaft between the forward edge of the aftermost shaft bearing, or aft strut bush, and the forward edge of the forward sterntube seal k =1,15, for all types of design.

Other terms are as defined in **5.2.1**.

On the portion of propeller shaft forward of the forward edge of the forward sterntube seal the diameter of the propeller shaft may be tapered to the actual diameter of the intermediate shaft.

Where surface hardening is used, the diameters of propeller shafts may be reduced on agreement with the Register.

5.2.4 The diameter of the shaft made of steel with tensile strength of more than 400 MPa may be determined by the following formula

$$d_{red} = d\sqrt[3]{560/(R_{msh} + 160)} \qquad (5.2.4)$$

where:

d_{red} – reduced diameter of the shaft, in mm;

d – design diameter of the shaft, mm;

R_{msh} – tensile strength of the shaft material.

In all cases the tensile strength in the formula shall be assumed not exceeding 760 MPa (for carbon and carbon-manganese steel)/800 MPa (for alloyed steel) for intermediate and thrust shafts and 600 MPa for propeller shaft.

However, where materials exhibit similar fatigue life as conventional steels, special approval of alloy steel used for intermediate shaft material (refer to Appendix **2**) shall be permitted.

5.2.5 The diameters of shafts in icebreakers and ice class ships shall exceed the design diameters by value indicated in Table 5.2.5.

Table 5.2.5 **Increase of shaft diameter, %**

Shafts	Icebreakers		Ice class ships				
	Side shaft	Centre shaft	**Ice6**	**Ice5**	**Ice4**	**Ice3**	**Ice2, Ice1**
Intermediate and thrust	20	18	15	12	8	4	0
Propeller	50	45	30	20	15	8	5

The diameter d of propeller shafts, in mm, for icebreakers and ice class ships (except for ships of ice class Ice1) shall, besides, meet the following condition in way of aft bearings

$$d \geqslant a\sqrt[3]{bs^2 R_{m_{bl}}/R_e}\,, \qquad (5.2.5)$$

where:
a – factor equal to:
10,8, with propeller boss diameter equal to, or less than 0,25D (D is the propeller diameter);
11,5, with propeller boss diameter greater than 0,25D;
b – actual width of expanded cylindrical section of the blade on the radius of 0,25R for unit-cast propellers and of 0,35R for CPP, m;
s – maximum thickness of expanded cylindrical section of the blade on the radii given for b, mm;
R_{mbl}– tensile strength of the blade material, MPa;
R_{eH} –yield stress of propeller shaft material, MPa.

5.2.6 If the shaft has a central hole, its bore shall not exceed 0,4 of the design diameter of the shaft.

If considered necessary, the diameter of central hole may be increased to the value obtained from the formula

$$d_c \le (d_a^4 - 0{,}97\,d^3\,d_a)^{1/4}\,, \qquad (5.2.6)$$

where:
d_c – diameter of central hole;
d_a – actual shaft diameter;
d – design diameter of the shaft without regard for central hole.

5.2.7 Where the shaft has a radial hole, the shaft diameter shall be increased over a length of at least seven diameters of the hole.

The hole shall be located at mid-length of the bossed portion of the shaft, and its diameter shall not exceed 0,3 of the shaft design diameter. In all cases, irrespective of the hole diameter, the diameter of the shaft shall be increased by not less than 0,1 times the design diameter.

The edges of the hole shall be rounded to a radius not less than 0,35 times its diameter and the inside surface shall have a smooth finish.

Note: This para does not consider a radial hole, intersection between a radial hole and an eccentric axial bore.

5.2.8 The diameter of a shaft having a longitudinal slot shall be increased by at least 0,2 of the design diameter of that shaft. The diameter ratio (refer to **5.2.6**) shall not exceed 0,7, the slot length shall not exceed 0,8 and slot width shall not exceed 0,15 of the design shaft diameter.

Up to three slots are permitted, with consideration for their equally-spaced location. The bossed portion of the shaft shall be of such length as to extend beyond the slot for not less than 0,25 of the design diameter of the shaft. The transition from one diameter to another shall be smooth.

The ends of the slot shall be rounded to a radius of half the width of the slot and the edges - to a radius of at least 0,35 times the width; the surface of the slot shall have a smooth finish.

5.2.9 The diameter of a shaft having a keyway shall be increased by at least 0,1 of its design diameter. After a length of not less than 0,2 of the design diameter from the ends of the keyway, no increase of the shaft diameter is required.

If the keyway is made on the outboard end of the propeller shaft, the diameter need not be increased.

Keyways are not recommended in the shafts with a barred speed range.

5.2.10 For intermediate shafts, thrust shafts and inboard end of propeller shafts the coupling flange shall have a minimum thickness of 0,2 times the required diameter of the intermediate shaft, or the thickness of the coupling bolt diameter (refer to Formula (5.3.2)) calculated for the material having the same tensile strength as the corresponding shaft, whichever is the greater.

The thickness of coupling flange of the outboard end of propeller shaft under the bolt heads shall not be less than 0,25 times the required diameter of the shaft at the flange.

5.2.11 The fillet radius at the base of aft flange of the propeller shaft shall not be less than 0,125 and for other flanges of shafts _ shall not be less than 0,08 of the required diameter at the flange. The fillet may be formed by multiradii in such a way that the stress concentration factor will not be greater than that for a constant fillet radius. The fillets shall have a smooth finish and shall not be recessed in way of nuts and bolt heads.

5.2.12 Fillet radii in the transverse section of the bottom of the keyway shall not be less than 0,0125 of the diameter of the shaft, but at least 1 mm.

5.2.13 Where keys are used to fit the propeller on the propeller shaft cone, the latter shall have a taper not in excess of 1:12, in case of keyless fitting _ according to **5.4.1**.

5.2.14 On the cone base side, the keyways in shaft cones shall be spoon-shaped, while in propeller shaft cones they shall be ski-shaped in addition.

Where the outboard end of a propeller shaft having the diameter in excess of 100 mm is concerned, the distance between the cone base and the spoon-shaped keyway end shall be at least 0,2 of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter less than 0,1 and 0,5 at least of the shaft diameter required, with the ratio of the keyway depth to the shaft diameter exceeding 0,1.

In coupling shaft cones, the ski-shaped keyway end shall not extend beyond the cone base.

Where the key is secured by screws in the keyway, the first screw shall be positioned at least 1/3 of the shaft cone length from the shaft cone base. The bore length shall not exceed the propeller diameter. The bore edges shall be rounded off. Where the shaft has blind axial bores, the bore edges and end shall also be rounded off. The fillet radius shall not be less than specified in **5.2.12**.

5.2.15 Propeller shafts shall be effectively protected against exposure to sea water.

5.2.16 Propeller shaft liners shall be made of such alloys, which possess sufficient corrosion resistance in sea water.

5.2.17 The thickness s of a bronze liner, in mm, shall not be less than

$$s = 0{,}03d_r' + 7{,}5, \qquad (5.2.17)$$

where: d'_r –diameter of the propeller shaft under the liner, mm.

The thickness of the liner between the bearings may be reduced to0,75s.

5.2.18 Continuous liners are recommended to be used.

Liners consisting of two or more lengths shall be joined by welding or by other methods approved by the Register.

The butt welded joints of the liner shall be arranged outside the region of bearings.

In case of non-continuous liners the portion of the shaft between the liners shall be protected against the action of sea water by a method approved by the Register.

5.2.19 To prevent water from reaching the propeller shaft cone, appropriate sealing shall be provided.

Structural provision shall be made for hydraulic testing of the sealing.

5.2.20 The liners shall be shrunk on the shaft in such a way as to provide tight interference between mating surfaces.

The use of pins or other parts for securing of liners to the shaft is not permitted.

5.3 SHAFT COUPLINGS

5.3.1 The bolts used at the coupling flanges of shafts shall be all fitted bolts of cylindrical section.

If using coupling flanges without fitted bolts the technical substantiation shall be submitted to the Register for review.

5.3.2 The coupling bolt diameter, in mm, shall not be less than

$$d_b = 0{,}65\sqrt{\frac{d_{int}^3\ (R_{m_{sh}} + 160)}{iDR_{m_b}}}, \qquad (5.3.2)$$

where:

d_{int} – diameter of intermediate shaft determined by Formula (5.2.1) taking into account the ice classes requirements under **5.2.5**, in mm.

If the shaft diameter is increased to account for torsional vibration, d_{int} will be taken as the increased diameter of intermediate shaft;;

R_{msh} – =tensile strength of the shaft material, in MPa;

R_{mb} – tensile strength of the fitted coupling bolt material, in MPa, taken $R_{msh} \le R_{mb} \le 1{,}7R_{msh}$, but not higher than 1000 MPa;

i – number of fitted coupling bolts;

D – pitch circle diameter of coupling bolts, in mm.

The diameter of bolts, by which the propeller is secured to the propeller shaft flange shall be agreed with the Register in each particular case.

5.4 KEYLESS FITTING OF PROPELLERS AND SHAFT COUPLINGS

5.4.1 In case of keyless fitted propellers and shaft couplings, the taper of the shaft cone shall not exceed 1:15.

Provided the taper does not exceed 1:50, the shafts may be assembled with the couplings without the use of an end nut or other means of securing the coupling.

The stoppers of the end nuts shall be secured to the shaft.

5.4.2 A keyless assembly shall generally be constructed without a sleeve between the propeller boss and the shaft.

If using constructions with intermediate sleeves the technical substantiation shall be submitted to the Register for review.

5.4.3 When fitting the keyless shrunk assembly, the axial pull-up of the boss in relation to the shaft or intermediate sleeve, as soon as the contact area between mating surfaces is checked after eliminating the clearance, shall be determined by the following formula

$$\Delta h = \left\{ \frac{80\,B}{hz} \sqrt{\left(\frac{1910\,PL^3}{nD_\omega} \right)^2 + T^2} + \frac{D_\omega(\alpha_y - \alpha_\omega)(t_e - t_m)}{z} \right\} k, \qquad (5.4.3)$$

where:

Δh – axial pull-up of the boss in the course of fitting, cm;

B – material and shape factor of the assembly, MPa^{-1}, determined by the formula

$$B = \frac{1}{E_y}\left(\frac{y^2+1}{y^2-1} + \nu_y \right) + \frac{1}{E_\omega}\left(\frac{1+\omega^2}{1-\omega^2} - \nu_\omega \right).$$

For assemblies with a steel shaft having no axial bore, the factor B may be obtained from Table 5.4.3-1 using linear interpolation;

E_y – modulus of elasticity of the boss material, MPa;

E_ω – modulus of elasticity of shaft material, MPa

ν_y – Poisson's ratio for the boss material;

ν_ω – Poisson's ratio for the shaft material; for steel $\nu_\omega = 0{,}3$;

y – mean factor of outside boss diameter;

ω – mean factor of shaft bore;

D_ω – mean outside shaft diameter in way of contact with the boss or intermediate sleeve (refer to Fig. 5.4.3).

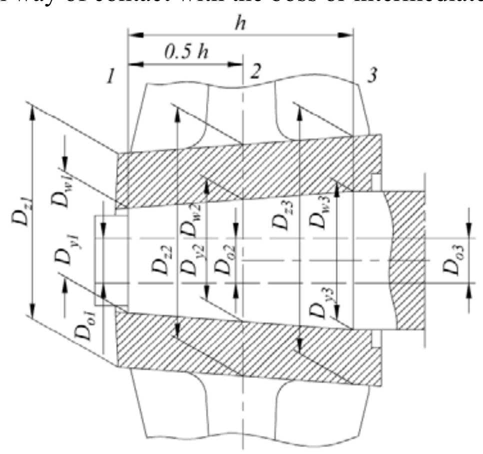


Fig. 5.4.3

without intermediate sleeve:

$D_{\omega 1} = D_{y1}$; $D_{\omega 2} = D_{y2}$, $D_{\omega 3} = D_{y3}$, $D_{\omega} = D_{y}$.

with intermediate sleeve:

$D_{\omega 1} \neq D_{y1}$; $D_{\omega 2} \neq D_{y2}$, $D_{\omega 3} \neq D_{y3}$, $D_{\omega} \neq D_{y}$.

$$y = \frac{D_{z1} + D_{z2} + D_{z3}}{D_{y1} + D_{y2} + D_{y3}}$$ – for the boss;

$$\omega = \frac{D_{01} + D_{02} + D_{03}}{D_{\omega 1} + D_{\omega 2} + D_{\omega 3}}$$ – for the shaft;

$D_{\omega} = (D_{\omega 1} + D_{\omega 2} + D_{\omega 3})/3$;

$D_{y} = (D_{y1} + D_{y2} + D_{y3})/3$;

D_y – mean internal boss diameter in way of contact with the shaft or intermediate sleeve, cm;
h – active length of the shaft cone or sleeve at the contact with the boss, cm;
z – taper of the boss;
P – power transmitted by the assembly, kW;
n – speed, rpm.
L – factor for ice class ships according to Table 5.4.3-2;
T – propeller thrust at ahead speed, in kN (where data are unavailable, refer to **2.2.2.6**, Part III "Equipment, Arrangements and Outfit");
α_y, α_ω – thermal coefficient of linear expansion of the boss and shaft material, 1/°C;
t_e, t_m – temperature of the assembly in service conditions and in the course of fitting, °C;
k = l – for assemblies without intermediate sleeve;
k = 1,1 – for assemblies without intermediate sleeve.

For ice class ships, the value Δh shall be chosen as the greater of the results obtained from calculations for extreme service temperatures, i.e.

t_e = 35 °C for$L$= 1;

t_e = 0 °C for L > 1.

In the absence of ice classes the calculation shall be made solely for the maximum service temperature t_e = 35°C for L = 1.

***Table 5.4.3-1* Factor $B \cdot 10^5$, MPa^{-1}, Steel shaft $\omega = 0$, $E_\omega = 2,059 \cdot 10^5$ MPa, $\nu_\omega = 0,3$**

Factor y	Copper alloy boss ν_y = 0,34 with E_y, MPa:							Steel boss ν_y=0,3 with E_y=2,05 $\cdot 10^5$, MPa
	$0,98 \cdot 10^5$	$1,078 \cdot 10^5$	$1,176 \cdot 10^5$	$1,274 \cdot 10^5$	$1,373 \cdot 10^5$	$1,471 \cdot 10^5$	$1,569 \cdot 10^5$	
1,2	6,34	5,79	5,34	4,96	4,63	4,34	4,09	3,18
1,3	4,66	4,26	3,95	3,66	3,43	3,22	3,04	2,38
1,4	3,83	3,52	3,25	3,03	2,83	2,67	2,52	1,98
1,5	3,33	3,07	2,83	2,64	2,48	2,34	2,21	1,74
1,6	3,01	2,77	2,57	2,40	2,24	2,12	2.01	1,59
1,7	2,78	2,48	2,38	2,22	2,09	1,97	1,87	1,49
1,8	2,62	2,38	2,23	2,09	1,97	1,86	1,76	1,41
1,9	2,49	2,29	2,13	1,99	1,88	11,77	1,68	1,35
2,0	2,39	2,20	2,05	1,92	1,80	1,70	1,62	1.29
2,1	2,30	2,13	1,98	1,86	1,74	1,65	1,57	1,25
2,2	2,23	2,06	1,92	1,79	1,69	1,60	1,53	1,22
2,3	2,18	2,01	1,88	1,75	1,65	1,57	1,49	1,19
2,4	2,13	1,97	1,84	1,72	1,62	1,54	1,46	1,17

Table 5.4.3-2 **Factor** ***L***

Assembly	Ice class ships					Icebreakers	
	Ice1, Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**	Centre shaft	Side shaft
Propeller with shaft	1,05	1,08	1,15	1,20	1,30	1,45	1,50
Coupling with shaft	1,0	1,04	1,08	1,12	1,15	1,18	1,20

5.4.4 When assembling steel couplings and shafts with cylindrical mating surfaces, the interference fit shall be determined by the following formula

$$\Delta D = \frac{80B}{h}\sqrt{\left(\frac{1910PL^3}{nD_\omega}\right)^2 + T^2}\ , \quad (5.4.4)$$

where: ΔD – interference fit for D_ω, cm.
Other terms are as defined in **5.4.3**.

5.4.5 Other terms are as defined in

$$\frac{A}{B}\left[\frac{C}{D_y} + (\alpha_y - \alpha_\omega)t_m\right] \le 0{,}75R_{eH}\ , \qquad (5.4.5)$$

where:
A – shape factor of the boss determined by the formula:

$$A = \frac{1}{y^2 - 1}\sqrt{1 + 3y^4}\ ;$$

$C = \Delta h_r z$ – for assemblies with conical mating surfaces;
$C = \Delta D_r$ – for assemblies with cylindrical mating surfaces;
Δh_r – actual pull-up of the boss in the course of fitting at a temperature t_m, cm,
$\Delta h_r \ge \Delta h$;
ΔD_r – actual interference fit of the assembly with cylindrical mating surfaces, in cm;
$\Delta D_r \ge \Delta D$;
R_{eH} – yield stress of the boss material, MPa.
The factor A may be obtained from Table 5.4.5 by linear interpolation.
Other terms are as defined in **5.4.3**.

Tabla 5.4.5 **Factor** ***A***

y	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,02	2,1	2,2	2,3	2,4
A	6,11	4,48	3,69	3,22	2,92	2,70	2,54	2,42	,33	2,26	2,20	2,15	2,11

5.5 ARRANGEMENT OF SHAFTING SUPPORTS

5.5.1 The number of the shaftline supports, their position along the axis and in the vertical plane as well as the loads carried shall be determined on the basis of calculation made by a proven procedure agreed with the Register.

5.5.2 The distance between the reaction forces of the adjacent shaftline bearings with no concentrated masses in span shall meet the following condition:

$$5{,}5a\sqrt{d} \le l \le a\lambda\sqrt{d} \qquad (5.5.2)$$

where:
l – span length (distance between the reactions of adjacent supports), m;
d – minimum outside shaft diameter in span, m;
λ – factor taken equal to:
$\lambda = 14$ — when $n \le 500$ rpm;
$\lambda = 300/\sqrt{n}$ — when $n > 500$ rpm.;
n – shaft speed, in rpm;
α –factor for bored shafts taken equal to:
$\alpha = \sqrt[4]{1 + b^2}$
$b = d_0 / d$ — ratio of the bore diameter d_0 to the outside shaft diameter d.

Note. Restriction on the minimum length (the left part of equation (5.5.2)) is used for all spans except for that nearest to the propeller.

5.5.3 It is recommended to seek the minimum number of shaftline supports and the maximum possible length of the spans between them.

5.5.4 The lengths of the spans between the shaft supports shall be checked by the bending vibration calculation.

5.5.5 The shaftline supports shall be so installed that the engine or reduction gear components (bearings, gear wheels) take up loads within the permissible limits.

5.5.6 The reactions of all shaftline supports shall be positive.

5.6 SHAFT BEARINGS

5.6.1 The propeller shaft bearing nearest to the propeller shall meet the requirements of Table 5.6.1. Those propeller shaft bearings, which are located forward of the bearing mentioned above, shall meet the condition:

$$l \geq R / qd \qquad (5.6.1)$$

where: here the symbols and values for q are taken from Table 5.6.1.

5.6.2 The water cooling of sterntube bearings shall be of forced type (refer to **15.1**, Part VIII "Systems and Piping"). The water supply system shall be provided with a flow indicator and with alarms for the minimum flow of water.

Where an open system of seawater lubrication is applied for the sternbush bearings of ships operating in shallow waters, and of specialized vessels, such as wet dredgers, suction dredgers, it is recommended that an efficient seawater cleaning device (filter, cyclone filter, etc.) shall be incorporated in the circulation system of the sternbush bearing, or sternbush bearings with mud collectors to be washed subsequently shall be fitted.

The non-return shut-off valve controlling the supply of water to sterntube bearings shall be fitted on the sterntube or the after peak bulkhead.

Table 5.6.1

Bearing material	l/d[1] , not less than	q[2], in MPa, not more than
Oily-lubricated white metal (babbit)	2[4]	1,0
Bakaut	4	0,25
Rubber or other water-lubricated materials approved by the Register	4[3]	0,25[3]
Rubber or other synthetic oil- or environment-friendly oily liquid-lubricated materials approved by the Register	2[4]	1,0

[1] l - length of bearing; d - design shaft journal diameter in way of bearing.

[2] q - contact pressure taken up by the bearing: $q = R/(l \times d)$, where R - reaction of suppor.

[3] Length of the bearing of synthetic material may be reduced to twice the design shaft diameter in way of the aft bearing, provided the results of the operational check (of the bearing design and material) are satisfactory.

[4] Length of the bearing may be reduced if the contact pressure does not exceed 0,8 MPa as determined by static bearing reaction calculation taking into account shaft and propeller weight which is deemed to be exerted solely on the aft bearing divided by the projected area of the shaft and if the results of the operational check are satisfactory. In all cases, the length of the bearing shall not be less than 1,5 of the actual shaft diameter in way of the bearing.

5.6.3 The oil-lubricated sternbush bearings shall be provided with forced cooling arrangements unless the after peak tank is permanently filled with water.

Indication of temperature of oil or bearing bush shall be provided.

5.6.4 If a gravity system of lubrication is used for sternbush bearings, the lubricating oil tanks shall be fitted with oil level indicators and low level alarms.

5.7 STERNTUBE SEALING ARRANGEMENTS

5.7.1 Sterntube arrangements shall be fitted with sterntube sealing arrangements providing the efficient protection against emergency intrusion of sea water inside the hull, and the environmental safety of sterntube arrangement.

5.7.2 The minimum and the maximum permissible volumes of the refrigerant leakage into the ambient space and inside the hull shall be technically substantiated.

5.8 BRAKING DEVICES

5.8.1 The shaftline shall comprise appropriate braking devices.

Such devices may be a brake, a stopping or a shaft turning gear preventing rotation of the shaft in the event the main engine goes out of action.

5.9 HYDRAULIC TESTS

5.9.1 Propeller shaft liners and cast sterntubes shall be hydraulically tested to a pressure of 0,2 MPa upon completion of machining.

Hydraulic tests of welded and forged-and-welded sterntubes may be omitted, providing non-destructive testing of 100 per cent of welds.

5.9.2 After assembling, the seals of the sterntube when the closed lubrication system is used shall be tested for tightness by a pressure head up to the working level of liquid in gravity tanks. In general, the test shall be carried out while the propeller shaft is turning.

6. PROPELLERS

6.1 GENERAL

6.1.1 The requirements of this Section apply to metal fixed-pitch propellers (FPP), both solid and detachable-blade propellers, as well as to controllable-pitch propellers (CPP).

6.1.2 The design and size of propellers of the main active means of the ship's steering shall meet the requirements of the present Section.

The scope of requirements for the design and size of propellers of the auxiliary AMSS may be reduced, subject to agreement with the Register.

6.2 BLADE THICKNESS

6.2.1 Propeller blade thickness is checked in the design root section and in the blade section at the radius *r*=0,6R where *R* is propeller radius.

The location of the design root section is adopted as follows:

for solid propellers – at the radius 0,2*R* where the propeller boss radius is smaller than 0,2*R*, and at the radius 0,25*R* where the propeller boss radius is greater than or equal to 0,2*R*;

for detachable-blade propellers – at the radius 0,3*R* where the propeller boss radius is smaller than 0,3*R*, and at the propeller boss radius where the propeller boss radius is larger than or equal to 0,3*R*.

The values of the factors A and c are adopted as in the case of r = 0,25*R*;

for CPP – at the radius 0,35*R* where the propeller boss radius is smaller than 0,35*R*, at the propeller boss radius where the propeller boss radius is larger than or equal to 0,35*R*.

Note: In the design section, the blade thickness is determined the fillets neglected.

In solid propellers, detachable-blade propellers and CPP, the maximum thickness *s*, in mm, of an expanded cylindrical section shall not be less than

$$s = 9{,}8\left[A\sqrt{\frac{0{,}14kP}{zb\sigma n}} + c\frac{m}{\sigma}\left(\frac{Dn}{300}\right)^2\right], \qquad (6.2.1\text{-}1)$$

where:

A – coefficient to be determined by Formula (6.2.1-2) depending on the relative radius r/R of design section and the pitch ratio H/D at this radius (for a CP-propeller, take the pitch ratio of the basic design operating condition);

k – coefficient obtained from Table 6.2.1-1;

P – shaft power at the rated output of the main propulsion engine, kW;

z – number of blades;

b – width of the expanded cylindrical section of the blade on the design radius, m;

$\sigma = 0{,}6R_{mb} + 175$ MPa, but not more than 570 MPa for steels and not more than 610 MPa for copper alloys;

R_{mbl} – tensile strength of blade material, MPa;

n – speed at the rated output, rpm;

c – coefficient of centrifugal stresses to be determined by Formula (6.2.1-3) ;

m – blade rake, mm;

D – propeller diameter, m;

$$A = \sum_{j=0}^{4} \sum_{i=0}^{3} a_{ij}(\check{r})^i (H/D)^j, \qquad (6.2.1\text{-}2)$$

where:
a_{ij} – factor determined from Table 6.2.1-2;
$\check{r}$ – relative radius of design section;

$$c = \sum_{i=0}^{3} a_{ij}(\check{r})^i, \qquad (6.2.1\text{-}3)$$

where:
a_i – factor determined from Table 6.2.1-3;
$\check{r}$ – relative radius of design section.

The holes for the items securing the blades of built-up and CP-propellers shall not reduce the design root section.

The thickness of propeller blades in ships of river-sea navigation and in ships of restricted areas of navigation **R2, R3, A-R2** and **D-R3** may be reduced by 5 per cent.

Table 6.2.1-1* Coefficient *k

Ships without ice class	Ice class ships					Icebreakers	
	Ice1, Ice2	**Ice3**	**Ice4**	**Ice5**	**Ice6**	Centre propeller	Side propeller
8	9	10	11,2	12,5	14	16	$16 + \frac{23500}{P^*}$
P* – shaft power, kW. *Notes:* 1. If reciprocating engines with less than four cylinders are installed in the ship, k shall be increased by 7 per cent. 2. For reciprocating engines fitted with hydraulic or electromagnetic couplings, k may be reduced by 5 per cent. 3. For side propellers of ships without ice class and ships of ice classes **Ice1 and **Ice2**, k may be reduced by 7 per cent							

***Table 6.2.1-2* Values of coefficient a_{ij}**

a_{ij}		j				
		0	1	2	3	4
i	0	709,29796	-1988,09402	2866,42279	-2021,48724	547,82587
	1	-3780,43298	14440,53576	-22809,83724	16918,28525	-4715,66016
	2	9066,98223	-36165,14189	59184,72549	-45171,89303	12819,32337
	3	-704,99029	29254,14486	-48753,36019	37837,58962	10848,55838

***Table 6.2.1-3* Values of coefficient a_i**

i	0	1	2	3
a_i	0,35	2,67381	-11,71429	10,47619

6.2.2 The blade tip thickness at the radius $D/2$ shall not be less than provided in Table 6.2.2.

The leading and trailing blade edge thickness measured at 0,05 of the blade width from the edges shall not be less than 50 per cent of blade tip thickness.

***Table 6.2.2* The blade tip thickness**

Ships without ice class	Ships with ice classes		Icebreakers
	Ice1 – Ice5	**Ice6**	
0,0035*D**	0,005*D*	0,006*D*	0,008*D*
**D* – diameter of the propeller.			

6.2.3 The blade thickness calculated in accordance with **6.2.1** and **6.2.2** may be reduced (e.g. for blades of particular shape), provided a detailed strength calculation is submitted for consideration to the Register.

6.2.4 The thickness of a high-skewed ($\theta > 25°$) blade with an asymmetrical outline of the normal projection shall be checked in compliance with the requirements of **6.2.1**.

Besides, the blade thickness at the radius 0,6*R* at a distance of 0,8 of the width of section b shall not be less than determined from the following formula

$$s_k = 0{,}4s(1 + 0{,}064\sqrt{\theta - 25}), \qquad (6.2.4)$$

where:
s – to be determined from Formula (6.2.1) at the radius 0,6R;
θ – angle, in degrees, equal to angle θ_1 or θ_2, whichever is the greater (refer to Fig. 6.2.4).

If smoothness of the blade section profile at the radius 0,6R under condition of mandatory compliance with the requirements for the minimum thickness close to the trailing edge (on 0,8b) is not provided, thickness s at the radius 0,6R is increased.

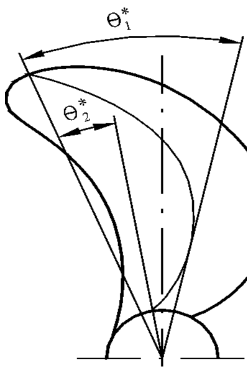


Fig. 6.2.4

θ_1^* – angle between the radius drawn through the blade tip and the radius tangent to the mid-chord;

θ_2^* – angle between radii drawn through the blade tip and root section centre of the blade.

Use of high-skewed blades (θ>5°) for icebreakers and ice ships of categories and of high-skewed blades (θ >10°) for ice ships of **Ice5** categories shall be substantiated.

6.2.5 In icebreakers and ships provided with ice strengthening, the stresses in the most loaded parts of pitch control gear shall not exceed yield stress of the material, if the blade is broken in direction of the weakest section by a force applied along the blade axis over 2/3 of its length from the boss and laterally over 2/3 from the blade spindle axis to the leading edge.

6.3 PROPELLER BOSS AND BLADE FASTENING PARTS

6.3.1 Fillet radii of the transition from the root of a blade to the boss shall not be less than 0,04D on the suction side of the blade and shall not be less than 0,03D on the pressure side.

If the blade has no rake, the fillet radius on both sides shall be at least 0,03D.

Smooth transition from the blade to the boss using a variable radius may be permitted.

6.3.2 The propeller boss shall be provided with holes through which the empty spaces between the boss and shaft cone are filled with non-corrosive mass; the latter shall also fill the space inside the propeller cap.

6.3.3 The diameter of the bolts (studs), by which the blades are secured to the propeller boss or the internal diameter of the thread of such bolts (studs), whichever is less, shall not be less than that determined by the following formula

$$d_{\text{ш}} = ks\sqrt{\frac{bR_{m\text{л}}}{dR_{m\text{б}}}}, \qquad (6.3.3)$$

where:
k = 0,33 in case of three bolts in blade flange, at thrust surface;
0,30 – in case of four bolts in blade flange, at thrust surface;
0,28 – in case of five bolts in blade flange, at thrust surface;
s – the maximum actual thickness of the blade at design root section (refer to 6.2.1), mm;
b – width of expanded cylindrical section of the blade at the design root section, m;
$R_{m\text{bl}}$ – tensile strength of blade material, MPa;
$R_{m\text{b}}$ – tensile strength of bolt/stud material, MPa;

d – diameter of bolt pitch circle; with other arrangement of bolts, $d = 0{,}85l$ where l = the distance between the most distant bolts, m.

6.3.4 The securing devices of the bolts (studs), by which the blades are fastened to the detachableblade propellers of ice class ships, shall be recessed in the blade flange.

6.4 PROPELLER BALANCING

6.4.1 The completely finished propeller shall be statically balanced.

The extent of balancing shall be checked by a test load, which when suspended from the tip of every blade in horizontal position, shall cause the propeller to rotate. The mass of the test load shall not be more than

$$m \le km_p / R\,, \qquad (6.4.1)$$

where:
m – mass of test load, kg;
m_p – =mass of propeller, t;
R – propeller radius, m;
k = 0,75 for $n \le 200$;
0,5 for $200 < n \le 500$;
0,25 for $n > 500$;
n – rated speed of propeller, rpm.

Where the propeller mass exceeds 10 t, the coefficient k shall not be greater than 0,5, irrespective of the propeller speed.

6.5 CONTROLLABLE PITCH PROPELLERS

6.5.1 The hydraulic power system of the controllable pitch propeller shall be supplied by two pumps of equal capacity, basic and standby, one of which may be driven from the main engine. The main engine driven pump shall provide turning of the blades under any operating mode of the main engines.

Where more than two pumps are available, their capacity shall be selected on the assumption that, if any of the pumps fails, the aggregate capacity of the rest would be sufficient to ensure the blade turningover time not longer than stipulated by **6.5.5**.

In ships with two CP-propellers one independent standby pump may be fitted for both CP-propellers.

6.5.2 The pitch control unit shall be designed so as to enable turning the blades into ahead speed position, shall the hydraulic power system fail.

In multi-screw ships, except icebreakers and ships with ice strengthening of categories **Ice 5** and **Ice 6**, this requirement need not be satisfied.

6.5.3 In ships with a CP-propeller, in which the main engine may become overloaded due to particular service conditions, it is recommended that automatic protection against overloading be used for the main engine.

6.5.4 The hydraulic power system of pitch control unit shall be constructed according to the requirements of Section **7**, Part IX "Machinery", and the pipes shall be tested according to Section **21**, Part VIII "Systems and Piping".

6.5.5 The time required for the blades to be turned over from full ahead to full astern speed position with main machinery inoperative shall not exceed 20 s for CP-propellers up to 2 m in diameter including, and 30 s for CP-propellers with diameters over 2 m.

6.5.6 In the gravity lubrication systems of CP-propellers, the gravity tanks shall be installed above the deepest load waterline and be provided with level indicators and low level alarms.

6.6 HYDRAULIC TESTS

6.6.1 The sealings fitted to the cone and flange casing of the propeller shaft (if such method of connection with the propeller boss is used) shall be tested to a pressure of at least 0,2 MPa after the propeller is fitted in place.

If the above sealings are under pressure of oil from the sterntube or the propeller boss, they shall be tested in conjunction with testing of the sterntubes or propeller boss.

6.6.2 After being assembled with the blades the boss of a CP-propeller shall be tested by internal pressure equal to a head up to the working level of oil in gravity tank, or by a pressure created by the lubricating pump of the boss. In general, the test shall be made during blade adjustment.

7. ACTIVE MEANS OF THE SHIP'S STEERING

7.1 GENERAL

7.1.1 The requirements of the present Section apply to steerable propellers with podded drives or with mechanical transmission of power to the propeller including retractable units of all types, waterjets, vertical-axis propellers, propellers in transverse tunnel (athwartship thrusters) and other devices of similar purpose.

7.1.2 Where AMSS is intended for main propulsion and steering of a ship, as a rule, minimum two AMSS shall be provided. Provision in this case shall be made for control stations equipped with necessary devices and means of communication as indicated in **2.5**, **3.1** to **3.3**.

Where one AMSS is intended for main propulsion and steering of a ship, the technical substantiation shall be submitted to the Register for review.

7.1.3 The type and structure of AMSS shall be selected during ship design considering the ship purpose and area of navigation, as well as operational peculiarities.

7.1.4 The requirements for installation of AMSS machinery and equipment, materials and welding are given in **1.3**, **2.4** and **4.4**.

7.1.5 For AMSS intended for the main propulsion and for the dynamic positioning, size and materials of shafts, couplings, connection bolts, propellers, gearing as well as electrical equipment shall meet the requirements of relevant parts and sections of the Rules.

All essential components used in steering arrangements for ship directional control shall be of sound reliable construction proved by appropriate calculations. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be periodically lubricated or provided with perrmanent lubrication fittings.

Moreover, the main AMSS shall comply with the applicable requirements for the steering gears, set forth in the relevant sections of the Rules.

All essential components used in steering arrangements for ship directional control shall be duplicated. When not duplicated or when the Rules contain no requirements for particular AMSS components, possibility of using them shall be agreed upon with the Register.

7.1.6 Calculations of the AMSS gearing shall be made following the procedure outlined in **4.2**, Part IX "Machinery" or by other methods recognized by the Register. The safety factors of gearing shall not be less than those specified in 4.2, Part IX "Machinery". The values of these factors for the AMSS gearing intended for dynamic positioning duty shall be taken as for the main AMSS.

7.1.7 To support operating capacity of AMSS till special survey the service life of the rolling bearings shall be at least:

30000 h for the main AMSS;

10000 h for the AMSS used for dynamic positioning duty;

5000 h for the auxiliary AMSS.

7.1.8 Spaces containing the AMSS machinery shall be equipped with appropriate ventilating, fire extinguishing, drainage, heating and lighting arrangements.

7.2 CONSTRUCTION REQUIREMENTS

7.2.1 Steerable propellers shall be capable to be locked in all angular positions.

7.2.2 The main AMSS shall be provided with an emergency turning mechanism. The main AMSS angle indicator shall be provided. The difference between the indicated and actual positions shall comply with **2.9.15**, Part III "Equipment, Arrangements and Outfit".

7.2.3 For a ship fitted with multiple steering systems such as steerable propellers, water jet propulsion systems or other propulsion systems, each of the steering systems shall be equipped with its own dedicated steering gear, water jet guiding devices or other devices to change the propeller angle in accordance with requirements **2.9.1** of Part III "Equipment, Arrangements and Outfit" and **6.2.1.1** of Part IX "Machinery".

7.2.4 The main steering arrangements for ship directional control shall be:

.1 of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated;

.2 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 rotational speed of not less than 2,3°/s with the ship running ahead at maximum ahead service speed (refer also to **2.9.2**, Part III "Equipment, Arrangements and Outfit");

.3 for all ships, operated by power;

.4 so designed that they will not be damaged at maximum astern speed.

Note. Declared steering angle limits (of steerable propeller, thrust angle changing arrangement) are the operational limits in terms of maximum steering angle, or equivalent, according to manufacturer's guidelines for safe operation, also taking into account the ship's speed or propeller torque/speed or other limitation. The declared steering angle limits shall be declared by the directional control system manufacturer for each ship specific non-traditional steering mean. Ship's manoeuvrability tests shall be carried out with steering angles not exceeding the declared steering angle limits.

7.2.5 In a ship fitted with two or more steering systems, such as but not limited to azimuthing propulsors or water jet propulsion systems, an auxiliary steering gear need not be fitted, provided that:

.1 in a passenger ship, each of the steering systems is capable of satisfying the requirements in **7.2.4.2**, while any one of the power units is out of operation;

.2 in a cargo ship, each of the steering systems is capable of satisfying the requirements in **7.2.4.2** while operating with all power units;

.3 each of the steering systems is arranged so that after a single failure in its piping or in one of the power units, ship steering capability (but not individual steering system operation) can be maintained or speedily regained (e.g. by the possibility of positioning the failed steering system in a neutral position in an emergency, if needed).

7.2.6 The requirements of the present paragraph apply to the steering systems having a certain proven steering capability due to ship speed also in case propulsion power has failed.

Where the propulsion power exceeds 2500 kW per thruster unit, an alternative power supply, sufficient at least to supply the steering arrangements which complies with the requirements of **7.2.14.2** and also its associated control system and the steering system response indicator, shall 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 shall be used only for this purpose.

In every ship of 10000 gross tonnage and upwards, the alternative power supply shall have a capacity for at least 30 min of continuous operation and in any other ship for at least 10 min.

7.2.7 The ability of the machinery to change the thrust direction for stopping the ship making a full ahead speed on an agreeable distance shall be proven and recorded.

The steerable propeller designed for reversing the thrust by turning the unit shall provide an acceptable reversing time depending on the purpose of the ship. The time required for turning the unit through 180° shall not then exceed 20 s for the units with a propeller of 2 m and less in diameter and shall not exceed 30 s for the units with a propeller of more than 2 m in diameter.

The stopping times, ship headings and distances recorded on trials, together with the results of trials to determine the ability of ships having multiple propulsion/steering arrangements to navigate and manoeuvre with one or more.

7.2.8 Sealing boxes of a type approved by the Register shall be installed to prevent sea water from gaining access to internal parts of the AMSS. For the main and for the dynamic positioning AMSS such sealing arrangement shall contain at least two separate, closely effective sealing elements.

7.2.9 An easy access shall be provided to component parts of the AMSS to allow their maintenance within the scope stipulated by the Service Manual.

7.2.10 Where the design of the main AMSS does not insure against free rotation of the propeller and shafting in case of failure of the prime mover, provision shall be made for a braking device in accordance with the requirements of **5.8** (refer also to **17.3.4**, Part XI "Electrical Equipment"). On agreement with the Register, braking devices for the AMSS intended for the dynamic positioning and for the auxiliary AMSS may be dispensed with.

7.2.11 The strength of the parts of the main AMSS turning mechanism, casing components and securing items of the component parts, shafts, gearings, CPP components shall be so calculated that they can withstand without damage a load, which may cause breakdown of the propeller blade.

7.2.12 Main AMSS of icebreakers and ships with ice categories**Ice4** – **Ice6** shall be provided with a device to prevent the ice overload of turning mechanism.

7.2.13 Strength of the parts of main AMSS turning mechanism, components for securing to ship's hull shall be so calculated that they can withstand hydrodynamic and ice loads acting upon the propeller, nozzle and AMSS casing without damage.

It is permitted to determine hydrodynamic and ice loads on the AMSS components according to the results of hydrodynamic tests and testing of self-propelled models in the ice model basin according to the procedures approved by the Register.

7.2.14 The auxiliary steering arrangements for ship directional control shall be (refer also to Note **7.2.4**):

.1 of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;

.2 capable of changing direction of the ship directional control system from one side to the other at declared steering angle limits at an average rotational 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;

.3 for all ships, operated by power where necessary to meet the requirements of **7.2.11.2** and in any ship having power of more than 2500 kW propulsion power per thruster unit.

7.2.15 For technical condition monitoring of the main AMSS in service, they may be fitted with control facilities considering the requirements of Section **9** and Section **11**.

The technical condition monitoring system shall combine functions of built-in (fixed) systems and portable control facilities.

A list of the technical condition monitoring system equipment, controlled parameters and frequency of their measurements, as well as standards of technical condition of the AMSS control items are developed by manufacturers and/or suppliers of the equipment.

Technical substantiation of required control of the main AMSS shall be agreed upon with the Register in each particular case.

7.3 ALARMS

7.3.1 The AMSS shall be at least provided with alarms to be operated in the event of the following faults:

.1 overload and emergency stop of prime mover;

.2 power failure in remote control and alarm system;

.3 low level in lubricating oil tank (if provided);

.4 low lubricating oil pressure (if forced lubricating oil system);

.5 low oil level in hydraulic supply system for turning steerable propellers and CP-propeller blades;

.6 low oil level in head tank for sealing arrangements;

.7 high level in bilge wells of the hull and AMSS spaces.

7.3.2 Individual indication units shall be provided on the bridge for:

.1 overload of prime mover AMSS and servo mover for steerable propellers (if no automatic protection is provided);

.2 frequency of the propeller rotation, vertical-axis propeller or water jet impeller;

.3 blade turning angle or propeller pitch for CP-propeller plants;

.4 direction of thrust for fixed propeller plants, vertical-axis propeller or water jet;

.5 angular position of steerable propeller, water jet steering and reversing gear or vertical-axis propeller eccentricity;

.6 available power in the alarm system.

7.3.3 For auxiliary AMSS the number of parameters covered by the alarm system and indicator units may be reduced subject to agreement with the Register.

7.4 HYDRAULIC TESTS

7.4.1 Once assembled, the internal parts of the unit casing shall be subjected to test hydraulic pressure corresponding to the maximum operational depth of immersion with an allowance made for the overpressure of the sealing arrangements. For water-jet propellers pressure generated by water head shall be considered in case of reversing.

7.4.2 Once installed, the sealing arrangements shall be subjected to leak testing by pressure equal to the height of a liquid column in head tanks at an operational level.

7.4.3 In addition, it may be necessary to carry out non-destructive testing of welds on the steerable propeller components and other welded structures within the scope of requirements set forth in Part XIV "Welding".

8. TORSIONAL VIBRATION

8.1 GENERAL

8.1.1 The present Section applies to propulsion plants with the main engines having a power of not less than 75 kW when ICE are used and of not less than 110 kW when using turbo or electric drives, and to auxiliary diesel generators as well as to ICE-driven machinery having a primary engine power of not less than 110 kW.

8.1.2 Torsional vibration calculations shall be prepared both for the basic variant and for other variants and conditions possible in the operation of the installation, as follows:

.1 maximum power take-off and idling speed (with the propeller blades at zero position) for installations comprising CP-propellers or vertical axis propellers;

.2 individual and simultaneous operation of main engines with a common reduction gear;

.3 reverse gear (propulsion plant reversing mode);

.4 connection of additional power consumers if their moments of inertia are commensurate with the inertia moments of the working cylinder;

.5 running with one cylinder missfiring, for installations containing flexible couplings and reduction gear; to be assumed not firing is the cylinder the disconnection of which accounts to the greatest degree for the increase of stresses and alternating torques;

.6 damper jammed or removed where single main engine installations are concerned;

.7 flexible coupling blocked due to breakage of its elastic components (where single main engine installations are concerned).

8.1.3 For ships of restricted areas of navigation **R3, R3-IN, D-R3-S, D-R3-RS** calculations stipulated by **8.1.2.6** and **8.1.2.7** are not necessary.

No calculations shall be submitted if it is documented that the installation is similar to that approved earlier or that its mass inertia moments and torsion stiffness between masses do not differ from the basic ones by 10 per cent and 5 per cent accordingly or the calculation may be limited to determination of the natural frequencies if at this stage of the calculation it is established that the differences in the mass inertia moments and torsion stiffness between masses do not result in change of the natural frequency of any one of the modes under consideration by more than 5 per cent.

8.1.4 Torsional vibration calculations shall include:

.1 details of all the installation components:

particulars of engine, propeller, damper, flexible coupling, reduction gear, generator, etc.;

speeds corresponding to the principal long-term operating conditions specified for operation under partial loads (half speed, slow speed, dead slow speed, trawling operation, zero-speed operation for installations comprising CP-propellers, main diesel generator conditions, etc.);

layouts of all installation operating conditions possible;

initial data for the design torsional diagram of the installation;

.2 natural frequency tables for all basic modes of vibration having a resonance up to the 12th order inclusive within the speed range $(0\text{-}1,2)n_r$, with relative vibration amplitudes of masses and moments, and with scales of stresses (torques) for all sections of the system;

.3 for each order of all vibration modes under consideration:

resonance vibration amplitudes of the first mass of the system;

resonance stresses (torques) in all the system components (shafts, reduction gear, couplings, generators, compression or compression-key joints, etc.) and temperatures of the rubber components of flexible couplings as compared to relevant permissible values;

.4 total stresses (torques), where it is necessary to consider the simultaneous effect of disturbing moments of several orders, as compared to relevant permissible values;

.5 stress (torque) curves for the principal sections of the system with indication of permissible values for continuous running and rapid passage and of restricted speed ranges where these are assigned;

.6 conclusions based on the results of calculation.

8.1.5 The alternating torsional stress amplitude is understood as $(\tau_{max} - \tau_{min})/2$, as it can be measured on a shaft in a relevant condition over a repetitive cycle.

8.2 PERMISSIBLE STRESSES FOR CRANKSHAFTS

8.2.1 For main engine crankshafts of icebreakers and of ships with ice categories **Ice4 – Ice6** within the speed range $(0,7 - 1,05)n_r$, and for main engine crankshafts of other types of ships and the crankshafts of engines driving generators and other auxiliary machinery for essential services within the speed range (0,9 - 1,05) n_r, the total stresses due to torsional vibration under conditions of continuous running shall not exceed the values determined by the following formulas:

when calculating a crankshaft in accordance with **2.4.5**, Part IX "Machinery"

$$\tau_1 = \pm\tau_N; \qquad (8.2.1\text{-}1)$$

when calculating a crankshaft by another method

$$\tau_1 = \pm 0{,}76\frac{R_m + 160}{18}C_d; \qquad (8.2.1\text{-}2)$$

within speed ranges lower than indicated

$$\tau_1 = \pm\frac{\tau_N\left[3 - 2(n/n_\text{p})^2\right]}{1{,}38}, \qquad (8.2.1\text{-}3)$$

or

$$\tau_1 = \pm 0{,}55\frac{R_m + 160}{18}C_d\left[3 - 2\left(n/n_\text{p}\right)^2\right], \qquad (8.2.1\text{-}4)$$

where:

τ_1 – permissible stresses, MPa;

τ_N – the maximum alternating torsional stress determined during crankshaft calculation from Formula (2.4.5.1), Part IX "Machinery" for the maximum value of W_p, in MPa;

R_m – tensile strength of shaft material, MPa. When using materials with the tensile strength above 800 MPa R_m = 800 MPa shall be adopted for calculation purposes.

n – speed under consideration, rpm.

For tugs, trawlers and other ships which main engines run continuously under conditions of maximum torque at speeds below the rated speed throughout the speed range $n = n_\text{r}$ shall be adopted and Formulas (8.2.1-1) and (8.2.1-2) shall be used. For the main diesel generators of ships with electric propulsion plants, all the specified values of n_r shall, by turn, be adopted as n, and in each of the ranges (0,9 - 1,05) n_r, Formulas (8.2.1-3) and (8.2.1-4) shall be used for partial loads;

n_r– rated speed, rpm;

C_d= 0,35 + 0,93$d^{-0,2}$ – scale factor;

d – shaft diameter, mm.

8.2.2 The total stresses due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through shall not exceed the values determined by the following formulas:

for the crankshafts of main engines

$$\tau_2 = 2\tau_1; \qquad (8.2.2\text{-}1)$$

for the crankshafts of engines driving generators or other auxiliary machinery for essential services

$$\tau_2 = 5\tau_1, \qquad (8.2.2\text{-}2)$$

where:

τ_2 – permissible stresses for speed ranges to be rapidly passed through, MPa;

τ_1 – permissible stresses determined by one of Formulas (8.2.1-1) to (8.2.1-4).

8.3 PERMISSIBLE STRESSES FOR INTERMEDIATE, THRUST, PROPELLER SHAFTS AND GENERATOR SHAFTS

8.3.1 Under conditions of continuous running, the total stresses due to torsional vibration shall not exceed the values determined by the formulas:

for the shafts of icebreakers and **Ice4 – Ice6** ice class ships within the speed range (0,7-1,05) n_r, and for the shafts of all other ships and generator shafts within the speed range (0,9 - 1,05) n_r

$$\tau_1 = \pm 1{,}38 \frac{R_m + 160}{18} C_k\ C_d\,; \quad (8.3.1\text{-}1)$$

within speed ranges lower than indicated

$$\tau_1 = \pm \frac{R_m + 160}{18} C_k C_d \left[3 - 2\left(n / n_{\text{p}}\right)^2\right], \qquad (8.3.1\text{-}2)$$

where:

τ_1 – допустимі напруження, МПа;

R_m – tensile strength of the shaft material, MPa.

When using the material with the tensile strength over 800 MPa (for intermediate and thrust shafts of alloyed steel) and over 600 MPa (for intermediate and thrust shafts of carbon and carbon-manganese steel, as well as for propeller shaft) R_m =800 MPa and R_m =600 MPa shall be assumed in the calculations accordingly;

C_k – factor obtained from Table 8.3.1;

for C_d, n, n_{p} – refer to 8.2.1.

Table 8.3.1 **Coefficient C_k**

Structural shaft type		C_k
Intermediate shaft, thrust shaft in external thrust bearing outside the area of roller bearing or the collar area, generator shaft	with integral coupling flanges or shrink fit couplings [1]	1,0
	with a radial hole (refer to **5.2.7**)	0,50
	with a taper joint keyway (refer to **5.2.9**)	0,60
	with a cylindrical joint keyway (refer to. **5.2.9**)	0,45
	with a longitudinal slot (refer to **5.2.8**)	0,30[2]
Thrust shaft in way of the collar or the roller thrust bearing (refer to **5.2.2**)		0,85
Гребний вал	forward sections (k=1,15, refer to **5.2.3**)	0,80
	sections in way of the aft stern-tube bearing and propeller (k=1,22, k=1,26, refer to **5.2.3**)	0,55

[1] when shafts may experience vibratory stresses close to the permissible stresses for continuous operation, the diameter increase in the compression joint shall be provided.

[2] other C_k value may be substantiated and calculated. C_k = 1,45/*scf*,

where: *scf* is defined as the ratio between the maximum local principal stress and √3 times the nominal torsional stress (determined for the bored shaft without slots).

8.3.2 The total stresses due to torsional vibration within speed ranges prohibited for continuous running, but which may only be rapidly passed through shall not exceed:

for intermediate, thrust, propeller shafts and shafts of generators driven by the main engine

$$\tau_2 = \frac{1{,}7\tau_1}{\sqrt{C_k}}\,; \qquad (8.3.2)$$

for the shafts of generators driven by auxiliary engines, the value determined by Formula (8.2.2-2).

8.4 PERMISSIBLE TORQUE IN REDUCTION GEAR

8.4.1 For the case of continuous running or rapid passage, the alternating torques in any reduction gear step shall not exceed the permissible values established for the operating conditions by the manufacturer.

8.4.2 Where the values mentioned under **8.4.1** are not available, the alternating torque in any reduction gear step for the case of continuous running shall satisfy the following conditions:

within the speed range (0,7 to 1,05) n_{r} - for the main propulsion plants of icebreakers and ice class ships **Ice4 – Ice6** and (0,9 to 1,05) n_{r} - for other ships

$$M_{alt} \leqslant 0{,}3 M_{nom}; \qquad (8.4.2\text{-}1)$$

within speed ranges lower than indicated, the permissible value of alternating torque calculations shall be submitted to the Register review but in any case

$$M_{alt} \leqslant 1{,}3 M_{nom} - M, \qquad (8.4.2\text{-}2)$$

where:

M_{nom} – average torque in the step under consideration at nominal speed, N/m;

M – average torque at the speed under consideration, N/m.

For the case of rapid passage, the alternating torque value shall also be submitted to the Register review.

8.5 PERMISSIBLE TORQUE AND TEMPERATURE OF FLEXIBLE COUPLINGS

8.5.1 For the case of continuous running or rapid passage, the alternating torque in a coupling, relevant stresses in and temperatures of the flexible component material due to torsional vibration shall not exceed the permissible values established for the operating conditions by the manufacturer.

8.5.2 Where the values mentioned under **8.5.1** are not available, the torque, stress and temperature values permissible for continuous running and rapid passage shall be determined by the procedures approved by the Register.

8.6 OTHER INSTALLATION COMPONENTS

8.6.1 Under conditions of continuous running, the total torque (average torque plus alternating torque) shall not exceed the frictional torque in the keyless fitting of the propeller and shaft or shafting couplings.

8.6.2 Where, for generator rotors, the manufacturer's permissible values are not available, the alternating torque shall not exceed twice, in the case of continuous running, or six times, in the case of rapid passage, the nominal generator torque.

8.7 TORSIONAL VIBRATION MEASUREMENT

8.7.1 Data obtained from torsional vibration calculations for machinery installations with the main engines shall be confirmed by measurements.

The measurements shall cover all the variants and operation conditions of the installation, for which calculations were made in accordance with **8.1.2**, except emergency operation conditions listed in **8.1.2.6** and **8.1.2.7**.

In well-grounded cases, the Register may require torsional vibrations to be measured in auxiliary diesel generators and ICE-driven auxiliary machinery for essential services.

8.7.2 The results of measurement obtained on the first ship (unit) of a series apply to all the ships (units) of that series, provided their engine-shafting-propeller (driven machinery) systems are identical.

8.7.3 The free resonance vibration frequencies obtained as a result of measurement shall not differ from the design values by more than 5 per cent. Otherwise, the calculation shall be corrected accordingly.

8.7.4 The stresses shall be determined proceeding from the greatest vibration or stress amplitudes measured in the respective section of the torsiogram or oscillogram.

When estimating the total stresses due to vibration of several orders, the registered parameters shall undergo harmonic analysis.

8.8 RESTRICTED SPEED RANGES

8.8.1 Where the shaft stresses, torques in some installation components or temperature of the rubber componenets of flexible couplings arising due to torsional vibration exceed the relevant permissible values for continuous running determined in accordance with **8.2.1**, **8.3.1**, **8.4** – **8.6**, restricted speed ranges are assigned.

8.8.2 No restricted speed ranges are permitted for the following speeds:

$n \geq 0{,}7n_r$ – with respect to icebreakers and **Ice4 – Ice6** ice class ships;

$n \geq 0{,}8n_r$ – with respect to other ships;

$n = (0{,}9–1{,}05)n_r$ – with respect to diesel generators and other auxiliary diesel machinery for essential services.

Where the main diesel generators of ships with electric propulsion plants are concerned, all the fixed speed values corresponding to the specified conditions of partial loading shall alternately be adopted for n_r.

In icebreakers and **Ice6** ice class ships fitted with a FPP, blade frequency resonance is recommended tobe avoided within the range $(0{,}5–0{,}8)n_r$.

Barred speed range with one cylinder misfiring in case of one main engine on board the ship shall not influence the ship's steerability.

8.8.3 If all the other methods of lowering stresses (torques) due to torsional vibration prove ineffective, a vibration damper or antivibrator may be fitted where the values permitted by **8.2** to **8.6** are exceeded:

in the case of continuous running, within speed ranges where restricted speed range is not permitted or undesirable;

in the case of rapid passage, in any point of the speed range $(0–1{,}2)n_r$.

8.8.4 The vibration damper or antivibrator shall ensure lowering of stresses (torques) by not less than 85 per cent of the relevant permissible values at the resonance to which it is adjusted.

8.8.5 For icebreakers and **Ice4 – Ice6** ice class ships within the main engine speed range (0,771,05)nr and for other ships and diesel generators within the speed range (0,9–1,05)n_r, vibration dampers or antivibrators may be used to eliminate restricted speed ranges shall be agreed upon with the Register.

8.8.6 A restricted speed range is established proceeding from the speed range, in which the stresses (torques, temperature) exceed the permissible values increased by 0,02 of n_{res} on both sides (with regard to tachometer tolerance). The engine shall be stable in operation at the barred range boundaries.

For calculation purposes, the restricted speed range borders may be determined by the following formula

$$\frac{16n_{res}}{18 - n_{res}/n_r} \leqslant n \leqslant \frac{(18 - n_{res}/n_r)n_{res}}{16}, \qquad (8.8.6)$$

where: n_{res} – resonance speed, rpm.

For CPP with the possibility of individual pitch and speed control, both full and zero pitch conditions shall be considered.

8.8.7 Restricted speed ranges shall be marked off on the tachometer in accordance with **2.5.2**. Information on restricted speed ranges and their borders shall be made available on plates fastened at all the stations, from which the installation may be controlled.

8.8.8 For the case of remote control of the main machinery from the wheelhouse, the requirements of **4.2.2.4**, Part XV "Automation" shall be complied with.

9. VIBRATION OF MACHINERY AND EQUIPMENT. VIBRATION STANDARDS

9.1 GENERAL

9.1.1 This Section sets down the limits of vibration levels (vibration standards) for ships machinery and equipment.

The standards are intended to determine whether actual vibration levels in machinery and equipment installed onboard the ships during construction (after repair) and ships in service are permissible proceeding from vibration parameter measurements. The vibration standards provide three categories of technical condition of ship machinery and equipment:

A - condition of machinery and equipment after manufacturing (construction of the ship) or repair at the commissioning;

B - condition of machinery and equipment during normal operation;

C - condition of machinery and equipment when technical maintenance or repair is required.

The standards determine the upper limits of categories A and B.

For machinery and equipment, not mentioned in this section but affecting the safe operation of the ship, if it is required to assess their levels of vibration, one shall be guided by the standards specified by the manufacturer, or applicable national and international standards.

Manufacturer of ships machinery and equipment may apply other standards provided convincing data are available that the product is capable of operating under other vibration conditions.

9.1.2 Vibration measurements shall be taken on all the first ships of a series being built at each shipyard, on the first ship of modified design, on the single buildings and on the ships undergone conversion.

Vibration measurements of machinery and equipment shall be taken during construction of the ship according to the program approved by the Register.

Technical documentation on the results of measurements is submitted in accordance with the requirements of **1.5**, Part II «Hull».

Vibration measurements of machinery and equipment shall be carried out in compliance with the instructions of **18.7**, Part **5** of the Guidelines on Technical Supervision of Ships under Construction.

9.1.3 During construction of the ship (or after repair) the vibration level of the machinery and equipment shall not exceed the upper limit of category A, determined as to ensure sufficient margin for changing of vibration level in operation.

Under conditions of long-term service of the ship the vibration level of the machinery and equipment shall not exceed the upper limit of category B, determined as to ensure vibration strength and reliability of ship machinery and equipment.

9.1.4 The measurement results shall be compared with the permissible vibration levels. Where vibration exceeds the standards, measures shall be taken to reduce it to permissible level.

9.1.5 Vibration levels of machinery and equipment shall not exceed the standards both when the ships is lying and at specified ahead speeds under different loading conditions.

At non-specified rates of speed vibration exceeding established standards may be permitted, when these rates are not continuous.

9.1.6 In case of withdrawal from the present standards the technical substatiation shall be submitted to the Register review.

9.2 STANDARDIZED VIBRATION PARAMETERS

9.2.1 The root-mean square value of vibration rate, measured in 1/3-octave band, is assumed as the basic vibration parameter.

Measuring of vibration in octave band is allowed.

9.2.2 Alongside with the vibration rate the root-mean square value of vibration acceleration may also be a parameter measured.

9.2.3 Vibration parameters are measured in absolute units or in decibels relatively to standard limiting values of speed or acceleration being equal to $5 \cdot 10^{-5}$ mm/s, and $3 \cdot 10^{-4}$ m/s^2, , accordingly..

Conversion of the measured values of vibration rate into relative units shall be made using the formula

$$L = 20\lg\frac{v_e}{v_{eo}}, \qquad (9.2.3)$$

where:

v_e – the measured root-mean square value of vibration rate, mm/s;

v_{eo} – $5 \cdot 10^{-5}$ mm/s.

9.2.4 When vibration is measured in octave bands, the permissible values of the parameter measured may be increased by $\sqrt{2} = 1{,}41$ times (3 dB) as compared to those stated in 9.3 to 9.8 for bands with geometric mean frequency values of 2; 4; 8; 16; 31,5; 63; 125; 250 and 500 Hz.

9.2.5 Measurements of vibration of the machinery and equipment shall be taken for each of the three inter-perpendicular direction about the ship axes: vertical, horizontal-transverse and horizontal-longitudinal.

For internal combustion engines, measurements of vibration shall be taken according to direction of axes:

X - axial (coincident with the direction of the crankshaft),

Y - horizontal-transverse,

Z - vertical. Such designation shall be applied for main diesel engines and diesel engines of diesel-generators. The points of vibration measuring are indicated in Fig. 9.2.5.

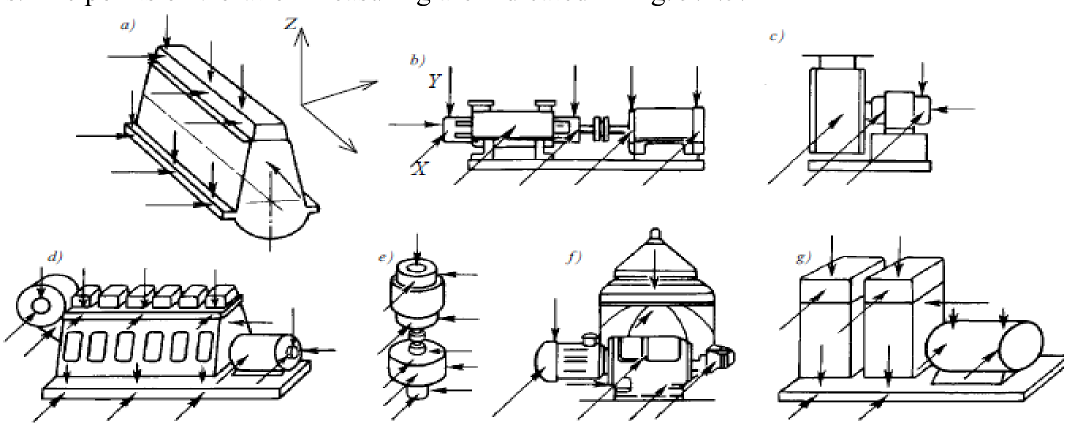


Fig. 9.2.5 Points of vibration measuring:

a - internal combustion engine; *b* - horizontal pump; *c* - fan; *d* - diesel-generator; *e* - vertical pump; *f* - separator; *g* - piston compressor. The points and directions of vibration measurement are shown by arrows.

9.2.6 Vibration standards of machinery are specified in the relative chapters for rigid and yielding supports to which machinery can be attached under shipboard conditions.

Rigid supports are those supports where the first natural frequency of the "support - machinery" system exceeds the basic exciting frequency (working frequency of revolution) in the vibration measurement direction by more than 25 per cent.

Yielding support is a support where the first natural frequency is less than 25 per cent of the machinery working frequency of revolution.

Yielding of the support is ensured by resilient mounting of the machinery or support (vibration insulators of various design - shock absorbers, springs, rubber insulators, etc.).

The vibration standards of categories A and B for machinery installed on rigid supports are specified in the relevant tables and figures. When the machinery is attached to yielding supports, the values of permissible vibration standards are increased. To determine the values of permissible vibration rate, multiplication factor for the particular type of machinery shall be applied.

9.3 VIBRATION STANDARDS FOR INTERNAL COMBUSTION ENGINES

9.3.1 Vibration standards are extended to cover ICE with 55 kW and above in power and rotation frequency ≤ 3000 m^{-1}.

9.3.2 Vibration of low-speed internal combustion engines installed on rigid supports is considered permissible for categories A and B, provided the root-means quare values of vibration rate and vibration acceleration measured in the direction of axes x and z do not exceed the values specified in Table 9.3.2 and Fig. 9.3.2.

When vibration is measured along the axis y (in horizontal-transverse direction) the permissible vibration rate standards for categories A and B shall be increased by 1,4 times.

When the internal combustion engines are installed on yielding supports (main medium-speed diesel engines and diesel engines of diesel-generators) the permissible vibration standards for categories A and B in the direction of axes x, y and z specified in Table 9.3.2 and Fig. 9.3.2 shall be increased by 1,4 times.

9.3.3 Vibration of machinery and devices hung on ICE shall not exceed the levels given in **9.3.2**.

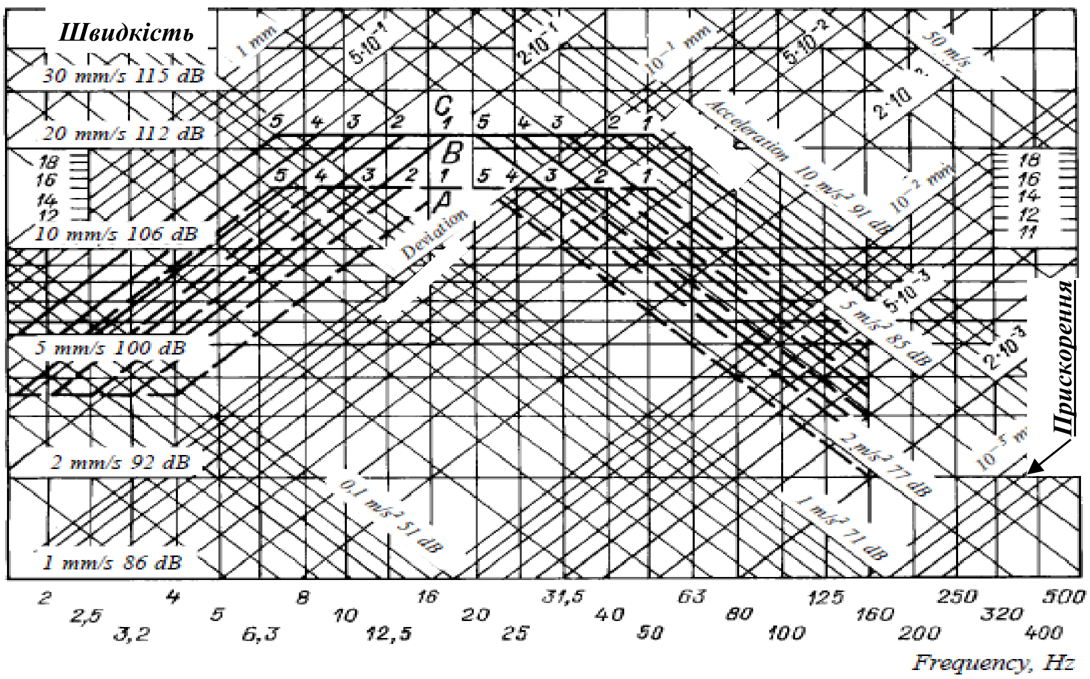


Fig.9.3.2. Vibration standards for internal combustion engines with a piston stroke:
1 – under 30 cm; 2 – 30 to 70 cm; 3 –71 to 140 cm; 4 –141 – 240 cm; 5 – over 240 cm;
.... Upper limit of category *A*; ——— Upper limit of category *B*.

9.3.4 Vibration of turbo-compressors measured on bearing housings is considered permissible for categories A and B, provided the root-meansquare values of vibration rate or vibration acceleration do not exceed the values specified in Table 9.3.4 and Fig. 9.3.4.

Table 9.3.2 **Vibration standards for internal combustion engines**

Line	Geometric mean frequencies of 1/3-octave bands, Hz	Engines with piston stroke, cm											
		under 30				30 to 70				71 to 140			
		Permissible values of vibration rate											
		category A		category B		category A		category B		category A		category B	
		mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	1,6	4	98	5,6	101	4	98	5.6	101	4	98	5,6	101
2	2	4	98	5,6	101	4	98	5.6	101	4	98	5,6	101
3	2,5	4	98	5,6	101	4	98	5,6	101	4	98	5,6	101
4	3,2	4	98	5.6	101	4	98	5.6	101	4.5	99	6,3	102
5	4	4	98	5.6	101	4.5	99	6,3	102	5,6	101	8,0	104
6	5	4,5	99	6.3	102	5.6	101	8,0	104	7.1	103	10	106
7	6,3	5,6	101	8.0	104	7,1	103	10	106	8.9	105	12,5	108
8	8	7,1	103	10	106	8.9	105	12.5	108	11	107	16	110
9	10	8,9	105	12.5	108	11	107	16	110	14	109	20	112
10	12,5	11	107	16	110	14	109	20	112	16	110	22	113
11	16	14	109	20	112	16	110	22	113	16	110	22	113
12	20	16	110	22	113	16	110	22	113	16	110	22	113
13	25	16	110	22	113	16	110	22	113	16	110	22	113
14	31,5	16	110	22	113	16	110	22	113	16	110	22	113
15	40	16	110	22	113	16	110	22	113	12,5	108	18	111
16	50	16	110	22	113	12,5	108	18	111	10	106	14	109
17	63	12,5	108	18	111	10	106	14	109	8	104	11	107
18	80	10	106	14	109	8	104	11	107	6,3	102	8,9	105
19	100	8	104	11	107	6.3	102	8.9	105	5	100	7.1	103
20	125	6,3	102	8.9	105	5	100	7,1	103	4	98	5.6	101
21	160	5	100	7.1	103	4	98	5.6	101	3,2	96	4,5	99

Line	Geometric mean frequencies of 1/3-octave bands, Hz	Engines with piston stroke, cm							
		141 to 240				over 240			
		Permissible values of vibration rate							
		category A		category B		category A		category B	
		mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
1	1,6	4	98	5,6	101	4	98	5,6	101
2	2	4	98	5.6	101	4,5	99	6.3	102
3	2,5	4.6	99	6,3	102	5,6	101	8,0	104
4	3,2	5.6	101	8,0	104	7,1	103	10	106
5	4	7.1	103	10	106	8.9	105	12,5	108
6	5	8.9	105	12,5	108	11	107	16	110
7	6,3	11	107	16	110	14	109	20	112
8	8	14	109	20	112	16	110	22	113
9	10	16	110	22	113	16	110	22	113
10	12,5	16	110	22	113	16	110	22	113
11	16	16	110	22	113	16	110	22	113
12	20	16	110	22	113	16	110	22	113
13	25	16	110	22	113	12,5	108	18	111
14	31,5	12,5	108	18	111	10	106	14	109
15	40	10	106	14	109	8	104	11	107
16	50	8	104	11	107	6,3	102	8,9	105
17	63	6,3	102	8,9	105	5	100	7,1	103
18	80	5	100	7,1	103	4	98	5,6	101
19	100	4	98	5,6	101	3,2	96	4.5	99
20	125	3.2	96	4,5	99	2,5	94	3,6	97
21	160	2.5	94	3,6	97	2	92	2,8	95

Table 9.3.4 Vibration standards for turbo-compressors

Line	Geometric mean frequencies of 1/3-octave band, Hz	Значення віброшвидкості, які є допустимими			
		category A		category B	
		mm /s	dB	mm /s	dB
1	**2**	**3**	**4**	**5**	**6**
1	1,6	10	106	1	109
2	2	12,5	108	16	110
3	2,5	14	109	20	112
4	3,2	20	112	25,5	114
5	4	24	114	34	116
6	5	24	114	34	116
7	6,3	24	114	34	116
8	8	24	11	34	116
9	10	24	114	34	116
10	12,5	24	114	34	116
11	16	24	114	34	116
12	20	24	114	34	116
13	25	24	114	34	116
14	31,5	24	114	34	116
15	40	24	114	34	116
16	50	24	114	34	116
17	63	24	114	34	116
18	80	24	114	34	116
19	125	24	114	34	116
20	160	24	114	34	116
21	200	24	114	34	116
22	250	18	111	26	116
24	320	14	109	20	112
24	400	11	107	16	110
25	500	9	106	13	109

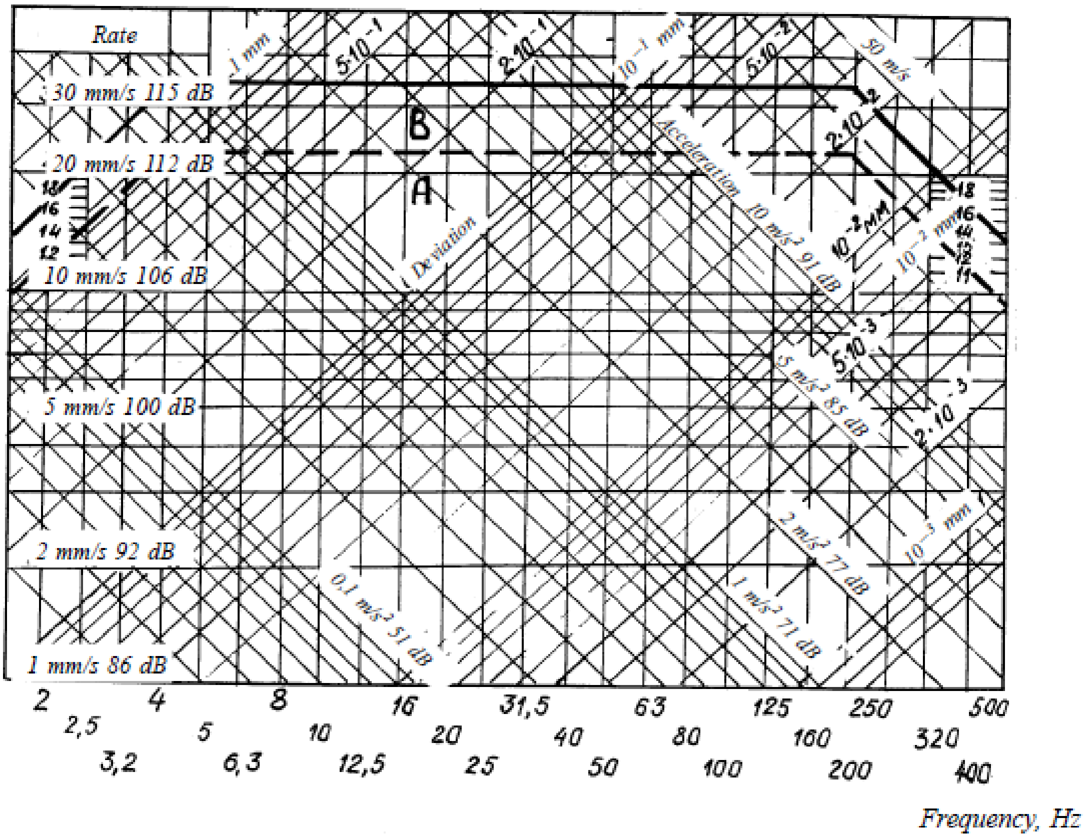


Fig.9.3.4. Vibration standards for turbo-compressors of internal combustion engines:
- - - - - - - - - - Upper limit of category *A*; ———————— Upper limit of category *B*.

9.4 VIBRATION STANDARDS FOR MAIN GEARED TURBINES AND THRUST BEARINGS

9.4.1 The running vibration of 15000 to 3000 kW horse power main geared turbines measured on the bearing housings is considered permissible for categories *A* and *B*, provided the root-means quare values of vibration rate or vibration acceleration do not exceed the values specified in Table 9.4.1 and Fig. 9.4.1.

The vibration standards specified in Table 9.4.1 and Fig. 9.4.1 shall be applied to the main geared turbines when installed both on rigid and on yielding supports.

Table 9.4.1 **Vibration standards for main geared turbines, thrust bearings, boilers, heat exchangers, ICE-driven generators, shaft-generators, turbo-drives, turbo-generators and piston compressors**

Line	Geometric mean frequencies of 1/3-octave bands, Hz	Main geared turbines and trust bearings				Boilers and heat exchangers			
		Permissible values of vibration rate							
		category A		category B		category A		category B	
		mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	1.6	1,5	90	2,5	94	3,5	97	5,6	101
2	2	1,9	92	3,1	96	3,5	97	5,6	101
3	2,5	2,4	94	3,8	98	3,5	97	5,6	101
4	3,2	3	96	4,8	100	4,4	99	7,1	103
5	4	3,7	97	6	102	5,6	101	8,9	105
6	5	4,6	99	7,5	104	7	103	11	107
7	6,3	5,7	101	9,3	105	8,8	105	14	109
8	8	7	103	11.5	107	10	106	16	110
9	10	8,8	105	14,5	109	10	106	16	110
10	12,5	11	107	18	111	10	106	16	110
11	16	11	107	18	111	10	106	16	110
12	20	11	107	18	111	10	106	16	110
13	25	11	107	18	111	10	106	16	110
14	31,5	11	107	18	111	10	106	16	110
15	40	11	107	18	111	10	106	16	110
16	50	8,8	105	14,5	109	8	104	12,5	106
17	63	7	103	11,5	107	6.3	102	10	106
18	80	5,7	101	9,3	105	5,2	100	8	104
19	100	4,6	99	7,5	104	–	–	–	–
20	125	–	–	–	–	–	–	–	–
21	160	–	–	–	–	–	–	–	–
22	200	–	–	–	–	–	–	–	–
23	250	–	–	–	–	–	–	–	–

Line	Geometric mean frequencies of 1/3-octave bands, Hz	ICE-driven generators, turbodrives and turbo-generators [1]				Piston compressors			
		Permissible values of vibration rate							
		category A		category B		category A		category B	
		mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
1	1.6	1	86	1,6	90	2	92	3,2	96
2	2	1,3	88	1,9	92	2,5	94	4	98
3	2,5	1,5	90	2,4	94	3,1	96	5,1	100
4	3,2	1,9	92	3	96	4	98	6.4	102
5	4	2,3	93	3,7	97	5	100	8	104
6	5	2,9	95	4,6	99	6,2	102	10	106
7	6,3	3,6	97	5,7	101	7,9	104	12,5	108
8	8	4,5	99	7,1	103	10	106	16	110
9	10	5,6	101	8,9	105	10	106	16	110
10	12,5	7	103	11	107	10	106	16	110
11	16	7	103	11	107	10	106	16	110
12	20	7	103	11	107	10	106	16	110
13	25	7	103	11	107	10	106	16	110
14	31,5	7	103	11	107	10	106	16	110
15	40	7	103	11	107	10	106	16	110
16	50	7	103	11	107	10	106	16	110
17	63	7	103	11	107	7.9	104	12,5	108
18	80	7	103	11	107	6.2	102	10	106
19	100	5,6	101	8,9	105	5	100	8	104
20	125	4,5	99	7,1	103	4	98	6,4	102
21	160	3,6	97	5,7	101	3,1	96	5,1	100
22	200	2,9	95	4,6	99	2,5	94	4	98
23	250	2,3	93	3,7	97	2	92	3,2	96
24	320	1,9	92	3	96	1,6	90	2,5	94
25	400	–	–	–	–	1,3	88	2,1	92
26	500	–	–	–	–	1	86	1,6	90

[1] Refer to 9.5.4

9.4.2 For main geared turbines of less than 15000 kW power the vibration standards are 3 dB lower than the values specified in Table 9.4.1 and Fig. 9.4.1.

9.4.3 Vibration of thrust bearings shall not exceed the standards given in **9.4.1** and **9.4.2**.

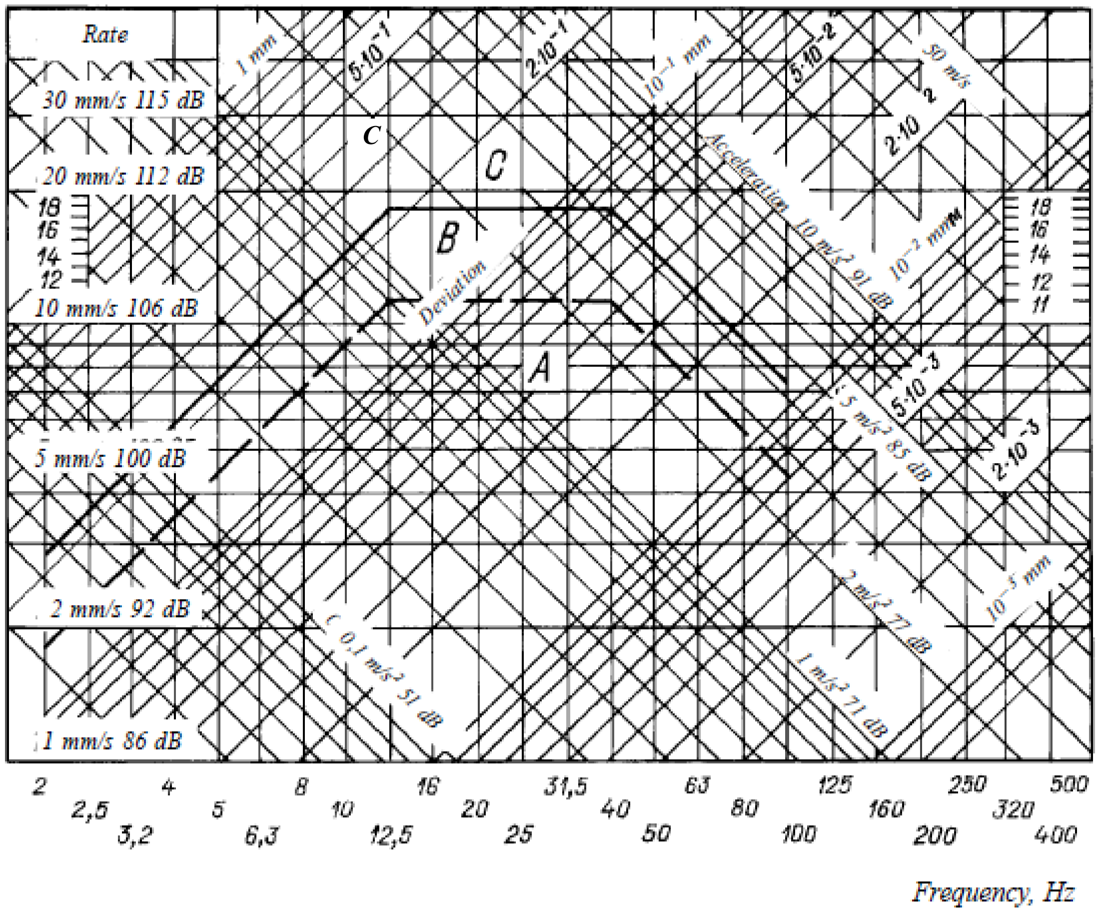


Fig. 9.4.1. Vibration standards for main steam geared turbines of 15000 to 30000 kW capacity and thrust bearings:

- - - - - - - - - - Upper limit of category A;

———— Upper limit of category B.

9.5 VIBRATION STANDARDS FOR AUXILIARY MACHINERY OF ROTARY TYPE

9.5.1 Vibration of vertical pumps with the capacity of 15 to 75 kW, including their electric drive, is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.1.

For pumps having the capacity of 2 to 15 kW the vibration standards for categories A and B are assumed being 3 dB lower compared with the vibration standards for the pumps hewing the capacity of 15 to 75 kW, and for the pumps with the capacity of 75 to 300 kW such standards shall be raised by 2 dB. Vibration standards for horizontal pumps for the above mentioned capacity range are assumed being 2 dB lower.

The vibration standards specified in Table 9.5.1 and Fig. 9.5.1 shall be applied to all pumps when installed on rigid support.

In case when the pumps are installed on yielding support, the permissible vibration standards shall be increased by 1,4 times for categories A and B.

9.5.2 Vibration of centrifugal separators is assumed permissible for categories A and B, when the rootmean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.2.

The vibration standards are specified considering the installation of separators on shock absorbers.

9.5.3 Vibration of fans and gas blowers of the inert gas systems is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.5.1 and in Fig. 9.5.3.

The vibration standards are specified considering the installation of fans and gas blowers on shock absorbers.

In case of rigid fixing, these standards shall also be applied.

***Table 9.5.1* Vibration standards for pumps, centrifugal separators and fans**

Geometric mean frequencies of 1/3-octave bands, Hz	Pumps with the capacity of 15 to 75 kW				Centrifugal separators				Fans			
	Permissible values of vibration rate											
	category *A*		category *B*		category *A*		category *B*		category *A*		category *B*	
	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1.6	1	86	1	86	1	86	1,3	88	1	86	1,3	88
2	1	86	1,2	88	1	86	1,6	90	1	86	1,6	90
2,5	1.1	87	1,4	89	1.3	88	2	92	1,3	88	2	92
3,2	1,4	89	2	92	1,6	90	2,5	94	1,6	90	2.5	94
4	1,7	91	2,5	94	2	92	3,2	96	2	92	3.2	96
1	2	3	4	5	6	7	8	9	10	11	12	13
5	2.2	93	3,3	96	2.5	94	4	98	2.6	94	4	98
6,3	2,7	95	4	98	3,2	96	5	100	3,3	96	5	100
8	3.5	97	5	100	4	98	6,4	102	4.1	98	6.4	102
10	4,3	99	6,3	102	5	100	8	104	5.2	100	8	104
12,5	5,5	101	8	104	5	100	8	104	6.7	103	10,3	106
16	7	103	10	106	5	100	8	104	8,5	105	13	108
20	7	103	10	106	5	100	8	104	8,5	105	13	108
25	7	103	10	106	5	100	8	104	8,5	105	13	108
31,5	7	103	10	106	5	100	8	104	8,5	105	13	108
40	7	103	10	106	5	100	8	104	8,5	105	13	108
50	7	103	10	106	5	100	8	104	8.5	105	13	108
63	7	103	10	106	5	100	8	104	6.7	103	10,3	106
80	5,5	101	8	104	5	100	8	104	5.2	100	8	104
100	4,3	99	6,3	102	5	100	8	104	4,1	98	6,4	102
125	3,5	97	5	100	4	98	6.4	102	3.3	96	5	100
160	2,7	95	4	98	3,2	96	5	100	2.6	94	4	98
200	2.2	93	3,3	96	2,5	94	4	98	2	92	3,2	96
250	1.7	91	2,5	94	2	92	3,2	96	1.6	90	2,5	94
320	1,4	89	2	92	1,6	90	2.5	94	1,3	88	2	92
400	–	–	–	–	1,3	88	2	92	1	86	1,6	90
500	–	–	–	–	1	86	1,6	90	1	86	1,3	88

9.5.4 Vibration of turbo-drives, turbo-generators and generators of diesel-generators (ICE-driven generators) with the capacity of 1000 to 2000 kW, measured on the bearing housings, is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.5.4.

For the turbo-drives, turbo-generators and generators of diesel-generators with the capacity under 1000 kW the vibration standards for categories A and B are by 4 dB lower than the values stated in Table 9.4.1 and in Fig. 9.5.4.

The vibration standards for turbo-drives and turbo-generators shall be applied when these are installed both on rigid and on yielding supports.

The vibration standards for generators of diesel-generators when installed on yielding supports shall be doubled.

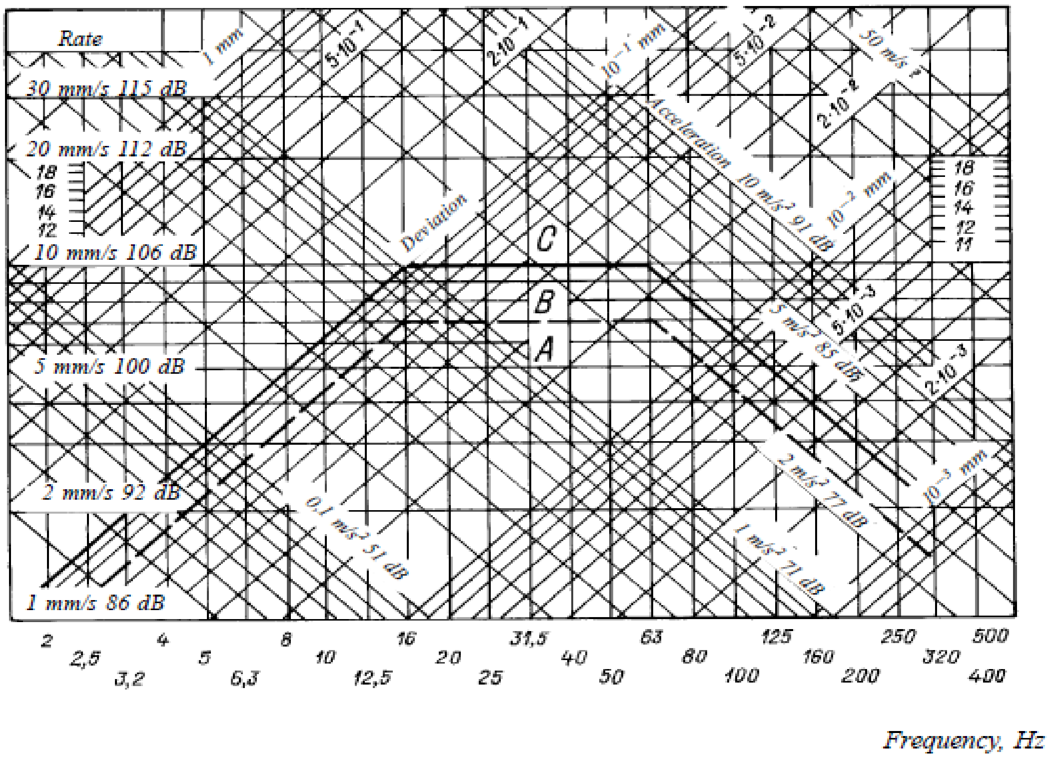


Fig.9.5.1. Vibration standards for pumps with the capacity of 15 to 75 kW

- - - - - - - - - - Upper limit of category A; ———— Upper limit of category B.

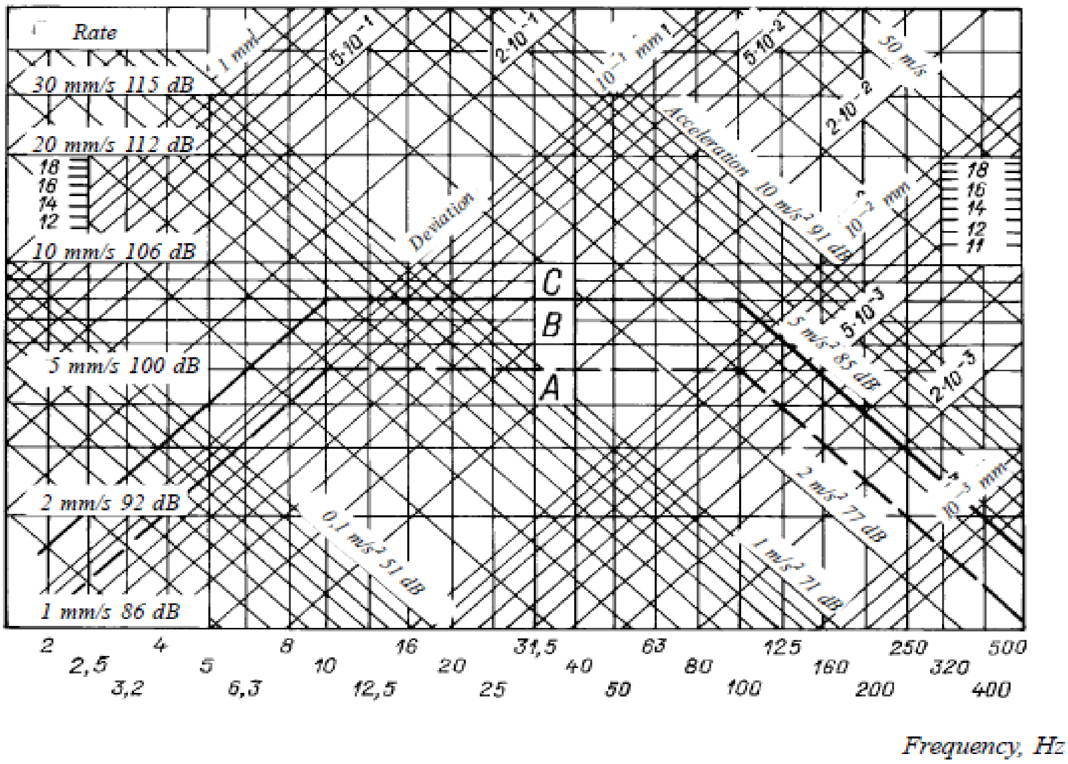


Fig.9.5.2. Vibration standards for centrifugal separators

- - - - - - - - - - Upper limit of category A; ———— Upper limit of category B.

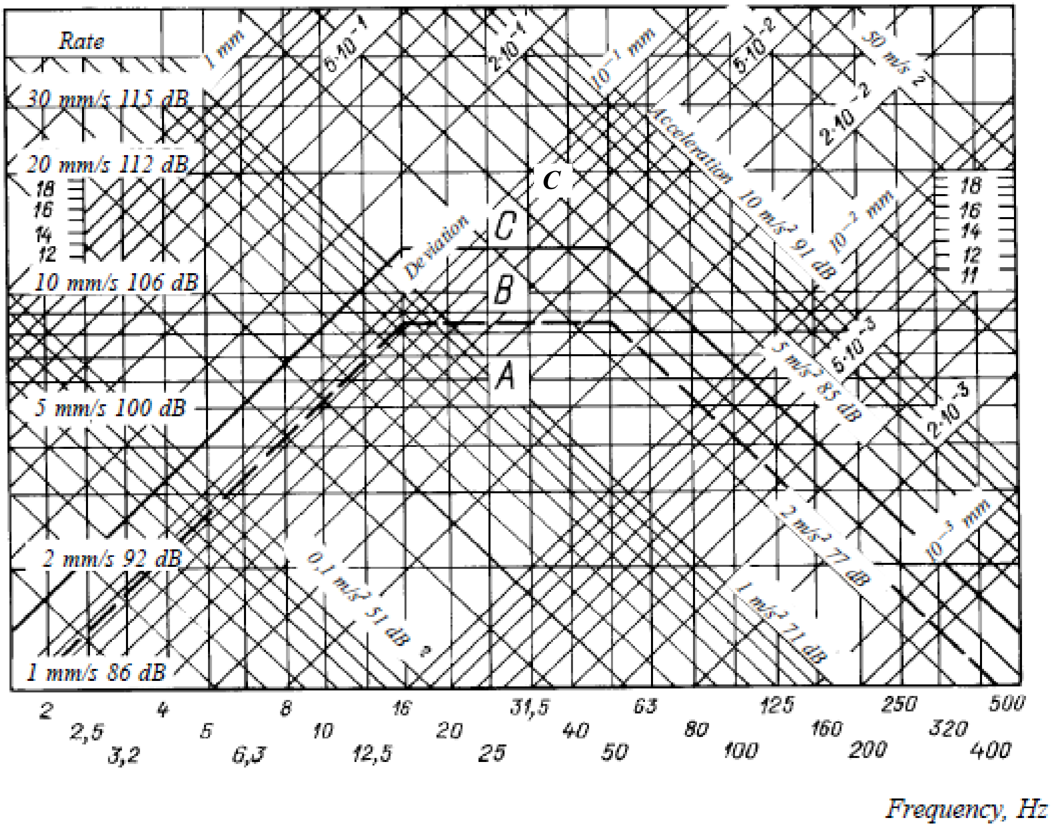


Fig.9.5.3. Vibration standards for fans

- - - - - - - - - - Upper limit of category A; ———— Upper limit of category B.

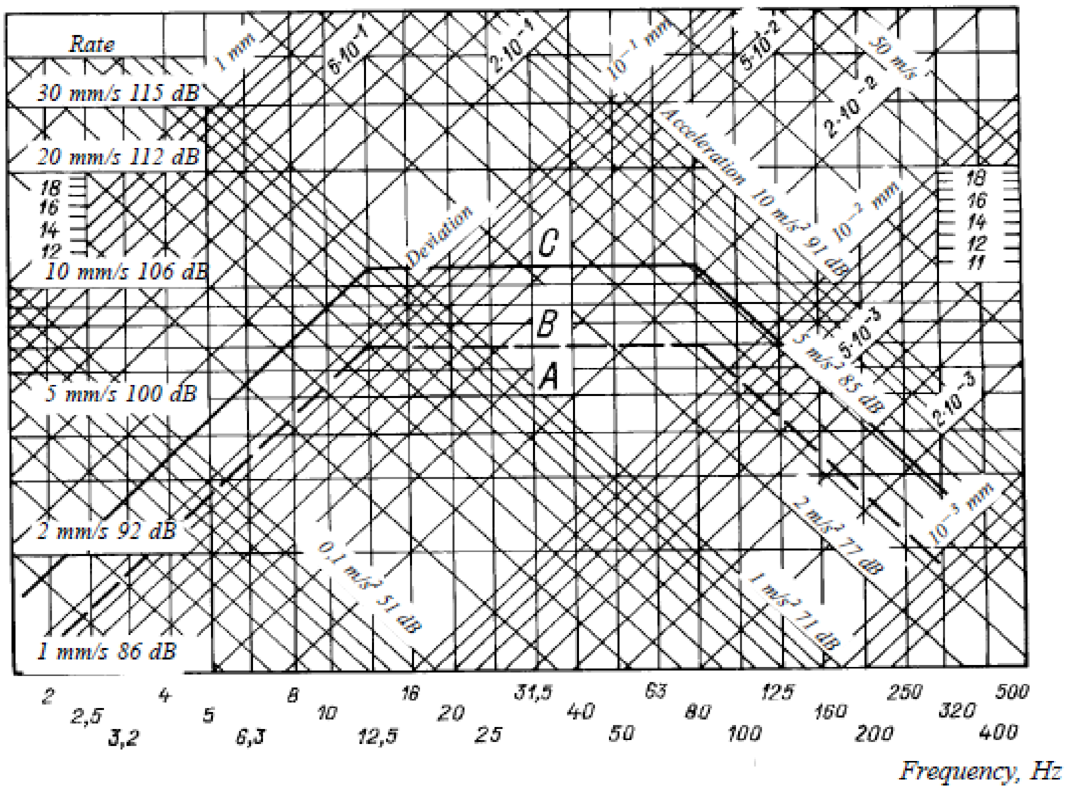


Fig.9.5.4. Vibration standards for ICE-driven generators, shaft-generators, turbo-drives and turbo-generators of 1000 to 2000 kW capacity

- - - - - - - - - - Upper limit of category A; ———— Upper limit of category B.

9.6 VIBRATION STANDARDS FOR PISTON AIR COMPRESSORS

9.6.1 Vibration of piston air compressors is assumed permissible for categories A and B, when the rootmean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.6.1.

When the compressor is mounted on the shock-absorbers, the vibration standards shall be raised by 4 dB.

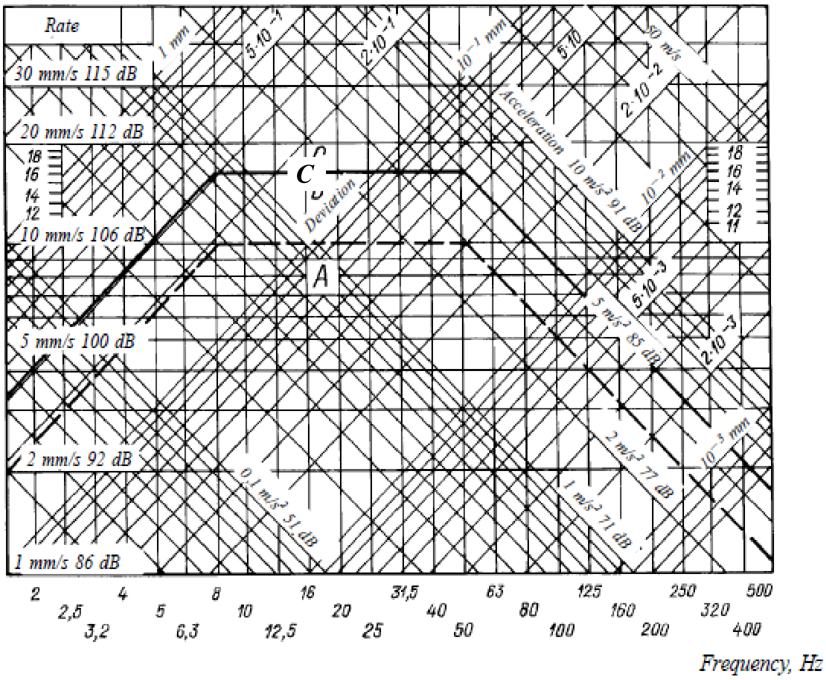


Fig.9.6.1. Vibration standards for piston compressors

- - - - - - - - - - Upper limit of category A; ———— Upper limit of category B.

9.7 VIBRATION STANDARDS FOR BOILERS AND HEAT EXCHANGERS

9.7.1 Vibration of boilers and heat exchangers is assumed permissible for categories A and B, when the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.4.1 and in Fig. 9.7.1.

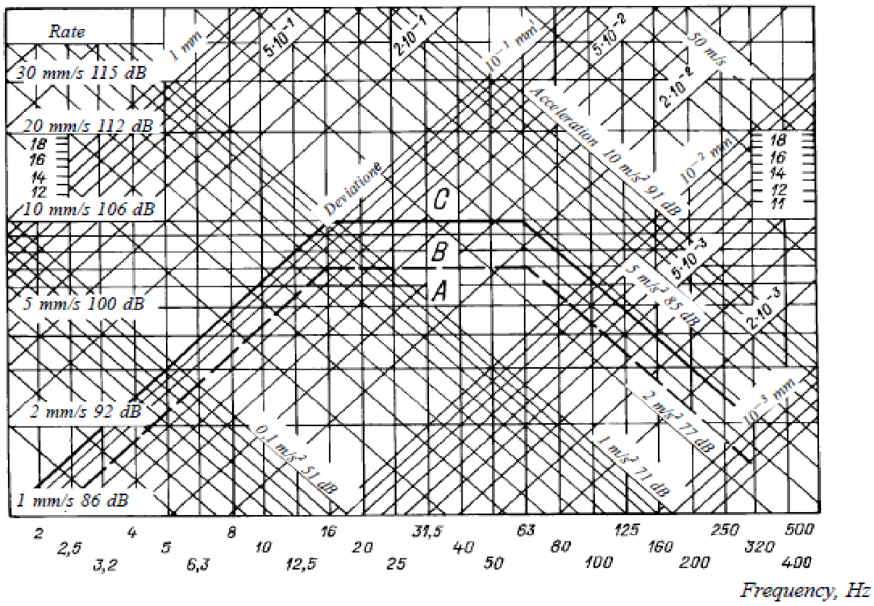


Fig.9.7.1. Vibration standards for boilers, auxiliary machinery and equipment

- - - - - - - - - - Upper limit of category *A*;

———— Upper limit of category *B*.

9.7.2 Vibration standards for auxiliary machinery and equipments, not covered by **9.5** and **9.6**, shall be chosen based on **9.7.1**.

9.8 VIBRATION STANDARDS FOR GEARED GAS TURBINES

9.8.1 Vibration of 250 to 25000 kW main geared gas turbines measured on the gas turbine supports and reduction gear bearings is considered permissible, provided the root-mean square values of vibration rate and vibration acceleration do not exceed the values stated in Table 9.8.1 and shown in Fig. 9.8.1.

9.8.2 Vibration standards for auxiliary gas turbines of less than 250 kW power shall be subject to special consideration by the Register and shall be submitted by the gas turbine manufacturer.

9.8.3 Vibration of gas-turbine-driven servo-machinery and devices shall not exceed the levels given in**9.8.1** and **9.8.2**.

9.8.4 Виробник ГТД може відступати від цих норм у випадку наявності переконливих даних щодо працездатності ГТД при інших рівнях вібрації.

Table 9.8.1 **Vibration standards for geared gas turbines**

Line	Geometric mean frequencies of 1/3-octave bands, Hz	Permissible values of vibration rate			
		category *A*		category *B*	
		mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**	**6**
1	1,6	1,6	90	2,9	96
2	2	1,8	91	3,5	97
3	2.5	2,2	93	4,3	9
4	3,2	2,7	95	5,3	100
5	4	3.2	96	7,0	103
6	5	4	98	9	105
7	6,3	5	100	11	107
8	8	6,7	103	13	108
9	10	8	104	16,5	1 0
10	12,5	8	104	16,5	110
11	16	8	104	16,5	110
12	20	8	104	16,5	110
13	25	8	104	16,5	110
14	31,5	8	104	16,5	110
15	40	8	104	16,5	110
16	50	8	104	16,5	110
17	63	8	104	16,5	110
18	80	8	104	16,5	110
19	100	8	104	16,5	110
20	125	8	104	16,5	110
21	160	8	104	16,5	110
22	200	8	104	16,5	110
23	250	8	104	16,5	110
24	320	8	104	16,5	110
25	400	8	104	16,5	110
26	500	8	104	16,5	110
27	640	6,5	102	12,5	108
28	800	4,8	100	10	106
29	1000	4	98	8	104
30	1280	3	96	7	103
31	1600	2,6	94	5	100
32	2000	2,1	92	3,9	98
33	2560	1,8	91	3	96
34	3200	1,5	90	2.4	95
35	4000	1	86	2	92
36	5120			1,7	91
37	6400			1,4	89
38	8000			1	86

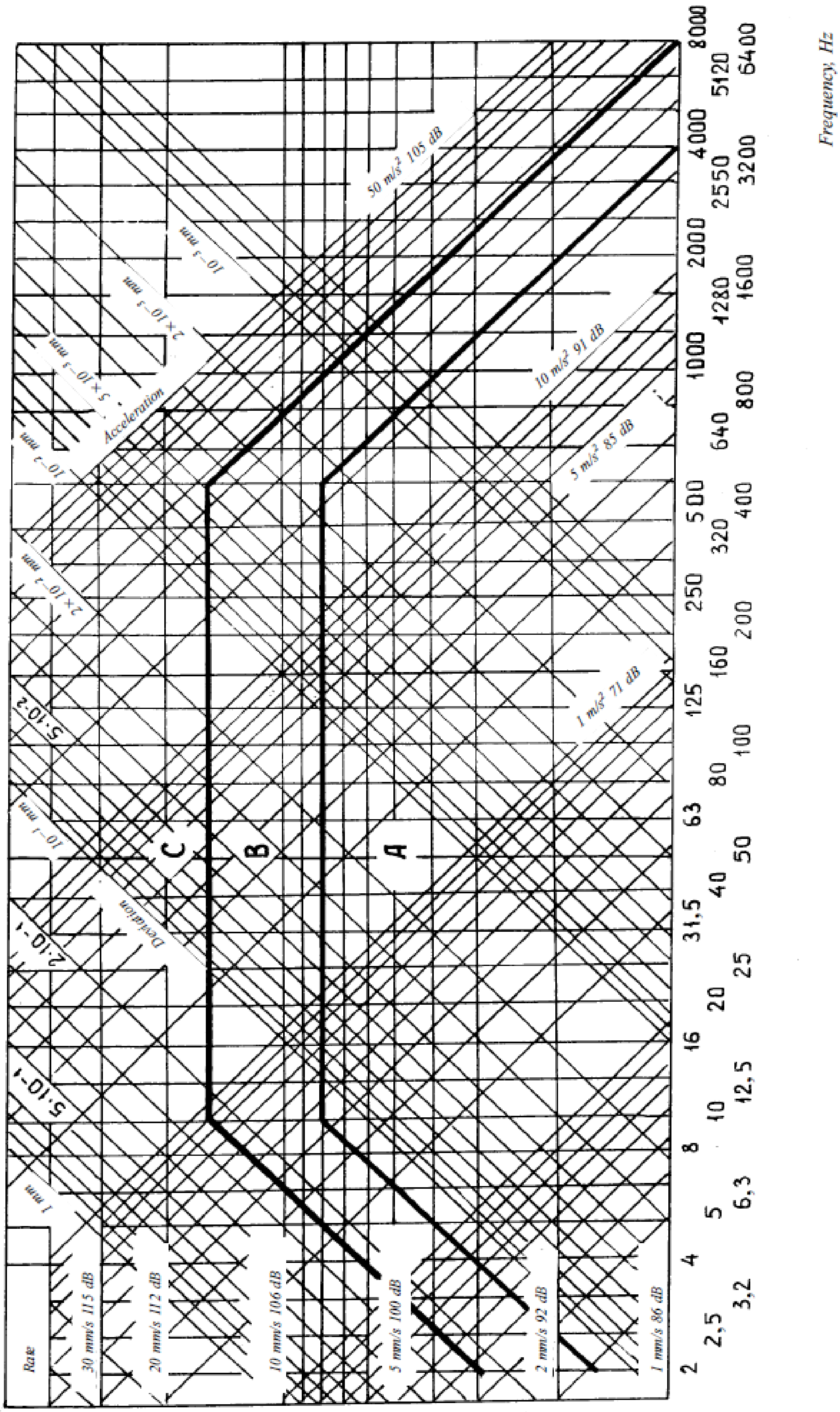


Fig. 9.8.1-1
Vibration standards for geared gas turbines

9.9 VIBRATION STANDARDS FOR MAIN AZIMUTH THRUSTERS

9.9.1 Vibration standards are extended to cover main azimuth thrusters driven by ICE- or electric motor wuth capacity 3000 kW with the main azimuth thruster speed of the inlett (drive) shaft 2000 rpm.

9.9.3 Vibration of main azimuth thrusters is considered admissible for the categories as follows A and B, if the root-mean square values of vibration rate measured in the range of 10 - 1000 Hz, calculated in accordance with ISO 10816-1, do not exceed the values specified in Table 9.9.3 and in Fig. 9.9.3.

9.9.4 Deviations from these standards, as, for example, in the case of the use of cardan shafts on the shaft line, shall in each case be the subject of special consideration by the Register.

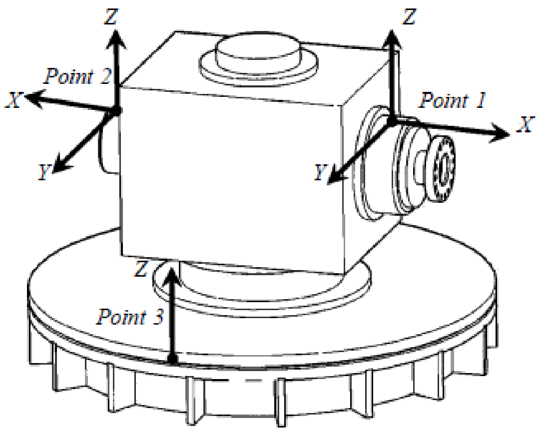


Fig. 9.9.2 Points of vibration measuring of main azimuth thrusters

Vibration measurements are carried out in three mutually perpendicular directions relative to the axes of the vessel: vertical, horizontal-traverse and horizontal-longitudinal.

The direction of vibration measurements is indicated by the direction of the axes:
X – axial (coinciding with the direction of the input shaft from the mechanical drive);
Y - horizontal-traverse;
Z – vertical.

Table 9.9.3 **Vibration standards of azimuth thrusters**

The relative speed of the input (drive) shaft, *n*	Permissible RMS Vibration speed[1]			
	category *A*		category *B*	
	mm/s	dB	mm/s	dB
1	**2**	**3**	**4**	**5**
0,54	0,83	84	1,06	86
0,61	1,98	92	2,70	95
0,67	3,01	96	4,16	98
0,73	3,92	98	5,44	101
0,79	4,71	99	6,54	102
0,85	5,38	101	7,46	103
0,91	5,91	101	8,20	104
0,97	6,36	102	8,76	105
1,03	6,67	102	9,14	105
1,10	6,86	103	9,34	105

[1]root-mean square values rate measured in the range of 10 - 1000 Hz in accordance with ISO 10816-1 (in Ukraine - ISO 10816-1:1995).

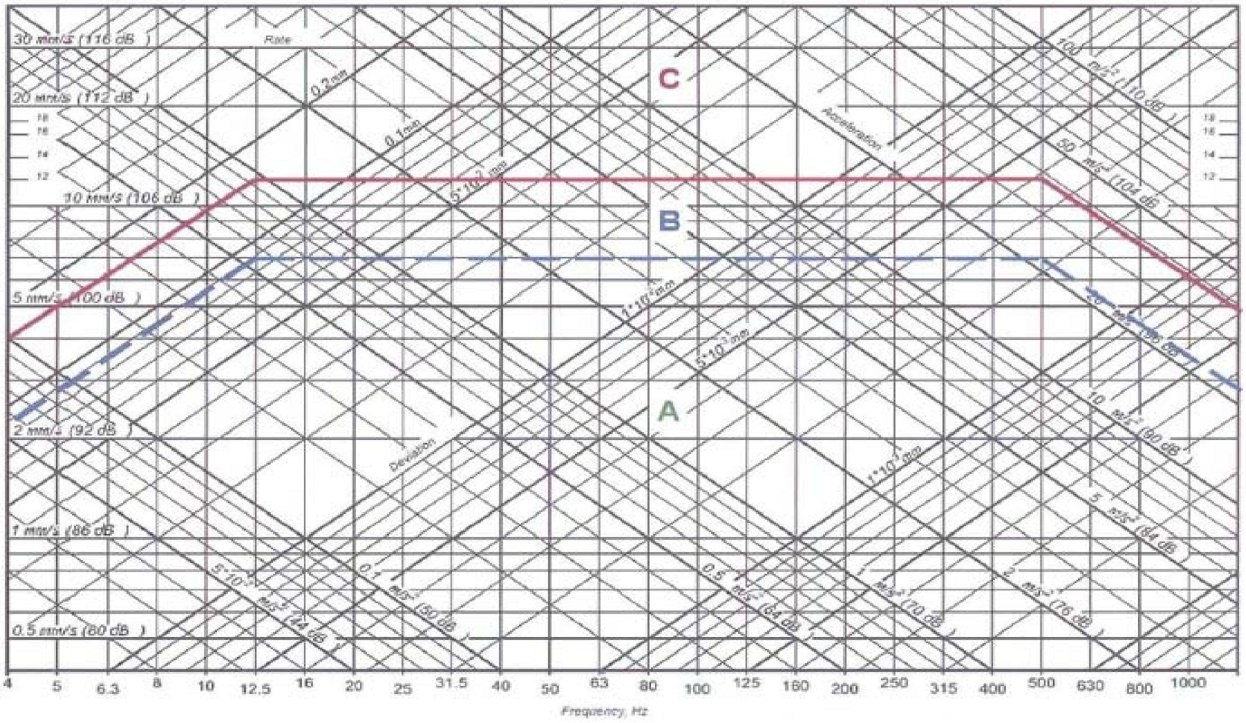


Fig. 9.9.3 Vibration standards of main azimuth thrusters

10. SPARE PARTS

10.1 GENERAL

10.1.1 The spare part standards given in this section set the minimum number of spare parts stored on board relating to the equipment essential to the propulsion and safety of the ship.

10.1.2 The nomenclature and the amount of spare parts for icebreakers and ships equipped with machinery of the types other than those indicated in 10.2 shall, in each case, be submitted for consideration to the Register with regard to the manufacturers' recommendations.

The availability of other spare parts on board the ship in addition to those specified in the Tables 10.2-1 to 10.2-8 is up to the shipowner's discretion.

10.1.3 Each ship shall be provided with a set of appropriate tools and appliances necessary for dismantling and assembling of the machinery in service conditions.

When dismantling and assembly of machinery can be carried out by the manufacturer's service or dedicated coastal service only, the amount of spare parts on board the ship shall be specially considered by the Register.

10.1.4 Each ship shall be provided with a set of flexible joints of every type and size used in the ship's systems and machinery.

10.1.5 The spare parts shall be properly secured in easily accessible places, marked and efficiently protected against corrosion.

When using spare parts, it is recommended to replenish them at the earliest opportunity.

10.1.6 If the number of spare parts determined according to the list given below is a fraction, then to define the amount of spares, the nearest greatest whole number shall be taken.

10.1.7 For ships of restricted navigation areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN**, **A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** and for floating docks, the required minimum of spare parts is not regulated.

For the definitions of restricted areas of navigation, refer to **2.2.5**, Part I "Classification"..

10.2 LIST OF MINIMUM RECOMENDED SPARE PARTS

Table 10.2-1 **List of minimum recommended spare parts for main internal combustion engines**

№	Spare parts	Main engines of ships considered with regard to navigation area [1,2,3]		Supply of spare parts	Auxiliary engines of ships considered with regard to navigation area [1,3,4]		Supply of spare parts
		Unrestricted, **A**	Restricted **R1, A-R1**		Unrestricted, **A**	Restricted **R1, A-R1**	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Main bearings or shells of each type and size fitted, complete with shims, studs (bolts) and nuts	1 set		M	1 set	–	–
2	Cylinder liner with valves, joint rings and gaskets	1		M	Joint rings and gaskets only — 1 set		R
3	Cylinder cover with valves, joint rings and gaskets	1		M	Joint rings and gaskets only — 1 set		R
3.1	Cylinder cover bolts and nuts	1/2 set per cover		R	–	–	–
4	Cylinder valves						
4.1	Exhaust valves, complete with casings, seats, springs and other valves, per cylinder	2 sets	1 set	R	2 sets	1 set	R
4.2	Air inlet valves: as for item 4.1	1 set		R	1 set	–	–
4.3	Starting air valve, complete with casing, seats, springs and other valves	1		M	1	–	R
4.4	Cylinder overpressure sentinel valve, complete	1		M	1	–	R
4.5[5]	Fuel valves of each size and type fitted, complete with all fittings, for one engine	1 set	¼ set	M	½ set	¼ set	R
5	Connecting rod bearings						
5.1	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set		M	1 set		R
5.2	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set		M	1 set		R
6	Pistons						
6.1	Crosshead type internal combustion engine; piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts	1		M	1		-
6.2	Trunk piston type internal combustion engine: piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod	1		M	1		R
7	Piston rings, for one cylinder	1 set		M	1 set		R
8	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set		M	1 set		R
9	Lubricator, complete, of the largest size, with its chain drive or gear wheels, or equivalent spare part kit	1	–	M	–		–
10	Fuel injection pumps						
10.1	Fuel pump complete or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.), or equivalent high pressure fuel pump	1		M	1		R
10.2	High pressure double wall fuel pipe of each size and shape fitted, complete with couplings	1	–	M	–	–	R

№	Spare parts	Main engines of ships considered with regard to navigation area [1,2,3]		Supply of spare parts	Auxiliary engines of ships considered with regard to navigation area [1,3,4]		Supply of spare parts
		Unrestricted, **A**	Restricted **R1, A-R1**		Unrestricted, **A**	Restricted **R1, A-R1**	
11[6]	Scavenge blower (including turbo chargers)						
11.1	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if other types	1 комплект	–	R	–		–

[1] For an installation comprising several engines of the same type, spare parts stock intended for one engine is sufficient. Engines of the same means the identical parts of which are interchangeable.
[2] For a thrust bearing built in main engine, see the requirements of item 1 of Table 10.2-4.
[3] The necessity of stocking further spares such as gear wheels, camshaft drive chains shall be determined by the shipowner with regard to the recommendations of engine manufacturers.
[4] For emergency engines, spare parts are not compulsory.
[5] Engines with one or two fuel valves per cylinder: one set of fuel valves, complete.
Engines with three or more fuel valves per cylinder: two fuel valves complete per cylinder, and a sufficient number of valve parts, excluding the body, to form, with those fitted in the complete valves, a full engine set.

[6] Locking devices shall be provided for the case of turbocharger being damaged. Spare parts may not be provided when the possibility of the internal combustion engine of this type operation without one turbocharger was demonstrated during the type tests with the satisfactory manoeuvring characteristics retained.

Note. For internal combustion engines with electronic control systems spare parts shall be supplied based on the recommendations of designer or manufacturer of the internal combustion engine

Table 10.2-2 **Steam turbines (main and auxiliary)1 [1,2]**

№	Spare part	Number of spare parts depending on the navigation area	
		Unrestricted **A**	Restricted **R1, A-R1**
1	Carbon sealing rings, where fitted, with springs, for each size and sealing rings type of gland, for one turbine	1 set	
2	Strainer baskets or inserts, for filters of special design, of each type and size	1 set per filter	

[1] Recommended minimum.
[2] When the installation consists of several turbines of the same type, the recommended minimum is assumed for one turbine only. By turbines of the same type, turbines are meant the identical parts of which are interchangeable.

Table 10.2-3 **Gears and couplings of main machinery [1,2,3]**

№	Spare part	Number of spare parts depending on the navigation area	
		Unrestricted, **A**	Restricted **R1, A-R1**
1	Plain bearing bushes of gears and couplings of each type and size fitted	1 set per bearing	
2	Pads of thrust block with liners or adjusting rings of each type and size fitted, with assorted liners for one face of thrust	1 set	
3	Roller type bearings of each type and size fitted, if used	1 set	

[1] Spare parts are necessary for the case of eventual replacement at sea by the crew.
[2] When several gears and couplings of the same type are used, spare parts are required for one gear or coupling, respectively. By gears and couplings of the same type, those gears and couplings are meant the identical parts of which are interchangeable.
[3] Supply is mandatory.

***Table 10.2-4* Shafting, propellers and active means of the ship's steering**

№	Spare part	Number of spare parts depending on the navigation area		Supply of spare parts
		Unrestricted, **A**	Restricted **R1, A-R1**	
1	2	3	4	**5**
1	Shafting			
1.1	Thrust block of shaftline			
1.1.1	Pads for ahead face of Mitchel type thrust block, where used	1		M
1.1.2	Inner and outer race with rollers where roller thrust bearings are used	1 set		R
1.2	Coupling bolts with nuts for flanges and shaft couplings, each type and size fitted	1 set of fittings		R
2	Propellers			
2.1[1]	Detachable propeller blades complete with securing items (for icebreakers and ships with ice categories **Ice4 - Ice6** only)	2 per propeller	–	M
2.2[1]	CPP blades complete with securing items (for icebreakers and ships with ice categories **Ice4**– **Ice6** only)	2 per propeller	–	M
2.3	Spare parts for arrangements of CP-propellers, steerable propellers, vertical axis propellers and servicing systems except those mentioned in items 2.1 and 2.2, depending on propeller type	On agreement with the Register	–	M

[1] Detachable blades are necessary for the case of eventual replacement by the crew when afloat.

***Table 10.2-5* Auxiliary machinery [1]**

№	Spare part	Number of spare parts depending on the navigation area	
		Unrestricted, **A**	Restricted **R1, A-R1**
1	**2**	**3**	**4**
1	Piston pumps		
1.1	Valves with seats and springs, each type and size fitted	1 set	–
1.2	Piston rings of each type and size fitted	1 set	1 set
2	Centrifugial pumps		
2.1	Bearings of each type and size fitted	1	
2.2	Rotor seals of each type and size fitted	1	
3	Rotary pumps (screw and gear pumps)		
3.1	Bearings of each type and size fitted	1	
3.2	Rotor seals of each type and size fitted	1	
4	Compressors		
4.1	Suction and delivery valves, each type and size fitted in one unit	½ set	
4.2	Piston rings of each type and size fitted in one piston	1 set	

[1] Supply is recommended.

***Table 10.2-6* Ship equipment and deck machinery**

№	Spare part	Number of spare parts depending on the navigation area		Supply of spare parts
		Unrestricted, **A**	Restricted **R1, A-R1**	
	Hydraulic steering gears			
1	Cylinder plunger seals, sealing rings for pumps of each type and size fitted	1 set		M
2[1]	Valve springs of each type and size fitted	1		M
3[1]	Safety and non-return valves of each type and size fitted	1	–	M
4	Ball or roller bearings	1 set for 1 pump		M

5	Special pipe connections of steering gear	1 set	M

[1] The list of spare parts is drawn up on agreement with the Register.

***Table 10.2-7* Steam boilers, thermal fluid boilers, pressure vessels and heat exchangers**

№	Spare part	Number of spare parts depending on the navigation area	Supply of spare parts
		Unrestricted, **A**, Restricted **R1**, **A-R1**	
1	2	3	4
1	Steam boilers (main and auxiliary for essential services), thermal fluid boilers		
1.1	Springs of safety valves of each type and size fitted 1	1 per boiler	M
1.2	Water gauge glasses, complete	1 per boiler	M
1.3[1]	Oil fuel burners, complete, each type and size fitted	1 per boiler	M
1.4[1]	Fuel atomizers complete with washers	1 per boiler	M
1.5	Tube plugs of each diameter fitted, including superheater plugs	For 4% of tubes but at most 20 pcs.	M
1.6	Boiler pressure gauge of each type and size fitted	1 set for 1 boiler unit	M
1.7	Metal gaskets of special type for superheater and economizer valves	1 set per boiler	R
1.8	Gaskets for manholes and other openings, each type and size fitted	1 set	R
2	Pressure vessels and heat exchangers		
2.1	Level gauge glasses of each type and size fitted	1	R
2.2	Gaskets and glands of special type for covers, manholes, openings and valves of each type and size fitted	1 set for 1 heat exchanger (pressure vessel)	R
2.3	Plugs for heat exchanger tubes	For 5% of tubes	M

[1]For boilers with automated burning units, the list of spare parts as per items **1.3** and **1.4** is drawn up on agreement with the Register.

***Table 10.2-8* Gas turbines (main and auxiliary)**

№	Spare part[1]	Number of spare parts depending on the navigation area		Supply of spare parts
		Unrestricted, **A**	Restricted **R1**, **A-R1**	
1	2	3		4
1	Flame tubes	1 set for 1 engine		M
2	Main burners	1 set for 1 engine		M
3	Auxiliary burners	1 set for 1 engine		M
4	Ignition arrangements, complete	1 set for 1 engine		M
5	Plasma igniters or ignition plugs	1 set for 1 engine		M
6	Spare parts for burners	1 set per 1 burner		M

[1] Additional spare parts as well as replaceable units (gas turbine-driven servo-machinery), the lifetime of which is less than the lifetime of the gas turbine, before shop repair shall be supplied by the gas turbine manufacturer on approval by the Register.

Symbols for Tables 10.2-1–10.2-8:
M — mandatory, R — recommended.

11 MACHINERY TECHNICAL CONDITION MONITORING SYSTEMS

11.1 GENERAL

11.1.1 The requirements of this Section apply to the machinery technical condition monitoring systems, which have been approved by the Register as the classification survey items on the basis of the Planned Maintenance Scheme (PMS) and condition control (CC).

11.1.2 Data of the machinery technical condition monitoring are intended for use:

by the Register surveyor, when carrying out surveys on the basis of PMS and CC;

by the ship crew to establish the terms for performing the machinery maintenance operations, i. e. providing maintenance on the “condition” basis;

by the Shipowner to assess the technical condition and to manage maintenance of ships, to schedule terms and scope of their repairs.

11.1.3 The composition of the equipment of the technical condition monitoring system, controlled parameters and frequency of their measurements, standards of the control item technical condition shall be approved by the Register when the survey system on the basis of PMS and CC is implemented on board the ship.

11.1.4 If the ship is fitted with machinery installation technical condition monitoring system, complying with the requirements of **11** with the introduction / application on the ship of Planned Maintenance Scheme for Machinery, then descriptive notation **PMS** (Planned Maintenance Scheme for Machinery) is added to the character of class in accordance with **2.2.28**, Part **I** «Classification».

11.2 CONTROL ITEMS AND PARAMETERS

11.2.1 The technical condition monitoring system may cover the following equipment:

main diesel engine, including turbocharger; main turbine;

AMSS; reduction gear;

shafting;

sterntube gear;

auxiliary diesel generators (turbogenerators);

systems maintaining operation of the main diesel engine (compressed air, fuel oil, lubricating oil and cooling);

steering gear.

11.2.2 On agreement with the Register, the ship may be equipped with the technical condition monitoring systems exercising control over:

the working process and wear of the cylinder and piston assembly of the main diesel engine;

the working process of the turbine;

the lubricating oil condition;

the vibration condition of the machinery;

the shock pulses of the roller bearings;

the electric values of the electrical equipment.

11.2.3 The conditions for acceptance of the technical condition monitoring results when carrying out surveys of the PMS and CC items are as follows:

the diagnostic parameters define the technical condition of the controlled item and are approved by the Register;

the limiting values of the diagnostic parameters have been determined on the basis of the requirements of the controlled item manufacturers and/or the Register;

the parameters used for the technical condition prediction shall be brought to standard conditions. The measured parameter values are brought to the standard conditions in accordance with **2.2.7**, Part IX “Machinery”;

the results of measurements, trend analysis and prediction of parameters shall be kept in a form accessible for the Surveyor:

in the tabular form, in the form of graphs on paper media or, preferably, on the PC media;

the frequency of the diagnostic parameter measurements shall provide reliability of determination of the control item technical condition;

the measuring instruments used in the technical condition monitoring systems shall have appropriate documents on verification by a competent authority.

11.3 GENERAL REQUIREMENTS FOR TECHNICAL CONDITION MONITORING SYSTEMS

11.3.1 The technical condition monitoring systems may be constructed on the basis of built-in (fixed) condition monitoring systems, portable control facilities or may combine both.

11.3.2 The built-in technical condition monitoring systems of the main engines, as a rule, shall be integrated structurally with the centralized monitoring systems and be capable of using the data obtained from the sensors of the centralized control system.

Technical condition monitoring system integrated with the centralized control system shall not affect the centralized monitoring functions.

11.3.3 The technical condition monitoring system integrated with the centralized control system shall incorporate the technical condition diagnosis functions with the aim to perform the maintenance and repair of the control item on the actual condition basis.

11.3.4 The built-in monitoring systems and their elements shall meet the requirements imposed on the ship automation systems (refer to Section **2**, Part XV "Automation").

The built-in monitoring systems installed on board the ships under construction or while in service shall be approved by the Register.

The built-in monitoring systems installed on board the ships are subject to the technical supervision with respect to:

check for functioning;

selection of cable cross-section;

protection, insulation and earthing means;

zero influence exerted by these systems on the operation of the equipment related to the items of the technical supervision of the Register.

Failures in the operation of the built-in monitoring system shall not adversely affect the operation of the equipment.

11.3.5 The portable control facilities and procedures for their application may be provided on board the ships under construction (or in service) after agreement with the Register.

The basis for the agreement is the attestation thereof and conclusion (on the basis of examination of the necessary materials and/or carrying out of tests) of a competent organization regarding techniques and means for diagnosis of the ship facilities.

11.3.6 The technical condition monitoring system shall provide for recording the diagnostic parameter values, their trend analysis, prediction of the control item technical condition. The condition prediction is performed on the basis of the previous history of diagnostic parameters with sufficient number of their measurements.

11.3.7 The requirements for computers used in the technical condition monitoring systems are similar to the requirements of Section **7**, Part XV "Automation".

11.3.8 The basic values of the diagnostic parameters used as initial (reference) data during the technical condition monitoring shall be obtained under the specific conditions of draught and the ship speed (at sea) and under operating conditions of the main engines and auxiliaries.

The basic data may be obtained on acceptance trials or on maiden voyage for a newbuilding or on another operational voyage under steady operating modes of the control items agreed with the Register.

11.4 TECHNICAL DOCUMENTATION

11.4.1 The following types of documentation on the technical condition monitoring system shall be submitted to the Register for review and approval:

.1 functional description with indication of the technical data and operating conditions (no approval stamp is affixed);

.2 methodological guidelines (instructions) for making measurements and control data processing (no approval stamp is affixed);

.3 test program for the built-in monitoring systems.

11.5 REQUIREMENTS FOR WORKING LUBRICATING OIL PARAMETERS

11.5.1 The requirements for the controlled parameters of working lubricating oils shall be consistent with the type of equipment to be surveyed.

Oil grades and methods of oil sampling for analysis shall be indicated for each machinery.

The oil sampling location shall be clearly described.

11.5.2 The range of the characteristics and rejected parameter values of the oils to be analysed are established by a developer of the monitoring system and agreed with the Register.

11.5.3 The oil sample shall be analysed by a recognized shore-based laboratory. On board the ships the ship rapid analysis attested by a competent organisation shall be used (refer to **11.3.5**).

11.5.4 The results of the oil analysis are submitted according to **11.2.3**.

11.6 REQUIREMENTS FOR CONTROL OF THE DIESEL ENGINE WORKING PROCESS PARAMETERS

11.6.1 The requirements apply to the equipment for measuring pressure in the engine cylinder and fuel supply parameters.

11.6.2 To process the measurement results of the working process parameters, use is also made of the parameters measured in the alarm system.

In this case, interference shall not be introduced into the operation of the alarm system.

11.6.3 The Register shall be given specifications of sensors, measuring equipment and measurement results processing program (including list of calculated parameters and method of presentation thereof).

11.6.4 The electronic unit used for measurement of the working process parameters shall have dynamic characteristics providing for the measurement of the maximum gas pressure in cylinder.

11.6.5 Measurement of the pressure in cylinder and fuel supply parameters with the use of the sensors presented is allowed to be made not on all cylinders simultaneously, but for all that the steady operating conditions of the diesel engine shall be maintained.

11.6.6 The equipment for measurement, processing and presentation of the cylinder pressure curve (indicator diagram) and the fuel supply characteristics shall provide for the analysis thereof with a resolution of not less than one degree of the crankshaft rotation.

11.6.7 The indicator diagram processing program shall calculate for each cylinder:

mean indicated pressure;

cylinder indicated power; maximum cylinder combustion pressure;

maximum compression pressure;

pressure on compression line at point 12° before the top dead centre (TDC);

pressure on expansion line at point 36° after the TDC;

the crankshaft rotation angle corresponding to the maximum combustion pressure;

ignition advance angle.

11.6.8 The fuel supply parameters processing program shall determine:

fuel injection beginning;

fuel injection time angle;

maximum fuel pressure.

11.6.9 The processing program shall provide for comparison of the loading in cylinders.

Permissible deviations of the working process parameters from the average over the cylinders:

mean indicated pressure - not more than ±2,5 %;

maximum combustion pressure - not more than ±3,5 %;

compression end pressure - ±2,5 %.

The cited values of the combustion pressure in any cylinder shall not be less than 85 % of the value obtained on basic tests.

The results of basic tests are considered to mean the results of the acceptance tests of the diesel engine on board or special tests on operational voyage) (refeer to **11.3.8**).

11.6.10 The measurement data shall be submitted according to **11.2.3**.

11.7 REQUIREMENTS FOR CONTROL OF WEAR PARAMETERS OF THE ENGINE CYLINDER AND PISTON ASSEMBLY

11.7.1 The parameter, which defines the engine cylinder and piston assembly condition (its wear), is the tightness of the combustion chamber.

11.7.2 The tightness of the combustion chamber is measured by a special instrument: pneumoindicator, which is a flow-metering device set at a particular cylinder diameter.

11.7.3 The methods for determination of the cylinder tightness and the standards for the cylinder and piston assembly condition shall be presented by the system developer.

11.7.4 The measurement data shall be submitted according to **11.2.3**.

11.8 REQUIREMENTS FOR CONTROL OF VIBRATION PARAMETERS

11.8.1 The objects of vibration control on the ship are the rotary type machinery listed in 11.2.1, as well as reciprocating compressors.

11.8.2 For the purpose of the machinery vibration condition monitoring, use shall be made of the following equipment, which provides for the measurement and processing of the vibration parameters: root-mean-square values of vibration rate or vibration acceleration in 1/3-octave band and in octave band, and the data analysis in temporal area:

vibrometers-analyzers;

vibration diagnosis systems performing measurement, processing, storage and spectrum analysis of the vibration parameters.

11.8.3 The basic requirements for the equipment used in the vibration condition monitoring system:

the housing of the vibrometer-analyzer shall correspond to the IP54 protection type (refer to **2.4.4.2**, Part XI "Electrical Equipment");

frequency range — not less than 4 to 16,000 Hz;

dynamic range — not less than 70 dB.

Special requirements for the vibration diagnosis systems:

the possibility of operating according to a process chart, which ensures performance of at least one complete measurement of the vibration parameters on all the monitoring system objects;

the possibility of transferring data to computer.

11.8.4 The composition of the vibration condition monitoring equipment and organization of the performance thereof shall be agreed upon with the Register when the PMS and CC based survey system is being implemented on board the ship.

11.8.5 When performing the vibration condition monitoring, consideration shall be given to the provisions of 18.7, Part V "Technical Supervision during Construction of Ships" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

11.8.6 The requirements for the installation and attachment of the vibration pickup on the controlled item shall be provided.

The preference shall be given to attachment of the pickup by a pin (screw).

To realize such attachment method, pins shall be fitted beforehand at all measurement points.

The vibration pickups may be installed on a magnet.

Where the vibration pickups cannot be installed using a pin or magnet, manual vibration pickups may be used.

11.8.7 For each machinery, points and directions for measuring vibration parameters shall be indicated. The manufacturers' recommendations shall be used. Where no such recommendations are available, type lay-out diagrams of the machinery vibration measurement points shall be taken as a guide (refer to **9.2.5**).

For the vibration condition monitoring, measurement may be restricted to one or two directions on one most loaded machinery bearing.

Note. For units consisting of a machinery and its driving unit (pump and electric motor, fan and electric motor), measurements are made on one machinery bearing and one motor bearing on the coupling side.

When exercising control of the separator vibration condition, measurements shall be made in two radial directions on both motor bearings and in three directions on the separator bowl bearing.

11.8.8 Standardization of the condition on the basis of the controlled parameter vibration levels shall be displayed in the documentation of the technical condition monitoring system submitted to the Register for review (refer to **11.4.1**).

It is necessary to use the recommendations of the control item manufacturer or to be guided by the Register standards (refer to Section **9**).

11.8.9 The results shall be submitted according to **11.2.3**.

11.9 REQUIREMENTS FOR CONTROL OF THE SHOCK PULSE

11.9.1 The condition of the roller bearings is assessed by a shock pulse method.

The controlled machinery manufacturer, developer or supplier of the technical condition monitoring system may propose another method of roller bearing condition assessment. In this case, the proposed method shall be approved by the Register.

11.9.2 For the bearing condition control by shock pulse method, special instruments are used: shock pulse meters and/or roller bearing condition indicators, which shall meet the following basic requirements:

.1 range of controlled bearings:

internal diameter — 50 to 1000 mm;

speed — 10 to 30,000 min^{-1};

dynamic range — not less than 90 dB;

.2 as regards dust- and watertightness, the instrument housing shall correspond to IP54 protection type (refer to **2.4.4.2**, Part XI "Electrical Equipment");

.3 instrument for control of the roller bearing condition may be combined with the vibrometer (refer to **11.8.2**).

11.9.3 The instrument for control of the roller bearing condition shall be fitted with a built-in calibrator to verify precision of readings.

11.9.4 The measurement methods shall make it possible to separate the values of shock pulses arising due to the roller bearing against the background of the signals from other sources.

The methods shall establish positions for other measurements to be made on the bearing housing on the basis of the maximum shock pulse value or contemplate special devices measuring bolts, where there is no direct access to the bearing housing.

11.9.5 The shock pulse standards defining lubrication condition and roller bearing damages shall be presented by the manufacturer of the technical condition monitoring system.

11.9.6 The results shall be submitted according to **11.2.3**.

11.10 REQUIREMENTS FOR THE TREND ANALYSIS OF THE DIAGNOSTIC PARAMETERS AND FOR THE TECHNICAL CONDITION PREDICTION

11.10.1 The processing program for the diagnostic parameters measured by the built-in condition monitoring systems shall contemplate a trend analysis and prediction of the parameter changing. The trend analysis of the diagnostic parameters measured by the portable control facilities shall be made after each last measurement.

11.10.2 The parameter trend is based on the measurements made during the period between special surveys with a frequency not less than 4 to 5 measurements at approximately equal time intervals.

11.10.3 The controlled item condition is predicted for the forthcoming time period between annual surveys.

The prediction is made either on the basis of the past history of the parameters defining condition or on the basis of the known rate of the parameter change.

On completion of the measurement, the prediction shall be adjusted.

11.10.4 Based on the prediction results, the frequency of the condition control may be changed.

If the prediction results indicates that the limiting values of the controlled parameters can be attained, the intervals between the measurements shall be reduced, the causes of the condition degradation established and the maintenance planned.

11.10.5 If the item condition is described by the several independent parameters, prediction shall be made for each parameter. In this case, maintenance becomes necessary when any of the parameters to be predicted reaches the limiting value.

11.10.6 The monitoring system shall be accompanied by the prediction procedure. Along with that, the Register shall be given data confirming reliability of the procedure.

12. REQUIREMENTS FOR BOILER MONITORING SYSTEMS

12.1 GENERAL

12.1.1 This Section specifies technical and organizational requirements for the ships with the distinguishing mark **BMS** (refer to **2.2.28**, Part I «Classification»), which shall be followed to allow the survey carried out by the chief engineer to be credited by the Register as boiler internal survey (refer also to **3.1.5**, Part X «Boilers, Heat Exchangers and Pressure Vessels»).

Documentation on the performed internal survey shall be presented to the attending Register surveyor who shall carry out the remaining scope of the boiler survey.

12.1.2 To assign the distinguishing mark **BMS**, the initial survey shall be performed to confirm that the boiler design and technical condition make it possible for the crew to perform the survey, that the ship is fitted with appropriate boiler condition control and monitoring system, and that the ship's chief engineer is qualified to partially perform the scope of boiler survey.

12.1.3 Distinguishing mark **BMS** may be assigned to auxiliary oil-fired steam boilers and waste-heat boilers with working pressure not exceeding 2,0 MPa.

12.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations related to the general terminology of this section are given in **1.2**.

Definitions and explanations that are also valid for the parts VIII «Системи і трубопроводи» and Part X "Boilers, Heat Exchangers and Pressure Vessels" have been additionally provided for the purpose of this Section.

In addition to the below mentioned, the definitions specified in Chapter 1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels".

Make-up water means water added to the feed water for replenishing the leaks and condensate losses; it is a mixture of distillate and chemically treated water.

Distillate means water generated in the desalinating plant by evaporation and condensation of sea water.

Feed water means water supplied by feed water pumps to the steam boiler to generate steam; it is a mixture of condensate and make-up water.

Condensate means water generated in the condensate and feed water system upon the waste steam condensation.

Boiler means a ship boiler that heats water or water-based coolant (eg, a solution of ethylene glycol in water) to the appropriate temperature.

Steam boiler means a ship boiler that produces a steam of appropriate parameters.

Boiler water means water inside the boiler and all its components.

Monitoring means continuous process of reading and recording item's parameters under control, which are assumed essential for the life duration, and comparing these parameters with specified values.

12.3 TECHNICAL AND OPERATING DOCUMENTATION

12.3.1 For steam boilers, the ship's Instruction on maintaining boiler water and chemistry quality shall be developed.

This document shall provide recommendations on pre-boiler and in-boiler water treatment and on prevention of scale formation and other factors leading to boiler plant excessive wear. This document shall be developed considering the requirements of instructions developed by boiler firms (manufacturers), standard instructions and applicable industry standards.

The content and availability of this document on board the ship shall be checked by the Register surveyor during the initial survey for assigning the distinguishing mark BMS to the ship.

12.3.2 Instruction on maintaining boiler water and chemistry quality shall contain:

.1 specification and brief description of water preparation process and equipment applied;

.2 schedule, scope and methods of water quality control;

.3 list and diagram of the sampling points;

.4 make-up, feed, boiler water and condensate quality standards;

.5 list of reagents necessary for water treatment and for ship's water laboratory;

.6 data on filter regeneration (if applicable);

.7 recommendations on boiler conservation for the period when they are not in operation.

12.3.3 The ship shall be provided with ship's boiler monitoring log-book.

The following shall be recorded in the log-book:

data on boiler maintenance in accordance with the manufacturer's recommendations and boiler survey results;

results of water chemical analyses;

measures taken to provide the feed and boiler water quality standards;

measures taken for burner units maintenance in accordance with the manufacturer's recommendations;

periodic testing of automatic burner unit interlocking and protecting devices as specified in Chapter 5.3, Part X "Boilers, Heat Exchangers and Pressure Vessels".

12.4 ADDITIONAL REQUIREMENTS FOR THE SHIPS WITH THE DISTINGUISHING MARK BMS

12.4.1 Additional requirements for boiler plants of ships with distinguishing mark BMS.

12.4.1.1 Special devices shall be provided for metering the chemicals and adding them to boiler and feed water.

12.4.1.2 Regular facilities shall be provided for collecting representative samples from boiler and feed water at safe temperature (e.g. by installing a sample cooler).

12.4.1.3 Facilities shall be provided for continuous early detection of excessive salinity, which shall immediately alarm when salt water is detected in the system.

12.4.1.4 Facilities shall be provided in condensate and feed water system for continuous early detection of oil products or transported goods in the boiler and feed water.

12.4.1.5 To remove oxygen, the feed water shall be kept in an open tank (e.g. in observation tank, hot well or a special deaerator) at temperature of at least 80°C.

12.4.1.6 Regular facilities shall be provided for monitoring pressure difference before and after exhaust boilers.

12.4.2 Boiler, feed and make-up water quality monitoring.

12.4.2.1 Feed water shall contain minimum dissolved salts, gases, organics and insoluble suspended solids.

The main water quality indicators to be controlled within the monitoring process are total hardness, chloride, oxygen and oil products content.

12.4.2.2 Boiler water quality shall be maintained and documented in accordance with recommended limiting values of boiler and feed water quality indicators as specified by the boiler manufacturer.

Where there are no any special instructions from the boiler manufacturer, the boiler and feed water quality requirements specified in Table **12.4.2.2** for steam boilers with working pressure not exceeding 2 MPa shall be followed.

12.4.2.3 Water quality shall be regularly checked using regular facilities and periodical water analysis in land-based laboratories.

Boiler and feed water shall be monitored with the use of on-board regular facilities at least every 24 h.

Boiler and feed water analysis results shall be recorded in a ship's log book.

12.4.2.4 Boiler water analysis in land-based laboratories shall be carried out at least once a month, and results shall be kept on board the ship.

12.4.2.5 In any cases, deviation of boiler water quality from the prescribed standards shall be immediately corrected.

Acceptable methods of maintaining water quality are maximum condensate return, surface and bottom blowdown, pre-boiler chemical treatment of the feed and make-up water, in-boiler chemical water treatment.

Another method to ensure water quality may be adopted instead of chemical treatment, provided that its equivalence is substantiated.

12.4.2.6 Boiler water quality shall be annually analyzed by the shipowner and corrected, if necessary.

Measures to improve the boiler water quality shall be developed to prevent hard deposit formation and corrosion damages; these measures shall be based on analyses (examinations) of hard deposits found in boiler and corrosion damages.

Table 12.4.2.2.

Water type	Quality indicator	Measurement unit	Gas-tube boilers	Water-tube and composite boilers
Feed water	Total hardness	mg-eq/l	not more than 0,5	not more than 0,3
	Oil and oil products	mg/l	not more than 3	not more than 3
	Oxygen	mg/l	not more than 0,1	not more than 0,1
	Chlorides	mg/l	not more than 50	not more than 15
Condensate	Chlorides	mg/l	not more than 50	not more than 15
Distillate [3]	Total hardness	mg-eq/l	-	not more than 0,05
Make-up water [3]	Total hardness	mg-eq/l	not more than 8	not more than 5
Boiler water	Chlorides	mg/l	not more than 8000	not more than 1200
	Base number	mg/l	150 - 200	150 - 200
	Residual hardness	mg-eq/l	not more than 0,4	not more than 0,2
	Total salinity	mg/l	not more than 13000	not more than 3000
	Phosphate number [1]	mg/l	30 - 60	30 - 60
	Nitrate number [1]	mg/l	75 - 100[2]	75 - 100[2]

Notes: [1] To be monitored for boilers with phosphate/nitrate water treatment. [2] The nitrate number shall be 50 % of the actual base number. [3] To be monitored during make-up water preparation.

12.4.3 Additional requirements for boilers of ships with distinguishimg mark BMS.

12.4.3.1 The boiler comply with the requirements for strength and construction, specified in Part X «Boilers, Heat Exchangers and Pressure Vessels».

The boiler shall not have signs of any damage, not documented and agreed with the Register during the last repair.

Plugged piping is not allowed.

Boiler heating surfaces shall not contain soot, sludge, scaling, traces of metal overheating. Boiler elements shall not have visible deformations and malfunctions.

12.4.3.2 The boiler shall provide internal inspections of steam and furnace spaces.

If the boiler has elements that are not available for internal survey, then hydraulic tests with a test pressure equal to 1.25 working shall be provided after the internal survey.

13. QUALITATIVE FAILURE ANALYSIS FOR PROPULSION AND STEERING ON PASSENGER SHIPS

13.1 APPLICATION

13.1.1 The requirements of the present Section refer to the qualitative failure analysis for propulsion and steering for new passenger ships, including those having a length of 120 m or more or having three or more main vertical zones (refer to 2.2.6.1, Part VI "Fire Protection") in compliance with the revised SOLAS Chapter II-2, Regulation 21 (IMO resolution MSC.216(82), Annex 3)..

13.1.2 For ships having at least two independent means of propulsion and steering to comply with SOLAS requirements for a safe return to port, the following shall be provided:

.1 knowledge of the effects of failure in all the equipment and systems due to fire in any space, or flooding of any watertight compartment that could affect the availability of the propulsion and steering;

.2 solutions to ensure the availability of propulsion and steering upon such failures specified in**13.1.2.1**.

13.1.3 Ships not required to satisfy the safe return to port concept will require the analysis of failure in single equipment and fire in any space to provide knowledge and possible solutions for enhancing availability of propulsion and steering.

13.2 SYSTEMS TO BE CONSIDERED

13.2.1 The qualitative failure analysis shall consider the propulsion and steering equipment and all its associated systems which might impair the availability of propulsion and steering.

13.2.2 The qualitative failure analysis shall include:

.1 propulsion and electrical power prime movers (diesel engines, electric motors);

.2 power transmission systems (shafting, bearings, power converters, transformers, slip ring systems);

.3 steering gear (rudder actuator or equivalent for azimuthing propulsor, rudder stock with bearings and seals, rudder, power unit and control gear, local control systems and indicators, remote control systems and indicators, communication equipment);

.4 propulsors (propeller, azimuthing thruster, water jet);

.5 main power supply systems (electrical generators and distribution systems, cable runs, hydraulic, pneumatic);

.6 essential auxiliary systems (compressed air, oil fuel, lubricating oil, cooling water, ventilation, fuel storage and supply systems);

.7 control and monitoring systems (electrical auxiliary circuits, power supplies, protective safety systems, power management systems, automation and control systems);

.8 support systems (lighting, ventilation).

To consider the effects of fire or flooding in a single compartment, the analysis shall address the location and layout of equipment and systems.

13.3 FAILURE CRITERIA

13.3.1 *Failures* are deviations from normal operating conditions such as loss or malfunction of a component or system such that it cannot perform an intended or required function.

13.3.2 The qualitative failure analysis shall be based on single failure criteria (not two independent failures occurring simultaneously).

13.3.3 Where a single failure cause results in failure of more than one component in a system (common cause failure), all the resulting failures shall be considered together.

13.3.4 Where the occurrence of a failure leads directly to further failures, all those failures shall be considered together..

13.4 VERIFICATION OF SOLUTIONS

13.4.1 The shipyard shall submit a report to the Register that identifies how the objectives have been addressed. The report shall include the following information:

.1 the standards used for analysis of the design;

.2 the objectives of the analysis;

.3 any assumptions made in the analysis;

.4 the equipment, system or sub-system, mode of operation of the equipment;

.5 probable failure modes and acceptable deviations from the intended or required function;

.6 evaluation of the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e. g. loss of propulsion power) of each failure mode as applicable;

.7 trials and testing necessary to prove conclusions.

Note. All stakeholders (the Register, shipowners, shipyard and manufacturers) shall as far as possible be involved in the development of the repor.

13.4.2 The report shall be submitted prior to approval of detail design plans. The report may be submitted in two parts:

.1 a preliminary analysis as soon as the initial arrangements of different compartments and propulsion plant are known which can form the basis of discussion. This shall include a structured assessment of all essential systems supporting the propulsion plant after a failure in equipment, fire or flooding in any compartment casualty;

.2 a final report detailing the final design with a detailed assessment of any critical system identified in the preliminary report.

13.4.3 Verification of the report findings shall be agreed between the Register and the shipyard.

APPENDIX 1.

SPECIAL APPROVAL OF ALLOY STEEL FOR INTERMEDIATE SHAFT MATERIAL

1. APPLICATION

1.1 General.

1.1.1 The requirements apply to the approval of alloy steel which has a minimum specified tensile strength greater than 800 MPa, but less than 950 MPa intended for use as intermediate shaft material.

1.1.2 The Section contains the main data on the steel fatigue evaluation by means of torsional fatigue testing. The purpose of the torsional fatigue test shall be meeting the requirements to the torsional fatigue to be equal to the intermediate shaft material, specified in the corresponding Sections of the Rules given by the formulae The torsional fatigue strength of said material is to be equal to or greater than the permissible torsional vibration stress τ_l, given by Formulae (8.3.1).

1.1.3 The chemical composition for forgings shall meet the minimum requirements specified in Table 3.7.2.3-2 of **3.7**, Part XIII "Materials", considering the content of sulphur, phosphorus and oxygen. The chemical composition, structures and mechanical properties shall meet the minimum requirements of Part XIII "Materials" and shall be submitted to the Register for consideration.

2. CARRYING OUT OF TESTS

2.1 The tests shall 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 shall be evaluated in consideration of the severest torsional stress concentration in the design criteria. Mean surface roughness shall be 0,2 μm R_a with the absence of localized machining marks verified by visual examination at low magnification (x20) as required by Section 8.4 of ISO 1352. (in Ukraine - ДСТУ ISO 13520:10).

Test procedures shall be in accordance with Section 10 of ISO 1352.

2.2. Test conditions shall be in accordance with Table 2.2.

Table 2.2

1	Loading type	Torsion
2	Stress ratio	$R = 1$
3	Load waveform	Constant - amplitude sinusoidal
4	Evaluation	S-N curve
5	Number of cycles for test terminal	$1x10^7$
6	Specimens	Notched and unnotched

2.3 The steels shall have a degree of cleanliness as shown in Table 2.3 when tested according to ISO 4967 method A.

Representative samples shall be obtained from each heat of forged or rolled products. The samples shall be subject to ultrasonic testing required by **3.7,7.2** Part XIII "Materials" prior to acceptance.

Table 2.3

Type A	Fine	1
	Thick	1
Type B	Fine	1,5
	Thick	1
Type C	Fine	1
	Thick	1
Type D	Fine	1
	Thick	1
Type DS	-	1

3 ACCEPTANCE CRITERIA

3.1 Total stresses shall be equal to or greater than the values given by the following formulae:
For measured high-cycle torsional fatigue strength:

$$\tau_{l1} \geq \tau_{l\lambda=0} = (\sigma_B + 160) \cdot C_k \cdot C_d / 6 \qquad (3\text{-}1)$$

For low-cycle torsional fatigue strength:

$$\tau_{l2} \geq (1{,}7 \cdot \tau_{l1}) / \sqrt{C_k} \qquad (3\text{-}2)$$

where:
τ_l - permissible amplitude of stress in MPa in the sample due to torsional vibration for continuous operation (refer to 8.3.1);
σ_B – specified minimum tensile strength in MPa of the shaft material;
C_k – = factor for the particular shaft design features; when selecting stress concentration factor, *scf*, (for calculating C_k for unnotched specimen *scf* = 1 (refer to Table 8.3.1);
C_d – size factor (refer to **8.2.1**).

PART VIII. SYSTEMS AND PIPING

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the following pumping and piping arrangements used in ships:

.1 bilge and drain;
.2 ballast, heel and trim;
.3 special systems of tankers and combination carriers;
.4 liquefied gas[1];
.5 toxic media;
.6 steam and blow-down pipelines;
.7 feed water and condensate;
.8 fuel oil;
.9 lubricating oil;
.10 water cooling;
.11 compressed air;
.12 air, venting, overflow and sounding pipes;
.13 exhaust gas;
.14 ventilation;
.15 open-ended steam pipes from safety valves;
.16 cleaning and washing of tanks;
.17 hydraulic drives;
.18 containing organic coolants;
.19 gas fuel[1].

Special requirements for systems other than stated above are set out in the relevant Parts of the Rules.

Pumping and piping of berth-connected ships shall comply with the requirements of the present Part in so much as applicable and sufficient unless expressly provided otherwise below.

1.1.2 The fuel oil used in ships shall comply with the requirements of **1.1.2**, Part VII "Machinery Installations".

1.1.3 The use of natural gas (methane) for the operation of dual-fuel internal combustion engines (DFE), gas-fuel engines (GFE), gas turbine engines (GTE) and boilers, in particular on gas carriers, the use of natural gas (methane), carried as fuel in accordance with 1.1.3 of part VII "Machinery Installations".

In addition to sea-going ships the above conditions for the use of gas fuel may be applicable to other offshore facilities subject to technical supervision of the Register, mobile offshore drilling units and sea constructions. In addition to the above conditions, such facilities shall comply with the relevant national requirements applicable to such facilities.

1.1.4 Machinery and other elements of the systems indicated in **1.1.1** shall remain operative under environmental conditions set out in **2.3**, Part VII "Machinery Installations".

1.1.5 Pumps, fans, compressors and their electric drives used in systems covered by the requirements of the present Part shall also comply with the requirements of Part IX "Machinery" and Part XI "Electrical Equipment".

Control and monitoring devices of piping systems shall comply with the requirements of Part XV "Automation".

Heat exchangers and pressure vessels used in ships systems shall comply with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

1.1.6 Pipes shall be painted in accordance with EN ISO 14726: 2008 or equivalent.

1.2 DEFINITIONS AND EXPLANATIONS

In the present Part the following definitions have been adopted:

[1] Gas fuel system for ships that use gases as fuel in accordance with the provisions of the IGF Code.

Valves are stop, regulating and safety devices, intended for motion control, consumption distribution and regulation and other parameters of the conveying medium by means of entire or partial opening or closing of flow section.

Pipeline fire resistance is the ability of pipeline to maintain strength and functional properties within the set period of time at flame exposure.

Gas fuel means any hydrocarbon fuel having at the temperature of 37,8 8C the absolute pressure of saturated vapours according to Reid equal to 0,28 MPa and above.

Low pressure gas – is gas, the pressure of which is not more than 1.0 MPa.

Gas engine means an engine capable of operating only on gas, and not able to switch over to operation on any other type of fuel.

Gas piping is a piping containing gas or a mixture of air and gas, including ventilated pipelines.

Gas Fuel Engine (GFE) is an engine capable of running only on gas fuel and unable to run on liquid fuel.

Dual fuel engine means a heat engine so designed that both gas and fuel oil may be used as fuel, simultaneously or separately, when using liquid fuel in the amount required for combustion (ignition fuel) or with more liquid fuel (in the mode of operation on gas fuel), and can also run only on liquid diesel fuel (in the mode of operation on diesel fuel).

Bottom and side valves are stop valves installed in shell plating of the ship or in sea chests and ice boxes and intended to close openings in shell plating.

Ignition fuel is a liquid fuel, which is supplied into the cylinder to ignite a mixture of gas and air in the DFE.

Keel cooler is is a sea cooler representing a system of tight ducts and pipes mounted under the hull through which engine cooling water is pumped to reduce the temperature.

IGF Code – the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuel, 2015, adopted by the resolution IMO MSC.391(95), as amended, including by the resolution IMO MSC.458(101).

IGC Code – the International Code of the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, reissued in accordance with the resolution IMO MSC.370(93), as amended by the resolutions IMO MSC.411(97) and MSC.441(99).

FSS Code – the International Code for Fire Safety Systems, adopted by the resolution IMO MSC.98(73) as amended, including by the resolution IMO MSC.457(101).

FTP Code – the International Code for the Application of Fire Test Procedures, adopted by the resolution IMO MSC.307(88).

IMSBC Code – the International Maritime Solid Bulk Cargoes Code, 2008 as amended, including by the resolution IMO MSC.462(101).

IMDG Code – International Maritime Dangerous Goods Code, renewed 2012.

MARPOL-73/78 – International Convention for the Prevention of Pollution from Ships, 1973, amended by the Protocol of 1978 (MARPOL-73/78) as amended by the Protocol of 1997 thereto (МАРПОЛ-73/78/97)[2].

SOLAS-74/78/88[3] – International Convention for the Safety of Life at Sea 1974 and the Protocols of 1978 and 1988 thereto, including the applicable codes.

BWM Convention – Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004 року.

Fire damper, Smoke damper – refer to **1.2**, Part VI «Fire Protection».

Box cooler is a sea cooler representing a heat exchanger where the cooled medium is pumped through cooling pipespaced in special enclosures with side shell openings to provide seawater natural circulation.

System is a combination of pipelines, machinery, apparatus, devices, appliances and reservoirs, intended for performance of certain functions providing ship's operation.

Steel or other equivalent material is any non-combustible material which, due to its properties or due to the insulation covering it, has until the end of the applicable fire exposure in the standard fire test, structural properties and fire resistance equivalent to steel (for example, aluminum alloy, coated with insulation).

Pipeline is a combination of pipes, valves, fittings, pipe joints, any internal and external linings, insulation coatings, fastening elements and components for protection of pipes, intended for conveying of liquid, gaseous and compound media, as well as for transmission of pressure and sound waves.

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[2] Hereinafter – MARPOL-73/78/97.

[3] Hereinafter SOLAS as amended.

Essential pipeline is a pipeline, which damage may result in a combustible medium spillage in the machinery spaces, flooding, toxic media leakage, failure of system ensuring the operation of main and auxiliary engines, loss of run or control.

Pipelines formed components (fittings) are bends, t-pieces, bulkhead and deck penetrations and other elements of pipelines, intended for pipelines branching, changing of conveying medium direction and ensuring of hull structures tightness.

1.3 SCOPE OF SURVEYS

1.3.1 General provisions relating to classification procedure, surveys during construction and in service, as well as requirements for technical documentation submitted to the Register for consideration and approval, are set forth in General Regulations for the Classification and Other Activity and in Part I "Classification" [4].

1.3.2 Proceeding from the type and characteristics of the conveyed medium pipes are subdivided into three classes as indicated in Fig. 1.3.2 and Table 1.3.2.

Test categories, types of joints, welding procedure and heat treatment are determined proceeding from the pipe class.

Table 1.3.2

Piping system for	Class I ($p > p_2$ or $t > t_2$)	Class II	Class III ($p < p_1$ or $t < t_1$)
1	2	3	4
Toxic and corrosive media	Without special safeguards [1]	With special safeguards [1,]	–
Inflammable media heated above flash point or having flash point below 60°C [2], liquefied gases	Without special safeguards [1]	With special safeguards [1]	–
Steam [3]	$p > 1{,}6$ or $t > 300$	Any pressure and temperature combination except the values indicated for Classes I and III	$p \leq 0{,}7$ and $t \leq 170$
Thermal oil [3]	$p > 1{,}6$ or $t > 300$	Any pressure and temperature combination except the values indicated for Classes I and III	$p \leq 0{,}7$ and $t \leq 150$
Fuel oil, lubricating oil and hydraulic oil [3]	$p > 1{,}6$ or $t > 300$	Any pressure and temperature combination except the values indicated for Classes I and III	$p \leq 0{,}7$ and $t \leq 60$
Other media [3,4,5]	$p > 4{,}0$ or $t > 300$	Any pressure and temperature combination except the values indicated for Classes I and III	$p \leq 1{,}6$ and $t \leq 200$

[1] Class II does not apply to toxic media.
[2] Cargo oil pipes belong to Class III.
[3] p – design pressure, MPa (refer to **2.3.2**); t – design temperature °C (refer to **2.3.5**).
[4] Including water, air, gases, non-flammable hydraulic fluids.
[5] For open-ended pipes (drains, overflows, vents, exhaust gas lines, boiler escape pipes) irrespective of the temperature, Class III pipes may be used.

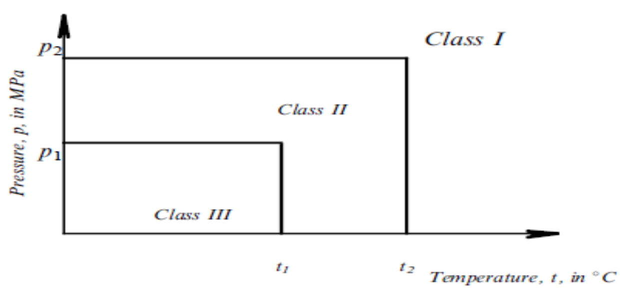


Fig. 1.3.2

[4] Hereinafter – Part I «Classification».

1.3.3 Class I and Class II pipes, pipelines valves, side and bottom valves, remote-controlled valves, venting valves, air pipe covers, flexible joints (including expansion joints), as well as the valves on the forepeak bulkhead, are subject to survey by the Register during manufacture.

1.4 PROTECTION AND INSULATION OF PIPING

1.4.1 Constructional measures on corrosion protection.

1.4.1.1 In order to reduce the corrosion and erosion wear of ship sea water pipelines during their design and installation, the following shall be taken into account:

.1 a number of detachable joints shall be kept to a minimum.

Detachable joints shall be located in places accessible for inspection, maintenance and repair;

.2 a number of shut-off devices on pipelines shall be kept to a minimum provided the system is functioning properly.

Valves shall be located in places accessible for inspection, maintenance and repair;

.3 pipelines shall have the minimum number of bends.

The radii of pipe bends shall be at least 2,5 times of their external diameter. Where the use of bends with less radii is required, the special fittings shall be applied;

.4 the use of welded bends made of segments for pipes of the nominal diameter less than 200 mm is not allowed.

A number of segments for the 90° bend shall not be less than three.

The use of bent or welded fittings for manufacturing of side or kingston valve branch pipes is not permitted (refer to **4.3.2.10**);

.5 the use of tee-pipes, branch pipes, nipples, welded-on pieces and other components shall not result in reduction of open flow area of the main in the places of their installation;

.6 the average design flow velocity determined according to Formula (1.4.1.1.6) shall not exceed the values specified in Table 1.4.1.1.6.

The compliance of the average flow velocity V_{mean} in the above sections of pipelines as well as in kingston connecting channels with these requirements shall be confirmed by the calculation according to the formula

$$V_{mean} = 354Q/d^2, \qquad (1.4.1.1.6)$$

where:

Q – permissible the maximum consumption at the design section, in m^3/h;

d – the internal diameter of a pipeline, in mm.

Table 1.4.1.1.6

Pipe material	Permissible average flow velocity, in m/s
Steel including galvanized,	2,5
Nodular graphite iron	2,5
Copper	0,9
Aluminium brass	2,0
Copper-nickel alloys:	
CuNi 5 Fe	2,0
CuNi 10 Fe	2,5
CuNi 30 Fe	3,5
Titanium alloys	10,0

Notes: 1. For pipelines of over 50 mm diameter with shaped elements having the rounding radii in the places of conjunctions with the main being equal to 0,15 diameter of the latter and more, bent with the bending radius in excess of 2,5 external diameters and without welded turns and throttle membranes, the flow velocity may be 30 % higher than specified in the Table.

2. In bilge, ballast, heel and trim systems the permissible values of a flow velocity may be 30 % higher than specified in the Table with regard to the possible flow velocity increase according to Note 1.

3. In fire-fighting, drenching, water screen, fire sprinkling systems not being constantly filled with water the flow velocity increase is allowed up to 5 m/s.

4. In systems with titanium pipes and valves of other materials, when permissible velocities are determined, the decisive components are those made of other materials.

1.4.2 Protection against general equal corrosion.

1.4.2.1 Steel pipes of sea water, as well as air and sounding pipes of ballast tanks, shall be protected against corrosion upon completion of bending and welding work by a method approved by the Register.

The following methods may be used as such protection:

.1 zinc coating applied by a hot method. The minimum thickness of zinc coating layer shall not be less than 50μ. Depending on the purpose of piping, the Register may require increasing of the coating thickness;

.2 zinc-filled paint coatings of not less than 120μ in thickness;

.3 effective paint protective coatings (epoxy or equal thereto in water-resisting property).

When selecting the coating type, consideration shall be given to its resistance to the medium conveyed by the system in accordance with the operating conditions of the pipeline.

Aluminium coatings of pipelines are allowed in ballast tanks, in cargo inerted tanks, as well as in hazardous areas on the open deck provided their protection of the accidental impacts. Application of zinc or other metal coating does not relieve of measures for protection of pipelines against contact corrosion.

1.4.3 Protection against contact corrosion.

1.4.3.1 One of the following methods to protect against contact corrosion shall be used when pipes made of different metals are joined in sea water systems: application of protective coating on internal pipelines surfaces, electrical insulation, cathodic protection, use of "sacrificial" branch pipes (refer to **1.4.3.5**).

1.4.3.2 The protective water proofing coating (polymeric, paintwork or of other type approved by the Register) is applied to contacting metals surfaces washed by sea water at the length of at least 5 pipe diameters from a contact point (but more than 1 m is not required).

The planar oxidation may be used for titanium alloys instead of a water proofing.

It is recommended to use coatings along with other methods of protection against contact corrosion.

1.4.3.3 Electrical insulation of different metals is effected by means of fitting electric insulating joints. In this case the following requirements shall be fulfilled:

.1 to protect heat exchangers, other equipment and pipes hooked up to them against contact corrosion, one electric insulating joint at the contact place of different metals and another one at a distance of at least 5 nominal those pipes diameters shall be fitted;

.2 to protect pipes and valves connected to them, bellows-shaped expansion joints and other similar pipeline components made of different metals against contact corrosion, electric insulating joints shall be fitted at both sides of those components;

.3 to protect interconnected pipes made of different materials against contact corrosion, the pipe made of any above pipe material and having a length of at least 5 nominal those pipes diameters shall be fitted between pipes using electric insulating joints at both ends;

.4 to protect hull structures from contact with bottom and side valves of nonferrous metal alloys, electric insulating joints shall be fitted at both ends of the bottom and side valves, and also on the very pipe and its branch pipes at a distance of at least 5 nominal pipe diameters if the pipe and the ship hull materials form an electric pair.

Bottom, side and pipeline valves shall be electrically insulated from all types of joints (control, heating, blow-off, etc pipelines), which may form a metal contact between the valves and the ship hull. Where bottom and side valves are provided with the second shut-off valves made of the same metal, they shall be electrically insulated as a unified structure;

.5 pipes with two or more electric insulating joints shall be insulated from hangers;

.6 the structure of an electric insulating joint shall be approved by the Register, have the tightness required, be tested by hydraulic pressure in accordance with **21.2** and have an electrical resistance in a dry condition (prior to system filling) not less than 10 kOhm and not less than 1 kOhm following the system filling and hydraulic tests.

1.4.3.4 A cathodic protection.

1.4.3.4.1 A cathodic protection shall be applied where sea water system components made of metals specified in Table 1.4.3.4 are in contact.

Protectors shall be fitted immediately between the surfaces of mating different metals.

Where it is impossible, they may be fitted on the surface protected as close to the pipe contact place as possible (at least one diameter).

Table 1.4.3.4

Metal combination		Material subjected to corrosion	Protector material
1	**2**	**3**	**4**
Carbon, low-alloy steel, cast iron	Copper, brass, bronze, copper-nickel alloys, corrosion-resistant steel, titanium alloys	Carbon, low-alloy steel, cast iron	Zinc alloy
Copper, brass, bronze, copper-nickel alloys	Corrosion-resistant steel of austenitic class, titanium alloys	Copper, brass, bronze, copper-nickel alloys	Carbon steel
Copper, brass	Corrosion-resistant non-austenitic steel	Copper, brass	Carbon steel
Bronze, copper-nickel alloys	Corrosion-resistant non-austenitic steel	Any material specified may be subjected to corrosion	Carbon steel
Corrosion-resistant steel	Titanium alloy	Corrosion-resistant steel	Carbon steel
Corrosion-resistant steel of austenitic class	Corrosion-resistant non-austenitic steel	Any material specified may be subjected to corrosion	Carbon steel
Brass	Bronze, copper, copper-nickel alloys	Brass	Carbon steel

1.4.3.4.2 In pipelines with valves and pipes of different metals, protectors shall be fitted behind each valve along a flow. For permanently closed valves and in sections with changing flow motion direction, protectors shall be fitted at both valve sides.

1.4.3.4.3 A corrosion-resistant steel, tin brass and manganese bronze, aluminium bronze may be used in sea water if only a cathodic protection is provided.

1.4.3.4.4 When fitting protectors, the reliable electrical contact of a protector with an article protected shall be provided.

1.4.3.4.5 The protector design shall permit its replacement, which is effected after the protector life cycle expires. In this case, joints tightness shall not be broken.

1.4.3.4.6 The protector service period shall be at least 2,5 years (at least 3 years for protection of kingston and side branch pipes) and shall be determined according to the formula

$$T = A \cdot M/S, \qquad (1.4.3.4.6)$$

where:

T – protector service period, in years;

M – mass of a protector working metal, in kg;

S – area of protected surface, in m^2; the protected pipe surface therewith is assumed equal to an internal surface area of 5 internal diameters long;

A – coefficient equal to 0,75 for zinc protector and to 1,71 for steel one.

1.4.3.5 "Sacrificial" branch pipes.

1.4.3.5.1 Where other methods of protection against contact corrosion can not be used, it is permitted to apply "sacrificial" branch pipes.

The "sacrificial" branch pipe is the thick-walled cylindrical section of a carbon steel pipe intended for displacement of a contact zone of pipelines components made of nonferrous metals and alloys from essential steel structures and equipment.

The "sacrificial" branch pipe shall not be internally coated.

1.4.3.5.2 "Sacrificial" branch pipes shall be machined of forgings or rolled products.

The length of a "sacrificial" branch pipe shall be at least 1,5 of the internal pipe diameter.

The sealing flange surface of the "sacrificial" branch pipe being in contact with a different metal shall be protected against contact corrosion by facing or by another approved method of cladding metal on the contacting item.

1.4.3.5.3 The wear margin of a "sacrificial" branch pipe wall shall provide a pipeline service period of at least 10 years on a basis of the total wall corrosion rate of 1,5 mm/year.

1.4.3.5.4 The "sacrificial" branch pipe shall be located in place accessible for inspection and replacement.

The spare "sacrificial" branch pipe shall be on the ship.

1.4.3.5.5 Dismantling, inspection of contact surfaces and measurements of "sacrificial" branch pipe wall thicknesses shall be carried out at least once in 5 years.

1.4.4 Protection against excessive pressure.

1.4.4.1 Pipelines, in which pressure in excess of the design pressure is possible, shall be equipped with safety devices so that the pressure would not exceed the design value for the pipes.

The liquid diversion from relief valves of pumps transferring flammable liquids shall be effected into the suction side of the pump or to the suction pipeline. This requirement does not apply to centrifugal pumps.

1.4.4.2 Where provision is made for a reducing valve on the pipeline, a pressure gauge and a safety valve shall be installed after the reducing valve.

An arrangement for by-passing the reducing valve is allowed for use.

1.4.5 Insulation of piping.

Insulation of piping shall comply with **4.6**, Part VII "Machinery Installations" and **8.2**, Part XII "Refrigerating Plants".

1.4.6 Protection against green sea forces.

1.4.6.1 The requirements of **1.4.6** are applicable to all ship types of sea-going service of length 80 m or more, where the height of the exposed deck over the forward 1/4*L* is less than 0,1*L* or 22 m above the summer load waterline, whichever is the lesser.

1.4.6.2 Air pipes of tanks, ventilator pipes and their closing devices located within the forward quarter length shall have strength sufficient to resist green sea forces at open sea.

The requirements of **1.4.6** do not apply to cargo tank venting systems.

1.4.6.3 Applied loading.

1.4.6.3.1 The pressures *p*, in kN/m^2, acting on air pipes, ventilator pipes and their closing devices may be determined by the formula

$$p = 0{,}5 \rho V^2 C_d C_s C_p, \quad (1.4.6.3.1)$$

where:

ρ - density of sea water (1,025 t/m^3);

V- velocity of water over the fore deck, m/s;

V= 13,5 for $d \le 0{,}5\, d_1$;

V= 13,5$\{2[1- (d / d_1)]\}^{0,5}$ for $0{,}5\, d_1 < d < d_1$;

d – distance from summer load waterline to exposed deck, in m;

d_1= 0,1 L or 22 m, whichever is the lesser, in m;

for L – refer to **1.1.3.2.1** Part II «Hull»;

C_d - shape coefficient taken equal to:

0,5 – for pipes,

1,3 – for air pipes or ventilator heads,

0,8 – for air pipes or ventilator heads of cylindrical form with its axis in the vertical direction;

C_s – slamming coefficient taken equal to 3,2;

C_p – protection coefficient taken equal to:

0,7 – for pipes and ventilator heads located immediately behind a breakwater or forecastle,

1,0 – – elsewhere and immediately behind a bulwark.

1.4.6.3.2 Forces acting in horizontal direction on the pipes and their closing devices may be determined by Formula (1.4.6.3.1) using the largest projected area of each component.

1.4.6.4 Strength requirements.

1.4.6.4.1 Bending stresses and loads in air and ventilator pipes shall be determined at critical positions: at penetration pieces, at weld or flange connections, at toes of supporting brackets. Bending stresses shall not exceed $0{,}8\sigma_y$, where σ_y — is the yield stress or proof stress of steel at 0,2 % elongation at room temperature.

Irrespective of corrosion protection, a corrosion addition to the net section of 2 mm shall be then applied.

1.4.6.4.2 For standard pipes of 760 mm height closed by heads of not more than the tabulated projected area, pipe thicknesses and bracket heights are specified in Table 1.4.6.4.2.

Where brackets are required, three or more radial brackets shall be fitted.

Brackets shall be of gross thickness 8 mm or more, of minimum length not less than 100 mm, and height according to Table 1.4.6.4.2 but shall not extend over the joint flange for the head. Bracket toes at the deck shall be suitably supported.

Table 1.4.6.4.2 **760 mm air pipe thickness and bracket standards**

Nominal pipe diameter, mm	Minimum pipe thickness, mm	Maximum projection area of head, cm ^{2}	Height of bracket, mm
50	6,0	–	520
65	6,0	–	480
80	6,3	–	460
100	7,0	–	380
125	7,8	–	300
150	8,5	–	300
175	8,5	–	300
200	8,5 [1]	1900	300 [2]
250	8,5 [1]	2500	300 [2]
300	8,5 [1]	3200	300 [2]
350	8,5 [1]	3800	300 [2]
400	8,5 [1]	4500	300 [2]

[1] Brackets shall be fitted where the pipe thickness is less than 10,5 mm, or where the tabulated projected head area is exceeded.
[2] For other air pipe heights, the relevant requirements of **1.4.6.4.3** shall be applied.

1.4.6.4.3 For other configurations, loads and means of support shall be determined in accordance with **1.4.6.3** and **1.4.6.4**. Brackets, where fitted, shall be of suitable thickness and length according to their height. Pipe thickness shall not be taken less than as indicated in **10.1.4**.

1.4.6.4.4 For standard ventilators of 900 mm height, pipe thicknesses and bracket heights are specified in Table 1.4.6.4.4.

Brackets, where required shall be as specified in **1.4.6.4.2.**

Table 1.4.6.4.4 **900 mm ventilator pipe thickness and bracket standards**

Nominal pipe diameter, mm	Minimum pipe thickness, mm	Maximum projection area of head, cm ^{2}	Height of bracket[1], mm
1	2	3	4
80	6,3	–	460
100	7,0	–	380
150	8,5	–	300
175	8,5	55	–
200	8,5	880	–
250	8,5	1200	–
300	8,5	2000	–
350	8,5	2700	–
400	8,5	3300	–
500	8,5	4000	–

[1] For other ventilator heights the relevant requirements of **1.4.6.4.5** shall be applied

1.4.6.4.5 For ventilators of height greater than 900 mm, brackets or alternative means of support are subject to pipe strength calculations.

1.4.6.4.6 All component parts and connections of the air pipe or ventilator shall be capable of withstanding the loads defined in **1.4.6.3**.

1.4.6.5 Rotating type mushroom ventilator heads are not permitted for installation in the areas defined in **1.4.6.2**.

1.5 WELDING AND NON-DESTRUCTIVE TESTING OF WELDS

1.5.1 Welding and non-destructive testing of welds in pipes shall be effected in compliance with **2.5** and Section **3**, Part XIV "Welding".

2. METAL PIPING

2.1 MATERIAL, MANUFACTURE AND APPLICATION

2.1.1 The materials, used for pipes and valves, as well as the methods of testing the materials shall comply with the requirements of Part XIII "Materials".

The fuel oil pipes shall be manufactured of steel or other material meeting the Register requirements as to its strength and fire-resistance. These requirements apply to lubricating oil pipes in machinery spaces and to pipes conveying other flammable oil products including hydraulic and thermal liquids if they are in spaces with sources of ignition.

The coatings and parts of non-metallic materials used during manufacture of valves shall be compatible with the medium conveyed at working pressure within the whole range of working temperatures.

The pipes and valves of fire extinguishing systems shall comply with 3.1.4, Part VI "Fire Protection".

2.1.2 In general, pipes and valves of carbon steel and carbon-manganese steel shall be used for media with temperature not exceeding 400 8C, of low-alloy steel - with temperature not exceeding 500°C.

These steels may be admitted for temperatures higher than the above mentioned, if their mechanical properties and the average stress to produce rupture in 100 000 h at the design temperature comply with the effective standards and are guaranteed by the steel maker as suitable for high temperature service.

Pipes and valves for media with temperature above 500°C shall be manufactured of alloy steel. Exhaust gas pipes are excluded from this requirement.

2.1.3 Copper and copper alloy pipes shall be seamless drawn pipes or other type approved by the Register.

Copper pipes for Classes I and II shall be seamless. Pipes and valves of copper and copper alloys shall generally be used for media having temperature not in excess of 200°C, and those of copper-nickel alloys, for temperature not over 300°C.

Bronze valves may be admitted for media having temperatures up to 260°C.

2.1.4 Grey cast iron may be admitted for pipes and valves of piping in Class III used at ambient temperature not lower than -15°C. In this case, the ultimate strength of the grey cast iron shall not be less than 200 MPa, and that of the fitting casings and shaped components - not less than 300 MPa. Apart from cargo pipelines, the permissible working pressure in the pipelines of grey cast iron shall not exceed 1 MPa and for steam pipelines - 0,3 MPa.

Pipes and valves of grey cast iron may be also used for cargo lines with pressures up to 1,6 MPa on the weather deck, inside cargo and slop tanks, except for the manifolds, their valves and connections to the cargo hoses.

The grey cast iron shall not be used for:

.1 pipes and valves handling media with temperatures above 220°C;

.2 pipes and valves subject to water hammer, increased strains and vibration;

.3 pipes directly connected to the shell plating;

.4 valves fitted directly on the shell plating and collision bulkhead;

.5 valves under static head, fitted directly on fuel and lubricating oil tanks, unless protected against mechanical damage by a method approved by the Register;

.6 fire smothering systems;

.7 ballast lines inside cargo and slop tanks.

2.1.5 Spheroidal or nodular graphite cast iron may be admitted for pipes and valves of piping in Classes II and III including ballast, bilge and cargo lines, if the elongation of this cast iron is not less than 12 %.

Where the elongation is less than that required, the area of application of the pipes and valves of spheroidal or nodular graphite cast iron shall be the same as specified in **2.1.4** for the grey cast iron.

The working temperature for piping components made of spheroidal graphite cast iron of perlitic or ferritic-perlitic structure shall not exceed 300°C and for the cast iron of ferritic structure 350°C.

The impact toughness (KCU) of the spheroidal graphite cast iron for pipes and valves used at the temperature lower than - 15°C shall not be less than 20 J/cm^2.

Ship bottom and side valves as well as the valves and fittings referred to in **4.3.2.4**, **4.3.2.6** to **4.3.2.7** and the valves on the collision bulkhead, fuel and lube oil tanks may be admitted to be of spheroidal graphite cast iron of fully ferritic structure in accordance with Table 3.9.3.1, Part XIII "Materials".

2.1.6 Pipes up to 50 mm in diameter and valves of ductile cast iron of ferritic structure with elongation more than 12 % may be used for services mentioned in **2.1.5** at the working temperature not lower than -15°C and not higher than 350°C and under working pressure up to 2 MPa.

The area of application of pipes and valves made of ductile cast iron with elongation less than 12 % shall be the same as specified in **2.1.4** for products made of grey cast iron.

2.1.7 The application of pipes, shaped elements, as well as filter bodies, valves and other piping components made of aluminium alloys is not permitted in fuel oil and lubricating oil systems. The requirements of this para fully apply to hydraulic systems containing flammable liquids in machinery spaces of category A and in other space with a high fire risk.

2.1.8 The plugs and threaded portion of deck bushes of sounding pipes, terminating on the open decks, shall be of bronze or brass.

2.1.9 Sight-glasses on fuel oil and oil pipes shall be refractory.

2.1.10 Materials other than steel with a melting point below 930°C and with an elongation below 12 % shall be used for the components of engines, turbines, gears, or other machinery containing fuel or oil and which are considered acceptable for the following applications:

.1 internal pipes which cannot cause any release of flammable fluid onto the machinery or into machinery space in case of failure;

.2 components that are only subjects to liquid spray on the inside when the machinery is running, such as machinery covers, rocker box covers, camshaft and covers, inspection plates and sump tanks. It is a condition that the pressure inside these components and all the elements contained therein is less than 0,18 N/mm^2, and that wet sumps have a volume not exceeding 100 litres; or

.3 in case other than specified in **2.1.10.1** and **2.1.10.2**, components attached to machinery which satisfy fire test criteria according to standard ISO 19921:2005/19922:2005 or other standards which are recognized by the Register equivalent, and which retain mechanical properties adequate for the intended installation.

2.2 RADII OF PIPE BENDS, HEAT TREATMENT AFTER BENDING

2.2.1 The inner radius

The inner radius of pipe bend of the boiler blow off pipes shall be at least 3,5 d_1 (d_1 - pipe inside diameter).

The inner radius of bend of the steel and copper pipes subjected to a pressure exceeding 0,49 MPa or a working medium temperature exceeding 60°C, as well as bending radius of pipes with allowance for thermal expansion, shall be at least 2,5*d* (*d* - pipe outside diameter).

Bending to a lesser radius may be permitted, provided no thinning of pipe wall below the values stated in **2.3** would occur during the bending.

2.2.2 Hot bending of stell pipes shall be generally carried out in the temperature range 1000 to 850°C; however, the temperature may decrease to 750°C during the bending process.

For pipes, the bending of which is carried out within this temperature range, the following applies:

.1 for C, C-Mn and C-Mo steels, no subsequent heat treatment is required;

.2 for 1 Cr - 0,5 Mo steel with a wall thickness greater than 8 mm, a subsequent stress relieving heat treatment in the temperature range 620 to 680°C is required;

.3 for 2,25 Cr - 1 Mo and 0,5 Cr - 0,5 Mo - 0,25 V steels of all thickness, a subsequent stress relieving heat treatment in the temperature range 650 to 720°C is required except for pipes with a wall thickness ≤8 mm, diameter ≤100 mm and the maximum service temperature up to 450°C, for which no subsequent heat treatment may be carried out.

2.2.3 When the hot bending is carried out outside the temperature range stated in **2.2.2**, a subsequent new heat treatment in accordance with Table 2.2.3 is generally required.

Table 2.2.3

Type of steel	Heat-treatment and temperature, °C
C and C - Mn	Normalizing, 880 – 940
0,3 Mo	Normalizing, 900 – 940
1 Cr - 0,5 Mo	Normalizing, 900 – 960 Tempering, 640 – 720
2,25 Cr - 1 Mo	Normalizing, 900 – 960 Tempering, 650 – 7 80
0,5 Cr - 0,5 Mo - 0,25 V	Normalizing, 930 – 980 Tempering, 670 – 720

2.2.4 After cold bending when r=*4d* (*d* - outer diameter), a complete heat treatment in accordance with Table 2.2.3 is generally required in any case.

A stress relieving heat treatment is required for 0,3 Mo steel with a wall thickness ≥15 mm at 580 to 640°C, 1 Cr - 0,5 Mo steel with a wall thickness ≥8 mm at 620 to 680°C and for 2,25 Cr - 1 Mo and 0,5 Cr - 0,5 Mo - 0,25 V steel with a wall thickness ≥8 mm, diameter ≥100 mm and service temperature above 450°C at 650 to 720°C.

2.2.5 Copper and copper-alloy pipes, except for the pipes of measuring instruments, shall be annealed before hydraulic testing.

2.2.6 Preheating before welding and postweld heat treatment shall be effected in accordance with **2.5.5** to **2.5.7**, Part XIV "Welding".

2.3 METAL PIPE WALL THICKNESS

2.3.1 The wall thickness of metal pipes (except cast iron pipes) operating under the internal pressure shall correspond to the greater of the values determined from Table 2.3.8 or by the following formula:

$$S = \frac{S_0 + b + c}{1-(a/100)}, \qquad (2.3.1)$$

where: $S_0 = \dfrac{dp}{2\sigma\varphi + p}$;

S_0 – theoretical wall thickness, mm;

d – outside diameter of the pipe, mm;

p – design pressure determined in accordance with **2.3.2**, MPa;

φ – weld efficiency factor taken in accordance with **2.3.3**;

b – allowance for a reduction of pipe wall thickness because of bending taken in accordance with **2.3.4**, mm;

σ – permissible (normal) stress determined in accordance with **2.3.5** to **2.3.7**, MPa;

c – corrosion addition taken in accordance with Table 2.3.1-1 for steel pipes and Table 2.3.1-2 for pipes of nonferrous metals, mm

a – = negative manufacturing tolerance for pipe wall thickness, % (when pipes without negative allowance are used a = 0).

2.3.2 The design pressure, on the basis of which pipe strength calculations are made, shall be assumed equal to the maximum working pressure of the system.

Where safety relief valves are fitted, the design pressure shall be their highest set pressure.

Pipelines and components of piping systems not protected by safety valves or may be disconnected from their safety valves, shall be calculated for the maximum possible pressure at the outlet of the pumps connected.

For pipelines containing heated fuel oil, the design pressure shall be taken according to Table 2.3.2.

For pipelines of steering gear the design pressure shall be assumed in compliance with **6.2.8.1**, Part IX "Machinery".

In special cases not provided by the Rules, the design pressure is subject to special consideration by the Register.

Table 2.3.1-1 **Allowance c for corrosion for steel pipes**

Working medium, piping service	***c***, мм
1	**2**
Superheated steam	0,3
Saturated steam	0,8
Heating steam coils for water and fuel oil products in tanks and cargo tanks	2,0
Feed water in open circuit systems	1,5
Feed water in closed circuit systems	0,5
Blow-down of boilers	1,5
Compressed air	1,0
Hydraulic oil systems	0,3
Lubricating oil	0,3
Fuel oil	1,0
Cargo pipelines	2,0
Liquefied gas	0,3
Refrigerant piping	0,3

Fresh water	0,8
Sea water	3,0

Notes: 1. . On agreement with the Register, the allowance for corrosion may be reduced for pipes protected against corrosion by special coatings, linings, etc.

2. Where pipes of steel with sufficient corrosion resistance are used, the allowance for corrosion may be reduced to zero.

3. For pipes passing through tanks and on the open decks the table values shall be increased by the allowance for the influence of the external medium, which is assumed for the appropriate medium in accordance with the Table.

Table 2.3.1-2 **Allowance c for corrosion for pipes of nonferrous metals and alloys**

Pipe material	c, mm
Copper, brass, copper-tin alloys and similar alloys, except those with lead content	0,8
Copper-nickel alloys (with Ni content ≥ 10%)	0,5

Note. Where pipes of special alloys with sufficient corrosion resistance are used, the allowance for corrosion may be reduced to zero.

Table 2.3.2 **Determination of design pressure for fuel oil systems**

Working pressure P, MPa	Working temperature T, °C	
	No more than 60	More than 60
No more than 0,7	0,3МПа or P_{max} (the greater of two values)	0,3МПа or P_{max} (the greater of two values)
More than 0,7	P_{max}	1,4МПа or P_{max} (the greater of two values)

2.3.3 The strength factor φ in strength calculations shall be taken as 1 for seamless pipes and approved welded pipes, which are considered to be equal to seamless pipes.

For other welded pipes the strength factor φ shall be assigned considering the requirements of 2.1.6.1-1, Part X "Boilers, Heat Exchanges and Pressure Vessels".

2.3.4 The allowance for an actual reduction of pipe wall thickness because of bending shall be chosen in such a way that the stresses in the bent part of the pipe because of internal pressure do not exceed the permissible stresses.

Where precise values of thickness reduction while bending are not known, the allowance b, mm, may be obtained by the formula

$$b = \frac{1}{2,5}\frac{d}{R}S_0, \qquad (2.3.4)$$

where: R – mean radius of pipe bend, mm.

2.3.5 In strength calculations the permissible stresses are taken considering the following properties of material and working conditions:

$R_{m/20}$ – ultimate resistance at room temperature, MPa;

$R_{eL/t}$ – the minimum yield strength at the design temperature, MPa;

$R_{0,2/t}$ – conventional yield strength at the design temperature, MPa;

$R_{m/t}^{100000}$ – ultimate long-term strength for 100 000 hours at the design temperature, MPa;

$R_{p1/t}^{100000}$ –1% of creep limit for 100 000 hours at the design temperature, MPa.

The design temperature t for determining permissible stresses is taken as the maximum temperature of the medium inside the pipes.

2.3.5.1 For carbon or alloy steel pipes the permissible design stresses are chosen equal to the lowest of the following values:

$R_{m/20}/2,7$; $R_{eL/t}/1,8$ або

$R_{0,2/t}/1,8$; $R_{m/t}^{100000}/1,8$; $R_{p1/t}^{100000}/1,0$.

When the design temperature is not included in the creep limit of the material, the permissible stresses on the creep limit are not compulsory for examination.

2.3.5.2 For copper and copper alloys pipes the permissible stresses shall be determined in accordance with Table 2.3.5.2.

Table 2.3.5.2 **Permissible stresses σ_{perm} for pipes of copper and copper alloys**

Pipe material	Heat treatment	Minimum tensile strength, MPa	σ_{perm}, MPa, at working medium temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealing	220	41	41	40	40	34	27	19	–	–	–	–
Aluminium brass	Ditto	320	78	78	78	78	78	51	25	–	–	–	–
Copper-nickel 95/5 and 90/10	Ditto	270	69	69	68	66	64	62	59	56	52	48	44
Copper-nickel 70/30	Ditto	360	81	79	77	76	74	72	70	68	66	64	62
Note: 1. Intermediate values shall be determined by linear interpolation.													

2.3.5.3 The permissible stresses for aluminium and titanium pipes in the strength calculations are assumed equal to the minimum of the following values:

$R_{m/20}/4{,}0$; $R_{m/t}^{100000}/1{,}6$; $R_{0{,}2/t}/1{,}6$.

When the design temperature is not included in the creep limit of the material, the permissible stresses on the creep limit are not compulsory for examination.

2.3.6 Steam pipes with an external diameter of 80 mm and over for superheated steam at a temperature of 350°C and over shall be calculated for stresses caused by thermal expansion, and flanged joints _ for strength and tightness.

The calculations of stresses in pipes because of thermal expansion shall comply with the requirements of **18.3**.

2.3.7 The wall thickness t_{min}, in mm, of cast iron pipeline components shall not be less than that obtained from the formula

$$t_{\min} = k\left(0{,}5 + 0{,}001D_y\right), \qquad (2.3.7)$$

where:

Dy — nominal diameter, in mm;

k — factor taken equal to:

9 — for pipes;

14 — for T-joints and valve bodies;

12 — for joint.

Moreover, the wall thickness of cast iron pipes and valves under internal pressure shall not be less than that obtained from Formula (2.3.1), and the allowance for a reduction of pipe wall thickness because of bending in this case is $b = 0$;

weld efficiency factor φ taken equal to:

1 — for pipes and couplings;

0,4 — for bends, T-joints and four-way unions;

0,25 — for fitting bodies;

permissible stress σ determined with regard to **2.1.4.3**, **2.1.4.6**, and **2.1.5.5**, Part X "Boilers, Heat Exchangers and Pressure Vessels";

corrosion addition c due to sea water is:

4 mm — for cast iron of ferritic and ferritic-perlitic structure;

3 mm —for cast iron of perlitic structure; for media with low corrosivity, corrosion addition c may be reduced.

2.3.8 The wall thickness of steel, copper, copper and titanium alloys pipes shall not be less than indicated in Table 2.3.8.

Table 2.3.8 **Minimum wall thickness of metal pipes, mm**

External diameter, mm	Pipes									
	Steel						Copper	Copper alloys	Corrosionresistant steel	Titaniumbased alloys
	Pipes of systems other than stated in columns 3 - 7	Venting, overflow and sounding pipes of structural tanks, excep for those stated in column 5 of the Table and in 10.1.4	Sea water pipes (bilge, ballast, cooling water, fire extinguishing systems, etc.)	Bilge, air, overflow and sounding pipes passing through ballast and fuel tanks; ballast pipes passing through fuel tanks; fuel pipings passing through ballast tanks	Pipings of CO_2 fire extinguishing system: from cylinders to starting valves	Pipings of CO_2 fire extinguishing system: from starting valves to discharge nozzles				
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
<8	1,0	–	–	–	–	–	–	–	1,0	0,8
8,0	1,2	–	–	–	–	–	1,0	0,8	1,0	0,8
10,2	1,6	–	–	–	–	–	1,0	0,8	1,0	0,8
12,0	1,6	–	–	–	–	–	1,2	1,0	1,0	1,0
13,5	1,8	–	–	–	–	–	1,2	1,0	1,0	1,0
16,0	1,8	–	–	–	–	–	1,2	1,0	1,0	1,0
17,2	1,8	–	–	–	–	–	1.2	1,0	1,0	1,0
19,3	1,8	–	–	–	–	–	1,2	1,0	1,0	1,0
20,0	2,0	–	–	–	–	–	1,2	1,0	1,0	1,0
21,3	2,0	–	3,2	–	3,2	2,6	1,2	1,0	1,6	1,0
25,0	2,0	–	3,2	–	3,2	2,6	1,5	1,2	1,6	1,0
26,9	2,0	–	3,2	–	3,2	2,6	1,5	1,2	1,6	1,0
30,0	2,0	–	3,2	–	4,0	3,2	1,5	1,2	1,6	1,0
33,7	2,0	–	3,2	–	4,0	3,2	1,5	1,2	1,6	1,0
38,0	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
42,4	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
44,5	2,0	4,5	3,6	6,3	4,0	3,2	1,5	1,2	1,6	1,0
48,3	2,3	4,5	3,6	6,3	4,0	3,2	2,0	1,5	1,6	1,5
51,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
54,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
57,0	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	1,6	1,5
60,3	2,3	4,5	4,0	6,3	4,5	3,6	2,0	1,5	2,0	1,5
63,5	2,3	4,5	4,0	6,3	5,0	3,6	2,0	1,5	2,0	1,5
70,0	2,6	4,5	4,0	6,3	5,0	3,6	2,0	1,5	2,0	1,5
76,1	2,6	4,5	4,5	6,3	5,0	3,6	2,0	1,5	2,0	1,5
82,5	2,6	4,5	4,5	6,3	5,6	4,0	2,0	1,5	2,0	1,5
88,9	2,9	4,5	4,5	7,1	5,6	4,0	2,5	2,0	2,0	2,0
101,6	2,9	4,5	4,5	7,1	6,3	4,0	2,5	2,0	2,0	2,0
108,0	2,9	4,5	4,5	7,1	7,1	4,5	2,5	2,0	2,0	2,0
114,3	3,2	4,5	4,5	8,0	7,1	4,5	2,5	2,0	2,3	2,0
127,0	3,2	4,5	4,5	8,0	8,0	4,5	2,5	2,0	2,3	2,0
133,0	3,6	4,5	4,5	8,0	8,0	5,0	3,0	2,5	2,3	2,0
139,7	3,6	4,5	4,5	8,0	8,0	5,0	3,0	2,5	2,3	2,0
152,4	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
159,0	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
168,3	4,0	4,5	4,5	8,8	8,8	5,6	3,0	2,5	2,3	2,0
177,8	4,5	5,0	5,0	8,8	–	–	3,0	2,5	2,3	2,0
193,7	4,5	5,4	5,4	8,8	–	–	3,5	3,0	2,3	2,5
219,1	4,5	5,9	5,9	8,8	–	–	3,5	3,0	2,6	2,5
244,5	5,0	6,3	6,3	8,8	–	–	3,5	3,0	2,6	2,5
267,0	5,0	6,3	6,3	8,8	–	–	3,5	3,0	2,6	2,5
273,0	5,0	6,3	6,3	8,8	–	–	4,0	3,5	2,9	3,0
298,5	5,6	6,3	6,3	8,8	–	–	4,0	3,5	2,9	3,0

323,9	5,6	6,3	6,3	8,8	–	–	4,0	3,5	3,6	3,0
355,6	5,6	6,3	6,3	8,8	–	–	4,0	3,5	3,6	3,0
368,0	5,6	6,3	6,3	8,8	–	–	4,0	3,5	3,6	3,0
406,4	6,3	6,3	6,3	8,8	–	–	4,0	3,5	4,0	3,0
419,0	6,3	6,3	6,3	8,8	–	–	4,0	3,5	4,0	3,0
457,2	6,3	6,3	6,3	8,8	–	–	4,0	3,5	4,0	3,0
508,0	–	–	–	–	–	–	4,5	4,0	4,0	3,5

Notes: 1. For pipes with thicknesses and diameters indicated in the Table, the nearest values specified in national and international standards may be accepted as agreed with the Register.

2. For the tabulated values no allowance need be made for negative manufacturing tolerance and reduction in thickness due to bending.

3. For the pipes with diameters greater than 450 mm, the minimum thickness shall be taken in accordance with the standards agreed upon with the Register; the minimum thickness value shall not be taken less than that specified for pipes with diameter of 450 mm.

4. The minimum internal diameters of drain, sounding, air and overflow pipes shall be accepted in compliance with **7.2.3**, **10.1.12**, **10.2.8** and **10.4.7**, accordingly.

5. For pipes protected against corrosion by special coatings, linings, etc., the minimum wall thicknesses of pipes, listed in columns 3, 4 and 5, may be reduced by an amount of not more than 1 mm.

6. For sounding pipes, the thicknesses stated in colns 3 and 5 apply to the parts, which are outside the tanks, for which these pipes are intended.

7. For threaded pipes, the wall thickness shown is the minimum thickness at the bottom of the thread.

8. The thicknesses stated in columns 6 and 7 apply to the pipes, which are galvanized on the inside.

9. The minimum wall thicknesses of bilge and ballast lines passing through cargo tanks, as well as cargo shall be not less than specified in **9.10.1**.

10. The Table is not applicable to the exhaust gas piping.

11. For low pressure carbon dioxide system the wall thickness of pipes on a length from tank to discharge nozzles shall be the same as in column 7.

12. Wall thickness of scuppers and discharge pipes shall not be less than stated in **4.3.2**.

13. Wall thickness of ballast and air pipes passing through cargo tanks shall comply with the requirements of Table 9.10.1.

2.4 PIPE JOINTS

2.4.1 Use of welded, flanged, threaded and mechanical joints, made in accordance with the standards approved by the Register, is allowed.

2.4.2 Welded joints.

2.4.2.1 Welded butt joints may be accomplished with or without special provisions for full root penetration.

Welded butt joints of full penetration type with special provisions for root side quality, for instance, performed with the use of double-sided welds, backing strap or other equivalent methods, are allowed for piping of any class and diameter.

Welded butt joints of full penetration type without special provisions for root side quality are allowed for Class II and III pipelines without diameter restrictions.

2.4.2.2 Slip-on and socket welded joints shall have sleeves and sockets of adequate dimensions, meeting the requirements of the standards approved by the Register.

Slip-on sleeve and faucet welded joints may be used for Class III pipelines regardless of pipe diameter.

In some cases such joints may be used for Class I and II pipelines with outside diameter up to 88,9 mm except the pipelines conveying toxic or corrosive media and for operation under heavy fatigue loads, excessive corrosion and erosion.

2.4.2. Welding and non-destructive testing shall be carried out in accordance with **2.5** and **3.2**, Part XIV "Welding".

2.4.3 Flange connections.

2.4.3.1 Dimensions and shape of flanges and connecting bolts shall comply with the standards approved by the Register.

The applied seals shall be compatible with the conveyed medium at the design pressure and temperature.

Flange connections shall be chosen in accordance with the national or international standards approved by the Register, depending on the medium being conveyed, design pressure and temperature, external and cycling loads, as well as the pipeline location.

2.4.3.2 Connection of flanges and pipes shall be made in accordance with Fig. 2.4.3.2.

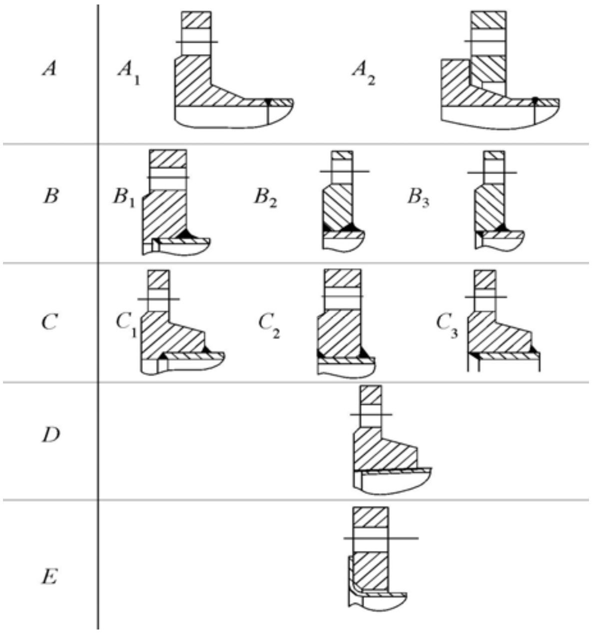


Fig. 2.4.3.2

Note. In tapered threaded connection of type D the outside diameter of pipe thread shall not be less than the pipe outside diameter. The pipe shall be flared after the flange is fitted.

Other types of flanges and pipes connections can be admitted by the Register after special consideration.

2.4.3.3 Choice of flange and pipe joints type depending on pipeline class shall be conducted in accordance with Table 2.4.3.3.

2.4.4 Tapered threaded connections.

2.4.4.1 Threaded connections shall be accomplished in compliance with the requirements of the approved national or international standards.

Such connections shall not be applied in systems conveying toxic and flammable media or media causing severe corrosive or erosive wear, as well as in conditions with heavy fatigue loads.

The threaded slip-on joints with taper thread may be applied in Class I pipelines with the diameter up to 33,7 mm and Class II and III pipelines with the diameter up to 60,3 mm.

Joints with parallel thread may be applied in Class III pipelines with the diameter up to 60,3 mm.

In particular cases, sizes in excess of those mentioned above may be accepted by the Register after special consideration if in compliance with the national or international standard.

Table 2.4.3.3

Class of piping	Toxic, corrosive and combustible media, liquefied ga [3]	Fuel oil, lubricating oil, combustible hydraulic oil	Steam	Other media [1]
I	*A, B*[5]	*A, B*	*A, B*[2, 5]	*A, B*
II	*A, B, C*	*A, B, C*	*A, B, C, D*[4]	*A, B, C, D*[4], *E*[4,6]
III		*A, B, C*	*A, B, C, D*	*A, B, C, D, E*[6]

[1] Including water, air, gases, non-combustible hydraulic oil.
[2] When design temperature exceeds 400°C - only type A.
[3] When design pressure is over 1 MPa - only type A.
[4] Types C_3, D and E (refer to Fig. 2.4.3.2) shall not be used when design temperature exceeds 250°C.
[5] Type B - only for pipes with nominal diameter of 154,4 mm and lower.
[6] For Type E the flanging technology shall be approved by the Register.

2.4.4.2 Application of threaded connections in CO_2 fire-extinguishing systems is allowed only inside the spaces to be protected and in CO_2 cylinders room.

2.4.5 Mechanical joints.

2.4.5.1 The present requirements are applicable to compression couplings, pipe unions and slip-on joints shown in Table 2.4.5.1.

Application of such joints may be also accepted by the Register.

Due to the great variations in design and configuration of mechanical joints, no specific recommendation regarding calculation method for theoretical strength calculations is given in these requirements.

Type approval of the mechanical joints shall be based on the results of testing of their specimens.

2.4.5.2 The application and pressure ratings of different mechanical joints shall be approved by the Register.

The approval shall be based on the type tests in accordance with a program approved by the Register.

2.4.5.3 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 shall be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

2.4.5.4 Material of mechanical joints shall be compatible with the piping material and internal and external media.

2.4.5.5 Mechanical joints shall be tested where applicable, to a burst pressure of 4 times the design pressure.

For design pressures of 20 MPa and above, the required test pressure may be reduced.

2.4.5.6 Where appropriate, mechanical joints shall be of fire resistant type as required by Table 2.4.5.11-1.

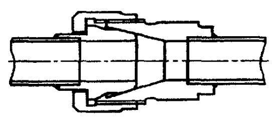
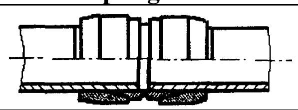
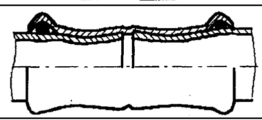
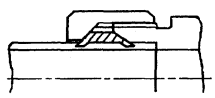
2.4.5.7 Mechanical joints, which in the event of damage could cause fire or flooding, shall not to be used in piping sections directly connected to the ship's side below the bulkhead deck of passenger ships and freeboard deck of cargo ships or tanks containing flammable fluids.

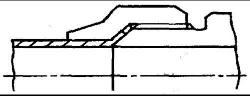
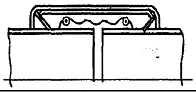
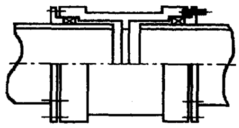
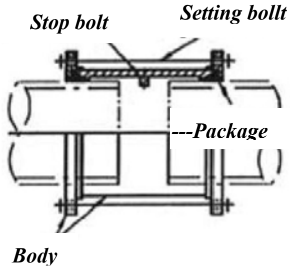
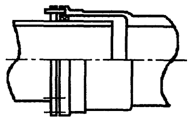
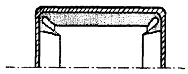
2.4.5.8 The number of mechanical joints in flammable fluid systems shall be kept to a minimum. In general, flanged joints conforming to recognised standards shall be used.

2.4.5.9 Piping in which a mechanical joint is fitted shall be adequately adjusted, aligned and supported.

Supports or hangers shall not to be used to force alignment of piping at the point of connection.

Table *2.4.5.1* Examples of mechanical joints

Pipe unions	
Welded and brazed types	
Compression couplings	
Swage type	
Press type	
Bite type	

<table>
<tr><td>Flared type</td><td colspan="2"></td></tr>
<tr><td colspan="3">Slip-on joints</td></tr>
<tr><td>Grip type</td><td colspan="2"></td></tr>
<tr><td rowspan="2">Machine grooved type</td><td colspan="2">Roll groove </td></tr>
<tr><td colspan="2">Cut groove </td></tr>
<tr><td>Slip type</td><td></td><td>
</td></tr>
<tr><td rowspan="2">Slip type</td><td colspan="2"></td></tr>
<tr><td colspan="2"></td></tr>
</table>

2.4.5.10 Slip-on joints shall not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible, unless approved by the Register.

Application of these joints inside tanks may be permitted only for the same media that is in the tanks.

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.

2.4.5.11 Application of mechanical joints and their acceptable use for each service is indicated in Table 2.4.5.11-1, dependence upon the Class of piping and pipe dimensions is indicated in Table 2.4.5.11-2.

Table 2.4.5.11-1 **Application of mechanical joints depending on the pipeline service**

Nos	Systems	Kind of connections		
		Pipe unions	Compression couplings	Slip-on joints
	Flammable fluids (flash point ≤ 60ºC			
1	Cargo oil lines[1]	+	+	+
2	Crude oil washing lines[1]	+	+	+
3	Vent lines[2]	+	+	+
	Inert gas			
4	Water seal effluent lines	+	+	+
5	Scrubber effluent lines	+	+	+
6	Main lines [1,3]	+	+	+
7	Distribution lines [1]	+	+	+
	Flammable fluids (flash point > 60°C			
8	Cargo oil lines[1]	+	+	+
9	Fuel oil lines[2,3]	+	+	+
10	Lubricating oil lines[2,3]	+	+	+
11	Hydraulic oil[2,3]	+	+	+
12	Thermal oil[2,3]	+	+	+

Sea water				
13	Bilge lines[4]	±	±	±
14	Water filled fire extinguishing systems, e.g. Sprinkler systems[2]	±	±	±
15	Non water filled fire extinguishing systems, e.g. foam, drencher systems[2]	±	±	±
16	Fire main (not permanently filled)[2]	±	±	±
17	Ballast system[4]	±	±	±
18	Cooling water system[4]	±	±	±
19	Tank cleaning services	±	±	±
20	Non-essential systems	±	±	±
Fresh water				
21	Cooling water system[4]	+	+	+
22	Condensate return[4]	+	+	+
23	Non-essential systems	+	+	+
Sanitary/drains/scuppers				
24	Deck drains (internal)[5]	+	+	+[1]
25	Sanitary drains	+	+	+
26	Scuppers and discharge (overboard)	+	+	—
Sounding/vent				
27	Water tanks/Dry spaces	+	+	+
28	Fuel oil tanks flash point > 60ºC [2,3]	+	+	+
Miscellaneous				
29	Starting/Control air[4]	+	+	–
30	Service air (non-essential)	+	+	+
31	Brine	+	+	+
32	Carbon dioxide system[4]	+	+	–
33	Steam	+	+	+[6]

Symbols:
\+ application is allowed;
— application is not allowed;
± fire resistance capability

If mechanical joints include any components which readily deteriorate in case of fire, the following footnotes shall be observeднань.

[1] only in pump rooms and open decks — only approved fire resistant types;

[2] approved fire resistant types except in cases where such mechanical joints are installed on exposed open decks, as defined in **2.4.2(10)** of Part VI "Fire Protection" and not used for fuel oil lines;

[3] slip on joints are not accepted 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;

[4] inside machinery spaces of category A — only approved fire resistant types;

[5] only above bulkhead deck of passenger ships and freeboard deck of cargo ships;

[6] slip type slip-on joints may be used for pipes on deck with a design pressure of up to 1 MPa.

***Table 2.4.5.11-2* Application of mechanical joints depending upon the class of piping**

Types of joints	Types of joints Classes of piping systems		
	I	I I	III
Pipe unions			
Welded and brazed type	+ (outside diameter/OD ≤60,3 mm)	+ (outside diameter/OD ≤60,3 mm)	+
Compression couplings			
Swage type	+	+	+
Bite type, flared type	+ (outside diameter/OD ≤60,3 mm)	+(outside diameter/OD ≤60,3 mm)	+
Press type	—	—	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	—	+	+

Slip type	—	+	+
Symbols: + application is allowed; — application is not allowed.			

2.4.5.12 Mechanical joints shall be tested in accordance with a program approved by the Register, which shall include at least the following:

.1 leakage test;
.2 vibration (fatigue) test;
.3 fire endurance test (where necessary);
.4 pressure pulsation test (where necessary);
.5 vacuum test (where necessary);
.6 burst pressure test (where necessary);
.7 pull out test (where necessary);
.8 assembly test (where necessary). The scope and nature of tests shall be specified subject to the joint type and pipeline service.

2.4.5.13 The installation of mechanical joints shall be in accordance with the manufacturer's assembly instructions. Where special tools and gauges are required for installation of the joints, these shall be supplied by the manufacturer.

2.5 FLEXIBLE HOSES

2.5.1 *Flexible hose* is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

2.5.2 Application.

2.5.2.1 The requirements **2.5.3** to **2.5.6** apply to flexible hoses of metallic or non-metallic material intended for permanent connection between a fixed piping system and items of machinery. The requirements may also be applied to temporary connected flexible hoses or hoses of portable equipment.

2.5.2.2 Flexible hoses may be accepted for use in fuel oil, lubricating, hydraulic and thermal oil systems (cold portions), fresh water and sea water cooling systems, bilge and ballast systems, and Class III steam systems where they comply with **2.5.3** to **2.5.6**. Flexible hoses in high-pressure fuel oil injection systems shall not be accepted.

2.5.2.3 The present requirements are not applicable to hoses of water fire main system.

2.5.3 Design and construction.

2.5.3.1 Flexible hoses shall be designed and constructed in accordance with the approved standards.

Flexible hoses constructed of rubber and intended for use in bilge, ballast, compressed air, fuel oil, lubricating, hydraulic and thermal oil systems shall incorporate a single or double closely woven integral wire braid or other suitable material reinforcement.

Flexible hoses for the above use constructed of plastic materials such as teflon and nylon where integral wire braid is not allowed, shall have other suitable material reinforcement, if necessary.

Flexible hoses used as part of fuel oil pipes of oil burner units shall have external wire braid protection in addition to the above reinforcement. Flexible hoses for use in steam systems shall be of metallic construction.

2.5.3.2 Flexible hoses shall be complete with approved end fittings.

Except the flange connections, the end connections shall comply with the applicable requirements of **2.4.5** and each type of hose/fitting combination shall be subject to prototype testing.

2.5.3.3 The use of hose clamps and similar types of end attachments is not acceptable for flexible hoses 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 there are double clamps at each end connection.

2.5.3.4 Flexible hoses intended for installation in piping systems where pressure pulses or high levels of vibration are expected to occur in service, shall be designed for the maximum expected impulse peak pressure and forces due to vibration.

The tests required by **2.5.5** shall take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

2.5.3.5 Flexible hoses constructed of non-metallic materials intended for installation in piping systems for flammable media and sea water systems where failure may result in flooding, shall be of fire-resistant type.

Fire resistance is not required in cases where flexible hoses are installed on open decks, as defined in **2.2.1.5(10)**, Part VI "Fire protection" and not used in fuel lines. Fire resistance shall be demonstrated by testing in accordance with the requirements of **2.5.5.6**.

2.5.3.6 Flexible hoses shall be selected for the intended location and application taking into consideration ambient conditions, compatibility with the conveyed fluids under working pressure and temperature conditions consistent with the manufacturer's instructions.

Flexible hoses for use in fire extinguishing systems shall comply with the requirement of **3.1.4.1.6**, Part VI "Fire Protection".

2.5.4 Installation.

2.5.4.1 In general, flexible hoses shall be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery equipment or piping.

2.5.4.2 Flexible hoses shall not be installed where they may be subjected to torsion deformation (twisting) under normal operation conditions.

2.5.4.3 The number of flexible hoses in piping systems shall be kept to minimum and shall be limited for the purpose stated in **2.5.2**.

2.5.4.4 Where flexible hoses are intended to be used in piping systems conveying flammable fluids that are in close proximity of heated surfaces the risk of ignition due to failure of the hose assembly shall be mitigated by the use of screens or other similar protection to the satisfaction of the Register.

2.5.4.5 Flexible hoses shall be installed in clearly visible and readily accessible locations.

2.5.4.6 The installation of flexible hoses shall be in accordance with the manufacturer's instructions and use limitations with particular attention to the following: orientation (with consideration for allowable movement in service); end connection support (where necessary); avoidance of hose contact that could cause rubbing and abrasion; minimum bend radi.

2.5.4.7 Flexible hoses installed in seawater piping, located in cargo holds or other spaces where they may be exposed to external influences (in fish holds, chain boxes, etc.), shall be protected from mechanical damage.

2.5.5 Tests.

2.5.5.1 Acceptance of flexible hoses is subject to satisfactory prototype testing. Prototype test programmes for flexible hoses shall be submitted by the manufacturer and shall be sufficiently detailed to demonstrate performance in accordance with the specified standards.

2.5.5.2 The tests shall be carried out on different nominal diameters of hose type complete with end fittings and shall incorporate tests in accordance with **2.5.5.3** to **2.5.5.6**.

2.5.5.3 Each flexible hose shall be tested by test pressure equal to 1,5 times the design pressure during 5 min. No residual deformations and damages are accepted.

2.5.5.4 All flexible hoses shall be tested by burst pressure equal to four times the design pressure. Residual deformations without visible damages or leaks are accepted.

2.5.5.5 Pressure impulse tests shall be carried out during prototype tests for flexible hoses intended for installation in systems where pressure impulses are expected. Pressure impulse tests shall be carried out to ISO 6802, ISO 6803 (in Ukraine – ДСТУ ISO 6803:2012), ISO 10380 or equivalent.

2.5.5.6 Fire resistance tests shall be carried out during prototype tests of flexible hoses referred to in **2.5.3.5**. The tests are carried out to ISO 15540 and ISO 15541 or equivalent.

2.5.6 Marking.

2.5.6.1 Flexible hoses shall be permanently marked by the manufacturer with the following details:

hose manufacturer's name or trademark;

date of manufacture (month/year);

designation type reference; nominal diameter;

pressure rating;

temperature rating.

Where a flexible hose is made up of items from different manufacturers, the components shall be clearly identified.

2.6 CONNECTION GASKETS AND INSULATION MATERIALS

2.6.1 Containing asbestos materials shall not be used in pipelines. During survey of installation of systems and piping the documents, confirming the absence of asbestos in the materials of insulation and connection gaskets shall be submitted.

2.6.2 The application of the rubber gaskets is allowed for systems and piping with the working medium temperature not more than 100°C, ftoroplast — not more than 150°C.

2.6.3 If the material of a sealing element is a material that has no Type Approval Certificate (except for copper and copper-base alloys, as well as rubber and ftoroplast) the Register reserves the right to require the performance of chemical analysis of the sample of the sealing material.

3. PLASTIC PIPING

3.1 DEFINITIONS

3.1.1 For the purpose of the present Section, the following definitions have been adopted:

Fire resistance is the ability of plastic pipeline to maintain strength and integrity (i.e. ability to operate to its designated purpose) within the set period of time under flame exposure.

Joint is joining pipes by adhesive bonding, laminating, welding, etc.

Nominal pressure is the maximum permissible working pressure as defined in **6.8.2.3**, Part XIII "Materials".

Plastic materials are thermoplastic (thermoplasts) and thermosetting (thermosets) materials with or without reinforcement, such as polyvinylchloride (PVC) and fibre reinforced plastic (FRP).

Plastic materials include caoutchouc and materials with similar thermomechanical behavior.

Design pressure is the maximum working pressure expected under operating conditions or the maximum pressure setting of the pressure-relief valve or pressure relieving device, if fitted.

Piping/piping system is a combination of plastic pipes, formed components, pipe joints and any internal or external coatings or linings necessitated by operating conditions.

Formed components are bends, elbows, connecting branches, etc. made of plastic.

3.2 SCOPE OF APPLICATION. GENERAL REQUIREMENTS

3.2.1 The present requirements are applicable to plastic pipes/piping systems on ships.

3.2.2 The requirements are not applicable to flexible and mechanical couplings used in metallic piping systems.

3.2.3 General requirements to plastic pipes and fittings are stated in **6.8**, Part XIII "Materials".

3.3 REQUIREMENTS FOR PIPING DEPENDING ON THEIR PURPOSE AND LOCATION

3.3.1 Fire-resistance.

3.3.1.1 Pipes and formed components, integrity of which has significant influence on ship's safety, shall meet the requirements of fire-resistance.

3.3.1.2 Depending on pipeline ability to maintain integrity during fire-resistance tests according to the procedure stated in IMO resolutions A.753(18) and MSC.313(88), five degrees of fireresistance are specified:

L1 for pipelines withstanding fire-resistance test in dry condition during 1 h without leakage during further hydraulic tests;

W1 for pipelines not carrying flammable liquid or any gas and withstanding fire-resistance test in dry condition during 1 h with a maximum 5 % flow loss in the system;

L2 for pipelines withstanding fire-resistance test in dry condition during 30 min without leakage during further hydraulic tests;

W2 for pipelines not carrying flammable liquid or any gas and withstanding fire-resistance test in dry condition during 30 min. with a maximum 5 % flow loss in the system;

L3 for pipelines withstanding fire-resistance test in filled condition during 30 min without leakage during further hydraulic tests.

Plastic pipelines scope of application depending on fire-resistance degree, location and media conveyed is given in Tabl3.3.1.2.

Table 3.3.1.2 **Application of plastic pipelines**

Nos	Medium to be conveyed	Piping systems	Location										
			A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Liquid cargoes with flash point ≤ 60ºC	Cargo	–	–	L1	–	–	O	–	O[1]	O	–	L 1[2]
		Crude oil tank washing	–	–	L1	–	–	O	–	O[1]	O	–	L 1[2]
		Exhaust gas	–	–	–	–	–	O	–	O[1]	O	–	+
2	Inert gas	Pipeline from hydraulic lock	–	–	O[3]	–	–	O[3]	O[3]	O[3]	O[3]	–	O
		Pipeline from purifier	O[3]	O[3]	–	–	–	–	–	O[3]	O[3]	–	O
		Main pipe	O	O	L1	–	–	–	–	–	O	–	L1[4]
		Distribution pipelines	–	–	L1	–	–	O	–	–	O	–	L1[2]
3	Flammable liquids with flash point > 60ºC	Cargo	+	+	L 1	+	+	–[5]	O	O[1]	O	–	L1
		Fuel oil	+	+	L1	+	+	–[5]	O	–	O	L1	L1
		Oil	+	+	L1	+	+	–	–	O	O	L1	L1
		Hydraulic	+	+	L1	+	+	O	O	O	O	L1	L1
4	Sea water	Drainage	L1[6]	L1[6]	L1	+	+	–	O	O	O	–	L1
		Drain pipelines of internal spaces	W1[7]	W1[7]	–	W1[7]	O	–	O	O	O	O	O
		Sanitary drains (internal)	O	O	–	O	O	–	O	O	O	O	O
		Drainage from weather decks	O[3,8]	O[3,8]	O[3,8]	O[3,8]	O[3,8]	O	O	O	O	O[3,8]	O
		Firemain system and water spraying	L1	L1	L1	+	–	–	–	O	O	+	L1
		Foam fire-extinguishing	W1	W1	W1	+	–	–	–	O	O	W1	W1
		Sprinkling	W1	W1	L3	+	–	–	–	O	O	L3	L3
		Ballast	L3	L3	L3	L3	+	O[1]	O	O	O	W2	W2
		Essential purpose cooling systems	L3	L3	–	–	–	–	–	O	O	–	W2
		Non-essential purpose cooling systems	O	O	O	O	O	–	O	O	O	O	O
		Tank washing	–	–	L3	–	–	O	–	O	O	–	L3[2]
5	Fresh water	Essential purpose cooling systems	L3	L3	–	–	–	–	O	O	O	L3	L3
		Condensate return system	L3	L3	L3	O	O	–	–	–	O	O	O
		Non-essential purpose systems	O	O	O	O	O	–	O	O	O	O	O
6	Other media	Air, sounding and overflow pipes: water tanks and dry compartments	O	O	O	O	O	O[1]	O	O	O	O	O
		Flammable liquids, T_{flash} > 60ºC	+	+	+	+	+	+[5]	O	O[1]	O	+	+
		Pneumatic control systems	L1[9]	L1[9]	L1[9]	L1[9]	L1[5]	–	O	O	O	L1[5]	L1[5]
		Air pipes for domestic needs	O	O	O	O	O	–	O	O	O	O	O
		Brine	O	O	–	O	O	–	–	–	O	O	O
		Low pressure steam	W2	W2	O[10]	O[10]	O[10]	O	O	O	O	O[10]	O[10]

Symbols : A - machinery spaces of category A; B - other machinery spaces; C - cargo pumps rooms, including accesses and trunks; D - cargo spaces of roll-on/roll-off ships; E - dry cargo rooms and trunks; F - cargo tanks and trunks; G - fuel oil tanks and trunks; H - ballast tanks and trunks;;	I - cofferdams, dry compartments, etc; J - accommodation, service spaces and control stations; K - weather decks; L1, L2, L3, W1, W2 – fire-resistance test in accordance with **3.3.1.2**; O – fire-resistance test is not required; «– » – not applicable; «+ » – only metal materials with fusion point above 925ºC.

End of Table. 3.3.1.2

[1] For tankers, where the requirements of item **3.6**, Regulation 19 of Annex I to MARPOL 73/78 shall be met, "–" shall be used instead of "O".
[2] For cargo tanks the remotely closing valves shall be provided.
[3] 4 From the side the valves with remote control located outside of the room shall be provided.
[4] For pipeline between engine room and deck hydraulic lock "O" may be used instead of "L1".
[5] When cargo tanks contain flammable liquids with flash point > 60 °C, "O" may be used instead of "–" or "+".
[6] For passenger ships "+" shall be used instead of "L1".
[7] For drainage pipelines servicing only the particular space "O" may be used instead of " L1".
[8] Scupper holes of weather decks in the positions 1 and 2 according to Regulation 13 of the International Convention on Load Line, 1966, shall be "+", if they are not provided with the appropriate blanking means.
[9] When control functions are not foreseen, "O" may be used instead of "L1".
[10] For essential purposes, such as heating of cargo tanks and ship's typhon, "+" shall be used instead of "O".

3.3.2 Flame spreading, flame-retardant coatings.

3.3.2.1 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 regulated in by Part 5 of Annex 1 to the 2010 FTP Code.

Piping materials shall fulfil the requirements of FTP Code, part 2, on smoke emission and toxicity test and they shall be used in accordance with the agreed manufacturer's recommendations.

3.3.2.2 When fire-retardant coatings are applied to provide the required degree of fire-resistance they shall comply with the requirements of **6.8**, Part XIII "Materials".

3.3.2.3 Fire-retardant coatings in junctions shall be applied after conducting of hydraulic tests of the system in compliance with pipe manufacturer recommendations according to the procedure approved by the Register in each case.

3.3.2.4 Fire-retardant coatings shall be used according to the agreed recommendations of the manufacturer.

3.4 INSTALLATION REQUIREMENTS

3.4.1 Supports.

3.4.1.1 Selection and spacing of pipe supports in shipboard systems shall be determined as a function of allowable stresses and maximum deflection criteria.

Support spacing shall not greater than the pipe Manufacturer's recommended spacing.

The selection and spacing of pipe supports shall 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 shall be considered.

3.4.1.2 The load from pipe weight shall be equally distributed over the entire load-bearing face of the support.

Measures shall be taken to minimize pipe wearing in the points of their junction with the supports.

3.4.1.3 Components of system having significant mass, such as valves, compensators, etc. shall be fitted with separate supports.

3.4.2 Heat expansion compensation.

3.4.2.1 When assembling of plastic pipelines the compensation tolerance for relative displacement between piping and steel structures with regard to difference in heat expansion ratio and ship's hull deformation shall be provided.

3.4.2.2 When calculating heat expansions the working temperature of system and the temperature, at which assembling is carried out, shall be taken into account.

3.4.3 Environmental stresses.

3.4.3.1 In pipe laying, where necessary, allowance shall be made for periodically involved concentrated loads.

At least, the force generating by the load of one person of 100 kg in the middle of span of any pipe with the outer diameter over 100 mm shall be taken into consideration.

3.4.3.2 Besides for providing adequate robustness for all piping including open-ended piping a minimum wall thickness, complying with the thickness specified on the basis of strength control, may be increased taking into account the conditions encountered during service on board ships.

3.4.3.3 When necessary, pipes shall be protected from mechanical damage.

3.4.4 Installation of electrically conducting pipes.

3.4.4.1 In systems of liquids transmission with electrical conductivity less than 1000 pico-siemens per meter (PS/m), such as raffinates, distillates, the electrically conductive pipes shall be used.

3.4.4.2 Regardless of the liquids transmitted the plastic pipes passing through explosive areas shall be electrically conductive.

Resistance in any point of pipeline system as relative to earth shall not exceed 10^6 Ohm. Pipes and formed components having electrically conducted layers shall preferably be of equal conductivity.

Such pipes shall be sufficiently protected from damage by electric discharge caused by difference in the electrical conductivity of layers.

3.4.4.3 After installation earth connection shall be checked. Earthing wires shall be accessible for examination.

3.5 PLASTIC PIPES JOINTS

3.5.1 Strength of joints.

3.5.1.1 Strength of joints shall not be less than strength of a pipeline where they are mounted.

3.5.1.2 Pipes may be connected with the use of glued, welded, flanged and other connections.

3.5.1.3 Glues used for pipes joints shall keep tightness of joints in the whole pressure and temperature range.

3.5.1.4 Tightening of joints shall be carried out in compliance with the instructions of the manufacturer.

3.5.2 2 Testing of joints quality.

3.5.2.1 For the inspection of pipe joint quality it is necessary in accordance with the accepted procedure to prepare test assemblies, which shall include at least one joint of pipe with pipe and pipe with formed component.

3.5.2.2 Following joint setting, a test connection shall be subjected to a hydraulic pressure test during at least 1 h at the pressure 2,5 times exceeding the design one. Leakage and breaks of joint are not allowed.

Tests shall be arranged in such a way that joints are loaded both in longitudinal and transverse directions.

3.5.2.3 When selecting pipes for test specimen the following shall be taken into consideration:

when the maximum outer diameter of joint assembly is less than 200 mm, the test assembly shall incorporate a pipe with the maximum diameter;

when the maximum outer diameter of joint assembly is over 200 mm, the outer diameter of test joint assembly shall be 200 mm or shall be equal to 25 % of the maximum diameter of the coupling, whatever is greater.

3.6 PLASTIC PIPING LAYING

3.6.1 Where plastic pipes pass through watertight bulkheads and decks, "A" and "B" class divisions the requirements of **5.1** shall be met.

3.7 INSPECTION DURING THE INSTALLATION

3.7.1 Installation shall be carried out in accordance with the instructions of the manufacturer.

3.7.2 The method of pipe connection (junction) shall be developed and approved prior to the installation.

3.7.3 Surveys and tests stated in the present Section of the Rules shall precede the approval of the method.

3.7.4 Personnel involved in the works shall be properly qualified and attested.

3.7.5 In the method of joints connection the following shall be reflected: the applied materials, tools and accessories, the requirements on preparation of joints, temperature conditions, the requirements on dimensions and tolerances, as well as the acceptance criteria upon the work and testing completion.

3.7.6 Any alterations in the method resulting in change of physical and mechanical properties of the joint call for its repeated consideration and re-approval.

3.8 TESTING OF PIPING AFTER INSTALLATION ABOARD THE SHIP

3.8.1 After installation the pipeline system of essential purpose shall be hydraulically tested with pressure at least 1,5 times higher than the design pressure.

3.8.2 The pipeline system of non-essential purpose may be tested for tightness with the working pressure.

3.8.3 For electrically conductive pipes the availability of grounding shall be checked and the spot check of resistance shall be carried out.

4. ELEMENTS OF THE SYSTEMS AND PIPING

4.1 CONSTRUCTION, MARKING, ARRANGEMENT AND INSTALLATION OF VALVES

4.1.1 Construction.

4.1.1.1 Valves shall comply with the agreed standards.

Valve threaded covers shall be fitted with reliable stops.

The plug nut shall be protected from unscrewing when operating the valve.

4.1.1.2 Valves with remote control shall be arranged for local manual operation independent of the remote operating mechanism or they shall be operated from a separate monitor console with tracker-balls and power supply to control valves from independent source, or it is provided with manual operation both directly where fitted and using manual remote control.

The remotely controlled valves shall be so constructed that in case of failure of the remote control system, the valves remain, or automatically return, in a position that will not bring the ship in dangerous situation.

4.1.1.3 Compressed air shall not be used in remote control systems to operate actuators inside cargo tanks.

4.1.1.4 Where the valves inside cargo tanks are remote-controlled by means of a hydraulic system, they shall be also operable with the aid of a hand pump, which can be connected to the hydraulic system in positions where the pipes are laid down to each valve, or to a separate pipe laid directly to the valve actuator.

4.1.1.5 The supply tank of the hydraulic remote control system of the valves inside cargo tanks shall be located as high as practicable above the level of the top of cargo tanks, and all supply pipes shall enter the cargo tanks through the highest part of the cargo tanks.

The supply tank shall also have an air pipe laid to a safe position on the open deck and fitted with a flame-arresting gauze at the open end.

This tank shall be fitted with a low level audible and visual alarm.

4.1.2 Marking of valves.

4.1.2.1 The shut-off valves shall be provided with conspicuous nameplates fixed in place and bearing clear inscriptions to show the purpose of valves.

4.1.2.2 At the control stations, the remote-controled valves shall have identification plates, as well as position indicators "open" and "closed".

Where the remote control is used only to close the valves, the indicators need not be fitted.

4.1.3 Installation of valves.

4.1.3.1 The valves arranged on watertight bulkheads shall be secured to welded pads by studs, or to bulkhead sockets with flange connections.

Joints of types "D" and "E" (refer to 2.4.3.2) are not allowed.

The stud holes shall not be through holes.

4.1.3.2 The valve chests and the hand-controlled valves shall be fitted in places where they are at all times readily accessible in normal operating conditions.

Where the valves of the fuel oil system are installed in the machinery space, the valve control gear shall be fitted above the plating.

4.1.3.3 The measuring instruments of fuel oil and lubricating oil systems shall be provided with valves or cocks to shut the instruments off from piping.

Thermometer sensors shall be fitted in compact sleeves.

4.2 FILTERS

4.2.1 The design and construction of filters shall facilitate cleaning.

4.2.2 Filters shall be provided with a device to indicate the absence of pressure therein before they are opened.

The tubes of such devices shall be directed to trays so that spillages are not sprayed around.

4.2.3 For filters forming part of systems with a combustible working medium, an interlock is recommended so that they cannot be opened when under pressure and that the working medium cannot be supplied therein when opened.

4.2.4 Filters shall be so arranged that they are readily accessible for maintenance.

Filters and strainers forming part of systems with a combustible working medium shall be located as far away as practicable from sources of ignition.

4.2.5 The pipelines used to supply and carry away fuel oil in/from the filters shall be equipped with shut-off valves or cocks.

4.2.6 Filters on seawater suction mains shall comply with **15.3.1**.

4.3 SEA CHESTS AND ICE BOXES. BOTTOM AND SIDE VALVES. OPENINGS IN SHELL PLATING

4.3.1 Sea chests and ice boxes.

4.3.1.1 Number and arrangement of sea chests for the cooling water system shall comply with **15.2.1**.

In **Ice5** and **Ice4** In.

In icebreakers and **Ice6** ice class ships, at least two sea chests shall be ice boxes.

In icebreakers and **Ice6, Ice5** and **Ice4** ice class ships the ice box design shall allow for an effective separation of ice and removal of air from the ice box to ensure reliable operation of the sea-water system.

Sea inlet valves shall be secured directly to sea chests or ice boxes.

4.3.1.2 In icebreakers and ice class ships, provision shall be made for the heating of the sea chests and ice boxes.

For this purpose cooling water recirculation shall be used for ice boxes and sea chests. For ice boxes, the recirculated water pipes shall be laid to the upper and lower parts of the box, and the total sectional area of these pipes shall not be less than the area of the cooling water discharge pipe.

For the heating of the sea chests and ice boxes the use of electric heating systems with the use of special electric heating cables is allowed. When using special electric heating cables, the requirements of **5.8** shall be met.

For ice boxes, the recirculated water pipes shall be laid to the upper and lower parts of the box, and the total sectional area of these pipes shall not be less than the area of the cooling water discharge pipe.

For sea chests, the diameter of the water recirculating pipe shall not be less than 0,85 of the discharge pipe diameter.

4.3.1.3 Provision shall be made for the access into these boxes via detachable gratings or manholes.

If a manhole is provided in the ice box it shall be located above the deepest load line.

4.3.2 Openings in shell plating. Bottom and side valves.

4.3.2.1 The number of openings in shell plating shall be kept to a minimum. Therefore, whereover possible, discharge pipes shall be connected to common discharges.

4.3.2.2 The location of sea inlet and discharge openings in ship sides shall be such as to prevent:

.1 sewage, ash and other wastes being sucked by sea water pumps;

.2 sewage and discharge water penetrating into the ship spaces through side scuttles as well as any discharge of water into lifeboats and liferafts when lowered.

Where it is impracticable to comply with the requirements of **4.3.2.2.2**, discharge openings shall be fitted with appropriate arrangements to prevent the ingress of water into ship spaces, lifeboats and liferafts.

4.3.2.3 All the openings in ship side for sea chests and ice boxes shall be fitted with gratings. Instead of gratings, holes or slots in shell plating are permissible. The net area through the gratings or slots shall not be less than 2,5 times the area of the valve connected to the sea inlet. The diameter of holes and the width of slots in ratings or shell plating shall be about 20 mm. The gratings of the sea chests shall be provided with a device for washing them (refer to **4.3.2.10**). For this purpose, blowing with compressed air or steam, backwash, can be used. The pressure in the blow-off system shall not exceed 0,5 MPa.

Non-return-shut-off valves shall be provided on the working medium feed piping.

Water for backwashing shall be taken from another sea chest.

The device for washing may not be provided for ice boxes.

4.3.2.4 The overboard discharges from enclosed spaces below the freeboard deck or from enclosed superstructures and deckhouses on the freeboard deck shall be fitted with accessible means for preventing water from passing inboard.

Discharges from piping, which have, or may have, open ends within the mentioned spaces shall comply with the requirements of 3.2.11, Load Line Rules for Sea-Going Ships.

4.3.2.5 In ships of less than 24 m in length, openings in shell plating of spaces on and below the freeboard deck may have one locally controlled non-return shut-off valve.

In floating docks, each discharge of pipes from spaces below the margin line, which have inboard ends in those spaces, shall have a non-return valve with a positive means of closing from a readily accessible position above the safety deck.

4.3.2.6 The scuppers and overboard discharge pipes from open decks and spaces not specified in **4.3.2.4** either 450 mm below the freeboard deck or less than 600 mm above the summer load waterline shall be fitted with non-return valves (dampers) at the outer shell.

In this case, the wall thickness of scuppers and discharge pipes shall not be less than stated in column 3 of Table2.3.8.

No valves may be provided if the wall thickness of pipes below the freeboard deck and in spaces within enclosed superstructures is less than:

7 mm for $d \leq 80$ mm;

10 mm for $d=180$ mm;

12,5 mm for $d \geq 220$ mm.

where: d – external diameter of pipes.

Intermediate sizes shall be determined by linear interpolation.

In open superstructures and deckhouses, overboard scuppers shall be provided.

In spaces intended for the carriage of motor vehicles with fuel in their tanks, overboard scupper pipes shall be provided to prevent accumulation of water during the operation of the water spraying system.

In floating docks, the overboard scuppers and discharge pipes below the margin line from spaces above the margin line and open decks shall have non-return valves at the outer shell. The valves may be omitted where the pipe thickness below the margin line is not less than that of the outer shell plating, however, it need not exceed 12 mm.

4.3.2.7 In engine rooms, the sea inlets and discharges of the systems and piping in connection with the operation of the main and auxiliary machinery shall be provided with readily accessible shut-off valves locally or remotely controlled.

The controls shall be provided with indicators showing whether the valve is open or closed.

The discharge valves, as a rule, shall be of the non-return shut-off type.

4.3.2.8 The controls of inlet bottom and side valves shall be readily accessible and shall be provided with an indicator showing whether the valve is open or closed.

In passenger ships, these controls shall be located above the floor level of the engine room.

4.3.2.9 In periodically unattended machinery spaces the location of the controls of any valve serving a sea inlet, a discharge below the waterline or a bilge injection system shall be so sited as to allow the time taken for the influx of water resulting from damage of piping related with the said valves to reach the control be greater than the time to reach and operate the control with the nominal speed of travel of a person onboard not more than 1 m/s.

In any case, the time taken for the influx of water to reach the control shall be not less than 10 min.

If the level, to which a space can be flooded with the ship in the fully loaded condition, is above the controls, provision shall be made to operate them from a position above this level.

Machinery spaces fully automated in respect of control of sea inlet and discharge valves of the main and auxiliary machinery systems and piping shall be regarded equal to attended machinery spaces on condition that the provision is made of arrangements, activating when the space is being flooded.

4.3.2.10 The stud holes shall not penetrate the shell plating and shall be only within the welded pads. The valves may be also installed on branch pipes welded to the shell plating, provided they are straight, rigid enough and have the minimum length and cathodic protection against contact corrosion. Branch pipes shall be located in readily accessible places for maintenance and for measuring of shell plating thickness under service conditions.

The use of flanged joins of *D* and *E* types (refer to **2.4.3.2**), thread and mechanical joints to install bottom and side valves below the waterline is not allowed.

For cooling systems of main or auxiliary machinery the wall thickness of a branch pipe at least 12 mm thick. In systems, used for pumping periodically, as well as in blow-off systems thickness of side branch pipes may be taken in accordance with **4.3.2.6**.

4.3.2.11 As a rule, the bottom and side valves shall be of flanged type.

Valves of other types may also be allowed provided that the attachment of the bottom and side valves to hull structures ensures their operability and watertightness of the hull when a piping section adjacent thereto is dismantled.

The material of the seal between the bottom and side valves and the hull shall not be easily deteriorated in case of fire, or special structural measures shall be taken to prevent deterioration of the seal.

4.3.2.12 The spindles and movable parts of bottom and side valves shall be manufactured of corrosionresistant materials. Protection against contact corrosion shall be provided in accordance with **1.4.3.4**.

4.3.2.13 The shell openings from garbage chutes of spaces located below the freeboard deck shall be provided with closing devices for preventing water from passing inboard.

The closing devices shall meet the requirements of **3.2.11.1** of the Load Line Rules for Sea-Going Ships.

4.3.2.14 Side valves of boiler blow off pipes shall be attached to welded pads.

Welded protection rings shall be fitted at the outer side of the shell plating.

The flange collar of a valve shall pass through the welded pad, plating and the protection ring.

Valve collars are not mandatory where such collars are fitted on the pad.

Valves shall installed in readily accessible places, not below the floor level of spaces.

It should be easily seen whether the valve is open or closed.

4.3.3 Sea inlets and cooling water systems on Polar and Baltic class ships.

4.3.3.1 Cooling water systems for machinery that are essential for the propulsion and safety of the vessel, including sea chests inlets, shall be designed for the environmental conditions applicable to the ice class.

4.3.3.2 At least two sea chests shall be arranged as ice boxes for class **PCI** — **PC5** ships.

The calculated volume for each of the ice boxes shall be at least 1 m3 for every 750 kW of the total installed power.

For **PC6** and **PC7** and Baltic ice class **IA Super** and **IA** ships there shall be at least one icebox located preferably near centre line (refer also to **2.9.3.2,** Part VII «Machinery Installations»).

4.3.3.3 Ice boxes shall be designed for an effective separation of ice and venting of air.

4.3.3.4 Sea inlet valves shall be secured directly to the ice boxes. The valve shall be a full bore type.

4.3.3.5 Ice boxes and sea chests shall have vent pipes and shall have shut off valves connected direct to the shell.

4.3.3.6 Means shall be provided to prevent freezing of sea chests, ice boxes, ship side valves and fittings above the load waterline (refer also to **4.3.1.2**).

4.3.3.7 Efficient means shall be provided to re-circulate cooling seawater to the ice box.

Total sectional area of the circulating pipes shall not be less than the area of the cooling water discharge pipe.

4.3.3.8 Detachable gratings or manholes shall be provided for ice boxes.

Manholes shall be located above the deepest load line.

Access shall be provided to the ice box from above.

4.3.3.9 Openings in ship sides for ice boxes shall be fitted with gratings, or holes or slots in shell plates.

The net area through these openings shall be not less than 5 times the area of the inlet pipe. The diameter of holes and width of slot in shell plating shall be not less than 20 mm.

Gratings of the ice boxes shall be provided with a means of clearing.

Clearing pipes shall be provided with screw-down type non return valves.

4.4. AIR PIPE AUTOMATIC CLOSING DEVICES

4.4.1 Air pipe automatic closing devices shall be self-draining have reliable attachments, and shall also:

.1 prevent the free entry of water into the tanks;

.2 allow the passage of air or liquid to prevent excessive pressure or vacuum coming on the tank.

4.4.2 Air pipe automatic closing device shall be constructed to allow inspection of the inside of the casing, as well as changing the seals.

4.4.3 Efficient float seating arrangements shall be provided for the closures. Besides seating arrangements other means shall be provided to prevent the float from contacting the inner chamber in its normal state and to prevent the float damage from the water impact in case the tank is overfilled.

4.4.4 The clear area through an air pipe automatic closing device in the open position shall be at least equal to the area of the inlet.

4.4.5 Air pipe automatic closing devices shall be so suitable for use at inclinations up to 40°.

4.4.6 In the case of air pipe automatic closing devices of the float type, suitable guides shall be provided to ensure unobstructed operation under all working conditions of heel and trim.

4.4.7 The maximum allowable tolerances for wall thi-ckness of floats shall not exceed 10 % of thickness.

4.4.8 8 The inner and the outer chambers of an automatic air pipe head shall be of a minimum thickness of 6 mm.

Where side covers are provided and their function is integral to providing functions of the closing device as outlined in **4.4.1**, they shall have a minimum wall thickness of 6 mm.

If the air pipe head can meet the tightness test in **21.4.1.2**, without the side covers attached, then the side covers shall not be considered integral to the closing device, in which case a wall less than 6 mm can be acceptable for side covers.

Casings of air pipe closing devices shall be of approved metallic materials adequately protected against corrosion.

For galvanized steel air pipe heads, the zinc coating shall be applied by the hot method and the thickness shall be 70 to 100 microns.

4.4.9 For areas susceptible to erosion due to the ballast water impact when the tank is being overfilled, (e.g. the inner chamber area above the air pipe, overlap of ±10° either side) an additional harder coating shall be applied. This shall be an aluminum bearing epoxy, or other equivalent, coating, applied over zinc.

4.4.10 Elements of closures made of non-metallic materials shall be compatible with the media carried in the tank and suitable for operating at ambient temperatures between -25°C and +85°C.

4.4.11 Air pipe automatic closing devices shall be type approved and the minimum test requirements shall be in compliance with **21.4**.

5. PIPING LAYING

5.1 PIPING LAYING THROUGH WATERTIGHT AND FIRE-PROOF DIVISIONS

5.1.1 The number of pipelines passing through the watertight bulkheads shall be kept to a minimum.

Pipelines passing through main watertight bulkheads, shall, as a rule, be situated at a distance from the ship's side of at least one-fifth of the ship's breadth (refer to **7.3.5**).

Where this requirement is impracticable, measures shall be taken to prevent the spread of sea water beyond the damaged compartment into other watertight compartments and tanks in case of damage to the ship's hull and deterioration of pipes.

5.1.2 In cargo ships of 80 m in length and more and in passenger ships irrespective of their length the collision bulkhead may be pierced below the bulkhead deck by not more than one pipe for dealing with liquid in the forepeak tank. This pipe, at its piercing the collision bulkhead, shall be fitted with a screw-down valve directly on the collision bulkhead inside the forepeak capable of being operated from a readily accessible place above the bulkhead deck. Such valve may be fitted on the after side of the collision bulkhead provided that the valve is readily accessible under all service conditions and the space in which it is located is not a cargo space.

On passenger ships, the replacement of the screw-down valve by butterfly valve is not allowed.

Cargo ships are allowed to use a butterfly valve if it is flanged or attached to the collision bulkhead separately from the pipe connected to it.

If the forepeak is divided by a longitudinal bulkhead into two watertight compartments to hold two different kinds of liquids, the collision bulkhead may be allowed to be pierced below the bulkhead deck by two pipes, each fitted with such valve.

On pipes passing through the collision bulkhead above the bulkhead deck or freeboard deck a screw-down valve may be omitted.

5.1.3 In cargo ships not mentioned in **5.1.2** each pipe piercing the collision bulkhead below the bulkhead deck shall be fitted with a screw-down valve directly on the collision bulkhead inside the forepeak.

Such valve shall be capable of being operated from a readily accessible place above the bulkhead deck for ships having the subdivision mark in the class notation, or above the freeboard deck for other ships.

Such valve may be fitted on the after side of the collision bulkhead, provided that the space in which it is located is not a cargo space.

5.1.4 Where pipelines pass through watertight bulkheads, decks and other watertight structures, there shall be used appropriate bulkhead (sockets), welded pads and other details to ensure the integrity of the structure concerned.

The holes for studs shall not penetrate through the plating of watertight structure and shall be kept within the welded pads.

Gaskets made of lead or a material, which will be readily deteriorated in the event of fire, shall not be used.

Sockets attached by welding to watertight decks and bulkheads shall have the wall thickness not less than wall thickness of attached pipes.

The bulkhead sleeves or sockets for pipes penetration through the watertight decks and bulkheads shall be attached by butt, full-penetration welding.

Use of lap or fillet welds may be allowed if the integrity is ensured by two welds (on both sides of the bulkhead).

5.1.5 Where plastic pipes pass through watertight bulkheads and decks forming boundaries of watertight compartments, valves operated from above the bulkhead deck shall be fitted.

The valves shall be of steel or another material equivalent to steel in fire resistance.

This requirement does not apply to ballast pipes laid within the double bottom.

5.1.6 Where pipes pass through fireresisting divisions, the requirements of 2.1.2.2, Part VI "Fire Protection" shall be complied with.

5.1.7 Where a plastic pipe passes through a division of the main vertical fire zone, provision shall be made for bulkhead steel sleeve and valve that may be closed from either side of the bulkhead.

The valves shall be of steel or another material equivalent to steel in fire resistance.

5.1.8 The bulkhead sockets in watertight bulkheads and decks shall be filled with sealing masses with good adhesion with the pipe and socket metal, resistant to vibration and to water and oily products, which do not shrink and do not cause loss of sealing during prolonged operation under conditions specified in **2.3.1**, Part VII “Machinery Installations”.

The sealing of the pipe bundle penetration through the fireproof bulkheads shall be such as to withstand standard fire test specified for the bulkhead of this type in **2.1.2.2**, Part VI “Fire Protection”.

5.2 PIPING LAYING IN TANKS

5.2.1 Bilge pipes, drinking water and feed water pipes shall not be laid through fuel oil and lubricating oil storage tanks, nor shall fuel oil and lubricating oil pipes pass through drinking water and boiler feed water tanks, unless the pipes are laid in oiltight ducts forming part of the tank structure.

Sea water and lubricating oil piping, with no ducts as well as air, overflow and sounding pipes may pass through the fuel storage tanks, if these pipes are of seamless type and have no detachable joints inside the storage tanks; where detachable joints cannot be avoided, they shall be flanged with oilproof gaskets placed between them or compression couplings according to Table 2.4.5.1.

5.2.2 Where the pipes passing through the tanks are not carried in ducts and thermal expansion shall be considered, pipe bends shall be arranged inside the tank.

Where pipes are laid in ducts, it is recommended that thermal compensators be arranged outside the duct.

5.2.3 The pipes laid in oil tankers shall comply with the requirements of **9.2**.

5.3 PIPING LAYING IN CARGO HOLDS AND OTHER SPACES

5.3.1 Pipes shall be secured in a way as not to interfere with the stresses from thermal expansion, undue deformation of ship structure and vibration.

5.3.2 Seawater pipes located in cargo holds and in other spaces where pipes may be subject to impacts (e.g. fish holds, chain lockers), are to be protected from mechanical damage.

5.3.3 Fuel, steam and water pipes as well as pressure pipes of the hydraulic drives shall not, as a rule, be carried in dry cargo holds. Bilge pipes are excluded from this requirement. These pipes may be allowed, provided they are laid in special ducts or not in ducts where the pipes employed are of increased thickness and protected by strong steel casings.

5.3.4 Steam pipes shall not be laid in paint room, lantern room or other spaces intended for the carriage of readily flammable materials.

5.3.5 Pipes conveying fuel oil shall not be laid through the accommodation and service spaces as well as under the coating, with the exception of fuel pipe of the emergency diesel-generator and the filling pipes, which are allowed to be laid through sanitary spaces, provided the pipes used have a thickness of not less than 5 mm and no detachable joints are employed.

5.3.6 Pipes having considerable longitudinal extension and conveying hot media shall have thermal compensators or as many bends as will provide adequate self-compensation of the pipeline.

Thermal compensators are fitted in order to take up the axial and transverse displacements and shall not be used to correct misalignment of the pipes.

Pipelines shall have appropriate supports.

Brackets and hangers shall not be used to produce forces that provide alignment of the pipes or elements.

The radii of bends shall be in compliance with **2.2.1**.

5.3.7 The pipes of all the systems and the vent ducts shall, where necessary, be fitted with arrangements for blow-down of the working medium or draining of liquid, if any. Appropriate structural measures shall be taken to protect ship's hull and equipment from adverse effect of the agents discharged.

5.3.8 The pipes of fire fighting system shall be laid in conformity with the requirements of **3.1.4.1**, Part VI "Fire Protection".

5.3.9 Group I and II refrigerant piping laying through accommodation and service spaces shall be carried out in compliance with **6.2.8**, Part XII "Refrigerating Plants".

5.4 PIPING LAYING IN REFRIGERATED CARGO SPACES

5.4.1 It is recommended that no pipes be laid through refrigerated cargo spaces, unless they are intended to serve these spaces. Where laying of such pipes cannot be avoided, they shall be carefully insulated. This requirement equally applies to air and sounding pipes.

In these spaces the pipes shall not have sections, in which water may collect and freeze.

5.5 PIPING LAYING IN THE VICINITY OF ELECTRICAL AND RADIO EQUIPMENT

5.5.1 Pressure pipes are not permitted to be laid above and behind the main and emergency switchboards as well as the control panels of essential machinery and equipment.

Piping may be laid at a distance of not less than 500 mm from the fronts and sides of the switchboards and control panels, provided that at a distance of 1500 mm to the switchboards and panels and along them no detachable joints are used on piping or the joints have protective casings.

5.5.2 Pipes shall not be laid either through special electric spaces (refer to **1.2**, Part XI "Electrical Equipment"), or through accumulator battery rooms, with the exception of fire carbon dioxide smothering system pipes, compressed air pipes and pipes serving the electrical equipment installed in these spaces.

Other pipes are allowed to be laid through such spaces when the requirements of **5.5.1** are fulfilled and provided there is no valves or detachable joints. Where necessary measures for protection of the pipes against condensate formation shall be applied.

5.5.3 Laying of pipes through the space containing the gyrocompass is not allowed, with the exception of cooling pipes for gyrocompass.

5.5.4 Laying of pipes through the radioroom is not allowed.

5.6 PIPING LAYING IN UNATTENDED MACHINERY SPACES

5.6.1 Class I pipes conveying fuel oil and lubricating oil shall have welded joints.

Detachable joints are permitted to be used, but their number shall be kept to a minimum; if considered necessary, protective casings shall be provided in places where detachable joints are fitted.

5.7 PIPING LAYING IN SHIPS WITH TWIN HULLS

5.7.1 When routed along the common upper deck, the pipes connecting identical systems of both hulls shall be provided with compensators where necessary and protected against damage.

Damage to these pipes shall not involve failure of the systems connected by them.

5.8 PIPELINES WITH ELECTRIC HEATING

5.8.1 Electrical equipment in systems incorporating pipelines provided with electric heating shall meet the requirements of **15.4.3** to **15.4.6**, Part XI "Electrical Equipment".

5.8.2 Cables and devices for control of electric heating of pipelines, as well as pipelines located in dangerous spaces shall be of safe-type.

5.8.3 The heating cable shall be installed after hydraulic tests of the pipelines and application of anticorrosive coating observing the manufacturer’s technique approved by the Register.

5.8.4 If necessary, pipelines equipped with electric heating shall be covered by a protective casing placed over the insulation to prevent mechanical damages of heating cables.

5.8.5 When installing the heating cable, provision shall be made for loops at the locations of demountable joints of the pipeline to ensure dismounting of the pipeline without break of integrity of the heating cable.

5.8.6 Warning notices "Caution, electric heating" shall be affixed to pipelines and valves with electric heating.

The notices shall be located in conspicuous places at a 3 m distance along the pipeline length.

5.9 SYSTEMS AND PIPING TO ENSURE LONG-TERM OPERATION AT LOW TEMPERATURE

5.9.1 Fittings, formed components, expansion joints.

5.9.1.1 Materials for manufacture of fittings, expansion joints and formed components of pipelines to be installed on the open decks, as well as in the open unheated spaces shall meet the requirements to materials of ships with distinguishing mark **WINTERIZATION(DAT)**.

For products and seals manufactured of rubber as well as materials of organic origin in fittings, cold endurance type tests may be replaced by checking the operability of assembled fittings in low temperatures. For this purpose, a sample of each standard sized valve shall be conditioned within 6 h at a temperature of 10 °C lower than design ambient temperature indicated in brackets of the distinguishing mark **WINTERIZATION(DAT)**.

Immediately after removal from the refrigerating chamber, 10 cycles of closing and opening of the fittings shall be made, after which hydraulic tests are carried out with working pressure at normal temperature.

5.9.1.2 The Register certificates issued for fittings, expansion joints and formed components of pipelines to be installed onboard the ships with distinguishing marks **WINTERIZATION(-40)** and **WINTERIZATION(-50)** and installed on the open decks, as well as in the open unheated spaces shall contain an indication whether it is allowed to use them at appropriate design ambient temperature.

5.9.1.3 Side fittings installed above the load waterline shall meet the requirements of **4.3.1.2**.

5.9.2 Welded and seamless steel pipes for systems on the open decks and in the open unheated spaces shall comply with the requirements of **3.4**, Part XIII "Materials", with the Register approved standards and/or Register agreed specifications.

The material for pipes shall be selected proceeding from the purpose of the systems, with regard to their operating temperature and the requirements of **3.5**, Part XIII "Materials" of the Rules, as well as the requirements of Table 2.1-4, Part IX "Materials and Welding" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk for the minimum design temperature of -55°C.

6. SHIP'S HOSES

6.1 CONSTRUCTION OF HOSES

6.1.1 The requirements of the present Section cover ship's hoses for taking over and transfer of liquid cargo, fuel oil, lubricating oil, bilge and dirty ballast waters and transfer of cargo vapors.

6.1.2 Only the hoses as finished items consisting of sleeves and end components (branch pipes with flanges, nipples or other joints) may be used in ships.

6.1.3 As a rule, a hose sleeve shall be made of rubber, reinforced with fabric, textile cord or cord from steel wire. In addition, the hose sleeve can be reinforced with one or several layers of wire coil, rings or by other means.

Sleeve material shall be resistant to the conveying medium within the whole range of temperatures, for this purpose special coating of the inner surface is allowed.

The outer surface shall be resistant to wear, attrition, exposure to sun rays, atmosphere and impermeable for sea water and cargo.

The outer surface may be coated with polyurethane or other material, which affords buoyancy. Such coating shall display the similar properties in reference to external actions.

6.1.4 End components shall be connected to the hose sleeve mechanically or chemically.

Connection of sleeves with end components by means of clamps is permitted only by agreement with the Register.

6.1.5 When welding is used in the structure of end components, such welding shall be performed by certified welders and is subject to 100 % check by non-destructive testing methods.

6.1.6 The material of end components and flanges shall exclude the possibility of spark formation during interaction with ship's hull.

Surfaces of end components shall be protected from corrosion influence of sea water and medium conveyed.

6.1.7 The hose is assumed to be floating when its buoyancy reserve is at least 20 %, provided the hose is completely immersed in sea water and completely filled with it.

The hose buoyancy reserve is calculated as follows

$$K = \frac{B-(W_h+W_w)}{W_h+W_w}\cdot 100\,\%, \qquad (6.1.7)$$

where:

K – buoyancy reserve, %;

B – weight of sea water displaced by the hose at its complete immersion, including weight of sea water displaced by materials ensuring buoyancy and weight of sea water inside the hose, kg;

W_w – weight of sea water inside the hose, kg;

W_h – weight of empty hose in air, including weight of materials ensuring buoyancy, kg.

Materials applied for provision of buoyancy shall be properly secured.

6.1.8 Floating hoses shall be orange-colored or marked with orange strip in the shape of spiral. The width of strip is 100 mm, the pitch of spiral is 450 mm. The strip is fixed to the facing in the process of curing.

6.1.9 For the transfer of cargo at sea from one ship to another and during the cargo operations with the use of offset point berths, as a rule, the floating hoses shall be used; in the hose lines the quick-action device for emergency disconnection shall be provided.

In the hose lines equipped with quick-action device of emergency disconnection the allowance shall be made for hydraulic impact which may occur when the device is actuated and, if necessary, the flow velocity of liquid shall be decreased.

Hoses and arrangements for carrying out bunkering operations underway are in each case subject to special consideration by the Register.

6.1.10 On both ends of a hose the following shall be clearly marked. In hose documentation the following shall be indicated:

name of the manufacturer or trade mark;

serial number of the hose according to the manufacturer's data;

month and year of production;

allowable working pressure;

indication of electrical conductivity.

6.1.11 Hoses shall be stored on ship in the place shielded from direct sun rays, with allowance for the minimum bending radius and in accordance with the recommendations of the hose manufacturer.

Provision shall be made for design means for discharge and removal of cargo remains from the hoses shall be provided.

Measures for prevention of wearing through of the hoses while handling and operation shall be taken.

6.1.12 For cargo vapor discharge, hoses with the allowable working pressure of at least 0,2 MPa and vacuum of at least 0,014 MPa shall be used.

Burst pressure of the hose shall not be less than 5 times working pressure of the hose. The last meter from each end of the hose shall be painted in compliance with Fig. **6.1.12** and marked with the sign "vapors" made in black letters with the height not less than 50 mm.

Each flange shall have an additional bore on the coupling bolts line for the stud of the shipboard manifold connecting flange (refer to Fig. 9.9.11-1). In the system for vapor to shore discharge only electrically conductive hoses shall be used.

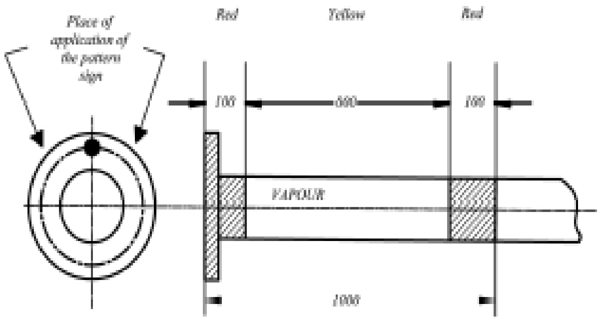


Fig.6.1.12. Marking of cargo vapor discharge hose

6.2 TESTING OF HOSES

6.2.1 Each sleeve type used for manufacture of hoses shall be subjected to type tests according to 6.2.2 to **6.2.2 - 6.2.5**, **6.2.7**, **6.2.8**.

Each hose type shall be type tested according to**6.2.2**, **6.2.6**, **6.2.7**, **6.2.8**.

The type tests of hoses may be combined with the type tests of sleeves.

After manufacture, each hose shall be tested in accordance with **6.2.6**.

6.2.2 Allowable working pressure p_w is determined as follows

$$p_{\mathrm{w}} = p_{burst}/k \qquad (6.2.2)$$

where:

p_w – pressure, at which the break of hose or end connection tightness occurs;

k – coefficient assumed equal to:

4 for transfer of crude oil and oily products, bilge and polluted ballast water;

5 for transfer of chemical cargoes, liquefied gases and cargo vapours.

Allowable working pressure of the hose shall not be less than 1,0 MPa, with exception of the hoses specified in **6.1.12**.

When conducting the burst pressure tests, the testing of samples with the length not less than 10 nominal diameters but at least 1 m may be allowed.

6.2.3 Sleeves for cargo and fuel oil hoses of ice-class ships shall be subjected to cold endurance type tests. For this purpose samples of the hoses shall be kept at the temperature of -40°C during 4 h. In 4 h the sample shall be tested for elasticity by means of bending for 1808 two times in the opposite directions around the adapter with a diameter of *R*, where *R* is a minimum bending radius; whereupon a visual examination is carried out.

After freezing and bending no cracks shall appear on the internal and external surfaces of the sample. Where necessary, the sample may be cut along the axis for the internal surface inspection.

In agreement with the Register, another method of checking for elasticity, taking into account the design features, may be used.

6.2.4 The sleeves of hoses intended for operation under ambient pressure conditions shall be vacuum tested with negative pressure of 85 kPa during 10 min.

After the tests the hose shall be examined and rejected where deformation or flattening is found.

6.2.5 The samples manufactured as strip test pieces in accordance with the procedure approved by the Register (refer to Fig. 6.2.5) are subject to adhesion test of all the rubber sleeve layers.

The adhesion strength of rubber contact faces is determined as a ratio of the mean force *F* originated at detachment, divided by the strip width and shall be at least 3 N/mm.

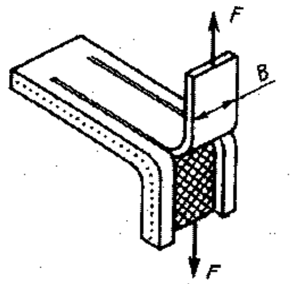


Fig. 6.2.5

6.2.6 Each hose after manufacturing shall be subjected to the following tests:

.1 determination of weight.

After weighing, the hose weight shall be recorded in the certificate.

For floating hoses, the buoyancy reserve shall be defined according to **6.1.7**.

.2 hydraulic tests by test pressure: $P_t = 1{,}5\ P_w$, where P_w – refer to **6.2.2**.

.3 electrotechnical tests including: measuring of resistance between flanges of hoses lacking electrical conductivity (the resistance shall not be less than 25000 Ohm and not more than 106 Ohm);

conductivity test for electrically conductive hoses with the voltage of 4,5 V and a bulb for testing.

6.2.7 The cargo hoses of oil tankers and hoses for taking on fuel and oil shall undergo type tests at normal temperature for 15 cycles of pressure rise from zero up to 1,5 times the maximum allowable working pressure.

After 15 cycles the sample shall be subjected to strength test by burst pressure according to **6.2.2**.

6.2.8 Cargo hoses for transfer of chemical cargoes and liquefied gases shall undergo type tests at normal temperature for 200 cycles of pressure rise from zero up to twice the maximum allowable working pressure.

After 200 cycles the sample shall be subjected to strength test by burst pressure according to **6.2.2**.

7. BILGE SYSTEM

7.1 PUMPS

7.1.1 Each self-propelled ship shall be provided with at least two power bilge pumps.

Centrifugal bilge pumps shall be of self-priming type, otherwise the system shall be equipped with an air sucking-off arrangement.

It is recommended that one of the installed pumps is of piston type.

Independent ballast, sanitary or general service pumps of sufficient capacity may be accepted as bilge pumps, and in ships of 91,5 m in length and less, including special purpose ships carrying not more than 60 persons, one of the bilge pumps may be a pump driven by the propulsion machinery, as well as a water or steam ejector, provided the steam boiler is always in operation**.**

steam ejector, provided the steam boiler is always in operation. If fire pumps are used as bilge pumps, the requirement of **3.2.3.2**, Part VI "Fire Protection" shall be met.

In cargo ships of less than 500 gross tonnage of restricted areas of navigation **R2, R2-S, R2-RS, R3-S, R3-RS, R3, R3-IN**, one of the pumps may be driven by the propulsion machinery, and the other may be an ejector or a hand type.

7.1.2 Passenger ships and special purpose ships carrying more than 60 persons shall be fitted with at least three power pumps connected to the bilge main; one of these pumps may be driven by the propulsion machinery.

Where the bilge pump numeral is 30 or more, one additional independent power pump shall be provided.

Where in ships intended for the carriage of motor transport a water fire extinguishing system is used, the Register may require the bilge pumps to be increased in capacity or number.

7.1.3 The bilge pump numeral shall be calculated as follows:

when P_1 is greater than P:

$$\textit{bilge pump numeral} = 72\,[(M + 2\,P_1)/(V + P_1 - P)];$$

in other cases:

$$\textit{bilge pump numeral} = 72\,[(M + 2\,P)/V],$$

where:

M − the volume of the machinery spaces below the bulkhead deck with the addition thereto of the volume of any permanent oil fuel bunkers which may be situated above the inner bottom and forward of, or abaft, the engine room, m^3. The volume of the machinery space shall include the volume between watertight boundaries of spaces containing the main propulsion plant, auxiliary machinery, including boilers, generators and electric motors generally intended for providing the propulsion plant operation;

P − the whole volume of the passenger and crew spaces below the bulkhead deck, which are provided for the accommodation and use of passengers and crew, excluding baggage, store, provision, m^3;

V − the whole volume of the ship below the bulkhead deck, m^3;

$P_1 = KN$,

where: $K = 0{,}056L$

L − the length of the ship as defined in the Load Line Rules for Sea-Going Ships, m;

N − the number of passengers for which the ship shall be certified.

However, if the value of KN is greater than the sum of P and the whole volume of the actual passenger spaces above the bulkhead deck, the figure to be taken as P_1 is that sum or two-thirds KN, whichever is the greater.

7.1.4 On passenger and special purpose ships carrying more than 60 persons of 91,5 m in length and upwards or having a bilge pump numeral of 30 or more (refer to **7.1.3**), the arrangements shall be such that at least one power bilge pump shall be available for use in all flooding conditions which the ship is required to withstand. This requirement is considered to be satisfied if one of the required bilge pumps is an emergency pump of a reliable submersible type having a source of power situated above the bulkhead deck; or the bilge pumps and their sources of power are so distributed throughout the length of the ship that at least one pump in an undamaged compartment will be available, and for ships, contracted for the construction on or after 1 January 2020, in case of any possible flooding of the compartments resulting from the consideration of minor damage in accordance with Part **3.7**, Part V "Subdivision".

This requirement is deemed to be fulfilled if one of the pumps is a reliable submersible pump and its power source is located above the bulkhead deck, or if the pumps and their power sources are located in different waterproof compartments in such a way that, with any acceptable flooding of the compartments for this vessel, at least, one pump will be in the intact compartment and will be operable.

7.1.5 It is recommended that in passenger ships and special purpose ships not specified in **7.1.4** and in ships having a subdivision mark in the class notation the bilge pumps, wherever practicable, be placed in different watertight compartments with the system so arranged that requirements of **7.3.6** are met.

The bilge system of passenger ships having length, as defined in **1.2.1** of the Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones shall comply with the requirements of **2.2.6.7.5**, **2.2.6.8** and **2.2.7.4**, Part VI "Fire Protection".

7.1.6 Each bilge pump required in **7.1.1** and **7.1.2** shall have a capacity Q, in m^3/h, not less than that determined from the formula

$$Q = 5{,}65 \cdot 10^{-3} \cdot d_1^2, \qquad (7.1.6)$$

where: d_1 – = inner diameter of the main determined in accordance with **7.2.1**, mm.

The bilge pump may be replaced by two pumps with a total capacity not less than that specified above.

For passenger ships, each bilge pump shall have a capacity determined on the assumption that the rated speed of water through the internal diameter required in **7.2.1** shall not be less than 2 m/s.

7.1.7 For drainage of non-propelled ships having no power-driven machinery, at least two hand pumps of reciprocating type shall be installed, and these shall have a total capacity not less than specified in Table 7.1.7.

Table 7.1.7

$0{,}8L \times B \times D^1$, m^3	Total pump capacity, m^3/h.
Up to 100	4
101 – 600	8
601 – 1100	10
1101 – 1800	12

[1] For definitions of L, B, D (length, breadth and depth, m), refer to Part IV "Stability".

In each case D is measured up to the bulkhead deck only. In a ship having an enclosed cargo space on the bulkhead deck, which is drained in accordance with **7.6.12.2** and which extends for the full length of the ship, D shall be measured to the next deck above the bulkhead deck.

Where the enclosed cargo spaces cover a lesser length, D shall be taken as the depth to the bulkhead deck plus*lh/L,* where *l* and *h* total length and height of enclosed cargo spaces, respectively.

The pumps shall be arranged above the bulkhead deck and shall have a sufficient suction head.

In non-propelled ships provided with power sources, it is recommended that power pumps shall be fitted, the number and capacity of which shall comply with the requirements for the hand pumps (refer to **7.1.7**).

7.1.8 In ships with twin hulls, provision shall be made for an independent bilge system for each hull, which shall comply with the requirements of the Chapter.

7.1.9 In berth-connected ships, at least two bilge pumps shall be installed, power-driven and having each a capacity not less than 11,0 m3 /h whereas the design water speed in the branch bilge suctions shall not be less than 2 m/s under normal service conditions.

In case where a berth-connected ship serves its direct service without shore power supply and the ship is not provided with a propulsion plant, the power-driven bilge pumps may be omitted, and the bilge system shall meet the requirements of **7.1.7**.

The pumps shall ensure drainage of any space below the bulkhead deck, and their drives shall be so arranged along the ship length that at least one of the pumps installed in an intact compartment could drain a flooded space.

7.1.10 Ships with distinguishing marks **FF1, FF1WS, FF2, FF2WS** in the class notation shall have bilge pumping arrangements for pumping water out of flooded compartments of ships in distress.

Used as such arrangements may be pumps (fixed and/or portable) and ejectors.

The type, number and capacity of the pumps shall be specified by the designer and agreed upon with the Register.

7.1.11 Instruments shall be provided to measure suction pressure and delivery pressure of each bilge pump.

7.1.12 Passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** and **D-R3-S**, **D-R3-RS** shall be fitted with power pumps, depending on the number of passengers that the ship can carry, in the next amount:

up to 250 passengers: one pump driven by the main engine and one pump driven by a power source located and driven outside the engine room;

over 250 passengers: one pump driven by the main engine and two pumps driven by the power source, one of which is located and has a drive outside the engine room.

The power pump driven by the main engine can be replaced by one pump driven by an power source.

If the main engines, auxiliary machinery and boilers are located in two or more watertight compartments, the pumps that can be used for the bilge system shall, if possible, be distributed between these compartments.

It is not allowed to place power pumps ahead of the collision bulkhead, except for those that are specially designed to service the spaces located ahead of the collision bulkhead..

Drainage of very small spaces can be performed with portable manual pumps.

7.2 PIPING DIAMETERS

7.2.1 The internal diameter d_1, in mm, of the main bilge line and that of bilge suctions directly connected to the pump, except in **7.2.3**, shall be determined by the formula

$$d_1 = 1{,}68\sqrt{L(B+D)} + 25. \qquad (7.2.1\text{-}1)$$

In vessels of dredging fleet having hopper spaces, the diameter of the bilge main and the direct bilge suctions directly connected to the pump may be obtained from the formula

$$d_1 = 1{,}68\sqrt{L(B+D) - l_1(b+D)} + 25\,, \qquad (7.2.1\text{-}2)$$

where:
l_1 – length of hopper space, m;
b – mean width of hopper space, m;
for L, B, D – refer to **7.1.7**.

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** the internal diameter of the bilge main and of direct bilge suctions directly connected to the pump may be obtained from the formula

$$d = 1{,}5\sqrt{L(B+D)} + 25. \qquad (7.2.1\text{-}3)$$

7.2.2 The internal diameter d_0, in mm, of the branch bilge suctions connected to the bilge main, and that of the hand pump suction, shall be determined by the formula

$$d_0 = 2{,}15\sqrt{l(B+D)} + 25, \qquad (7.2.2\text{-}1)$$

where:
l – length of hopper space, as measured at its bottom, m;
for B, D – refer to **7.1.7**. In the case of ships with twin hulls, B is assumed to be the breadth of one hull.

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** the internal diameter of branch bilge suctions connected to the bilge main and the diameter of the hand pump suction may be obtained from the formula

$$d = 2{,}0\sqrt{l(B+D)} + 25. \qquad (7.2.2\text{-}2)$$

7.2.3 The internal diameter of the main bilge line and bilge suctions determined from Formulae (7.2.1-1, 7.2.2-1) shall not be less than 50 mm, and the internal diameter determined from Formulae (7.2.1-3, 7.2.2-2) shall not be less than 40 mm.

The internal diameter of the pipes directly connected to the pump shall not, in any case, be less than the bilge pump suction diameter.

7.2.4 The cross-sectional area of the pipe, connecting the distribution chest with the bilge main shall not be less than the total cross-sectional area of two largest branch bilge suctions connected to that chest, but it need not be greater than the sectional area of the bilge main.

7.2.5 In oil tankers and other ships, in which the bilge pumps are intended for draining only the engine room, the cross-sectional area of the bilge main shall not be less than twice the cross-sectional area of the branch suction, the diameter of which is determined by Formula (7.2.2-1).

7.2.6 The diameter of the emergency bilge suction in the engine room shall be determined in compliance with **7.4.6**.

7.3 PIPING LAYING

7.3.1 The bilge lines and their branch suctions shall be so arranged as to enable any watertight compartment to be drained by one of the pumps required in **7.1.1**, **7.1.2** and **7.1.12**.

This requirement does not apply to the spaces of ammonia refrigerating machinery, the peaks, the pump rooms and cofferdams of oil tankers, drained by individual pumps, as well as to the tanks intended only for storage of liquids.

Drainage of spaces not connected to the bilge system shall be carried out by the drain pipes laid to the drained spaces or by hand pumps, compliance with the requirements of **7.12.2** shall also be provided.

7.3.2 The system shall be arranged so as to prevent the possibility of sea water passing inside the ship, or from one watertight compartment into another, in case of pipe break or any other pipe damage in any other compartment because of collision or grounding. For this purpose the suction valves of the drainage pipes open ends, connected directly to the chests, shall be of screw-down non-return type.

In case the only general pipeline system for all pumps is available, the provision shall be made for the possibility to control the required valves servicing suction branch pipes from the places above the bulkhead deck. Other equivalent arrangements are allowed.

7.3.3 The arrangement of the bilge pipes shall be such as to ensure the possibility of draining the engine rooms through the suctions directly connected to the pump, the other compartments being simultaneously drained by other pumps.

7.3.4 The arrangement of the bilge pipes shall be such as to enable one of the pumps to be operated in case the rest of pumps are inoperative or are used for other purposes.

7.3.5 The bilge suction pipes, where they are at any part situated nearer to the ship's side than one-fifth of the breadth of the ship (measured at right angles to the centre line at the level of the deepest subdivision load line), as well as when passing in duct keel or within double bottom, shall have non-return valves fitted to their branch suctions in each watertight compartment.

For ships contracted for the construction on or after 1 January 2020, the highest subdivision load line shall be accepted as draft at the highest subdivision load line.

7.3.6 On passenger ships of more than 91,5 m in length, special purpose ships carrying more than 60 persons and in passenger ships having a bilge pump numeral of 30 or more, all the distribution chests, cocks and valves associated with the bilge pumping system shall be so arranged that in the event of flooding one of the bilge pumps may be operative on any flooded compartment.

Moreover, damage of a pump or its pipe connecting to the bilge main outboard of a line drawn at one-fifth of the breadth of the ship shall not put the bilge system out of action.

Where there is only one system of pipes common to all the pumps, the necessary cocks and valves for controlling the bilge suctions shall be fitted with means enabling them to be controlled from above the bulkhead deck. In the places of their installation they shall be provided with the controls with clear indication of their purpose and also means for indicating whether they are open or closed.

Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it shall be independent of the main system and shall be so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the cocks and valves required for controlling the emergency system need be suited for being operated from above the bulkhead deck, while the pump and associated suction pipes shall be situated farther from the ship's side than one-fifth of the breadth of the ship.

7.3.7 In general, the bilge pipes shall be laid outside the double bottom.

Where it is necessary to lay these pipes through the tanks for storage of fuel oil, lubricating oil, boiler feed water and drinking water, the pipes shall meet the requirements of **5.2.1**.

Where the pipe is laid within the double bottom, the bilge suctions in each watertight compartment shall be fitted with non-return valves.

7.3.8 Oily-water separating and filtering equipment shall be used for purification of water before discharging overboard.

The installation and operation of such equipment shall not interfere with normal working of the bilge and ballast systems indicated in **13.1.2**.

7.3.9 Measures shall be taken to prevent accidental flooding with sea water of deep tanks with bilge and ballast suctions where these tanks contain cargo, or pumping through the bilge line, when the tanks contain ballast water or fuel.

7.3.10 All bilge pumping system distribution chests and valves that are manually driven shall be located in areas allowing full access under normal conditions.

7.3.11 If one line is provided for drainage from the pump located in the engine room, to the bow and to the stern, the control of non-return valves fitted on the branches to drained compartments shall be performed from the bulkhead deck.

Piping for direct drainage of the engine room, or spaces with oil-containing bilge water, shall be separated from other piping of the system and appropriate valves shall be sealed.

Where bilge system is remotely controlled, valve sealing is not allowed. In this case, the remote valve drives shall be sealed.

7.4 DRAINAGE OF MACHINERY SPACES

7.4.1 Where the engines and boilers are located in the same compartment and the double bottom extends either the full length forming bilges at the wings, or the full length and breadth of the compartment, it will be necessary to provide two bilge suctions at each side near the bulkheads in the compartment, one of which shall be connected directly to an independent bilge pump.

7.4.2 Where the engines and boilers are located in the same compartment with no double bottom, and the rise of floors is not less than 5°, two bilge suctions shall be provided, one of which shall be direct-connected to an independent bilge pump; where the rise of floor is less than 5°, additional bilge suctions connected to the bilge main shall be provided, one at each side.

7.4.3 Where the engines and boilers, as well as the auxiliaries or electric propulsion motors, are located in separate watertight compartments, the number and position of bilge suctions therein shall be adopted as set forth in **7.6**.

In ships having in the class notation a mark of subdivision, each of these compartments shall be fitted with an additional bilge suction direct-connected to an independent bilge pump.

In passenger ships each of the independent power bilge pumps, located in machinery spaces, shall have direct suctions in these spaces. More than two such suctions are not required for these spaces.

Where two or more such suctions are fitted, at least one of them shall be located on the port and the other on the starboard side. Bilge pumps not associated with each other, located in other spaces may have direct suctions in these spaces.

7.4.4 Where the machinery space is situated at the after end of the ship, bilge suctions shall be fitted in the forward wings of the space. One or two suctions shall be provided, in agreement with the Register, depending on the shape of the aft end.

7.4.5 Suctions for bilge drainage of machinery spaces and tunnels shall be fitted with readily accessible mud boxes. The pipes between the mud boxes and bilges shall be as straight as practicable. The lower ends of these pipes need not be fitted with strum boxes.

Mud boxes shall have covers that may be easily opened.

In ships under 24 m in length, instead of the mud boxes, strum boxes may be used, provided they are accessible for cleaning**.**

7.4.6 In all self-propelled ships provision shall be made for emergency bilge drainage of the engine rooms, in addition to the suctions required by **7.4.1** to **7.4.4**. For this purpose any of the main circulating pumps in steam ships, and the cooling pump of maximum capacity in motor ships, shall be fitted with direct suction pipe at the drainage level of the engine room and fitted with non-return stop valve. The diameter of this direct suction shall be at least two-thirds of that of the pump suction in steam ships, and shall be of the same size as the suction branch of the pump in motor ships.

No strum boxes or strainers shall be fitted on the suction for emergency bilge drainage.

Where the pumps specified above are not suitable for operation as bilge pumps, a direct emergency bilge suction shall be laid from the drainage level of the engine room to the largest available power pump, which is not a bilge pump. The capacity of this pump shall exceed that required in **7.1.6** by an amount satisfactory to the Register. The diameter of the emergency bilge suction shall not be less than that of the pump suction branch.

The spindles of the screw-down non-return valves fitted to the suction branches shall extend above the engine room floor plates to a sufficient height and shall have nameplate:

«FOR EMERGENCY USE ONLY»

The use of fire pumps for emergency bilge drainage of engine rooms shall be in compliance with 3.2.3.2, Part VI "Fire Protection".

In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2, R2-S, R2-RS, R3-S, R3-RS, R3, R3-IN,** which have no independent pump of a capacity exceeding that of the bilge pump, the emergency drainage system of machinery spaces may be operated by an attached sea-water cooling pump.

If side and bottom valves in accordance with **4.3.2.9** are installed between the emergency bilge drainage valve and the side, the requirements of **4.3.2.9** need not apply to the emergency drainage shut-off valve of non-return type.

7.4.7 Where there is a double bottom, the machinery spaces shall be fitted with bilge wells of a capacity not less than 0,2 m^3.

7.4.8 Additional bilge suctions shall be laid in the log and echo sounder trunks, and also to the double-bottom bilge wells under the machinery and in other places, which may accumulate water.

7.4.9 In ships having an electric propulsion plant, the arrangements shall be such that the bilge wells under the propulsion motors are properly drained and automatic alarms are fitted to give warning at excess of permissible level in the wells.

Automatic drainage of bilge wells is recommended to be used.

7.4.10 The space of ammonia refrigerating machinery shall have an independent bilge system.

Where a water spraying system is provided in this space, the capacity of the bilge pump shall be sufficient for the water consumption during the operation of that system. The discharge pipe of the bilge system shall be laid directly overboard.

The space for freon refrigerating machinery may be drained through the bilge main of the ship.

7.4.11 The spindles of the valves fitted to the suction branches shall extend above the engine room floor plates to a sufficient height.

7.4.12 Piping used exclusively for emptying sewage (drainage) wells of engine rooms, using bilge system pumping means, shall be securely separated from the system piping, and the appropriate valves - sealed.

7.5 DRAINAGE OF TUNNELS

7.5.1 Each shaft tunnel and each accessible pipe tunnel shall be drained by a bilge suction situated in the after part of the tunnel.

Where required, additional suctions shall be provided in the fore part of the tunnel.

The bilge suctions of the shaft tunnel shall be made in compliance with the requirements set forth in **7.4.5.**

7.6 DRAINAGE OF CARGO SPACES

7.6.1 Each cargo space, where the double bottom forms bilges at the wings, shall have at least one bilge suction in the after part of the hold at each side of the ship.

7.6.2 Where the inner bottom plating extends the full breadth of the space, bilge wells shall be arranged in the after part of the hold, one at each side.

The capacity of the wells shall comply with the requirements of **7.4.7**.

7.6.3 In spaces where the inner bottom plating has an inverse camber, provision shall be made also for suctions at the centre line, in addition to the suctions situated at the wings. Where a bilge well extends over the entire breadth of the space and the inverse camber exceeds 5°, one branch suction may be laid to this well.

7.6.4 Where manholes for access to bilge wells are provided, they shall be arranged as near to the suction strums as practicable.

7.6.5 Where there is no double bottom and the rise of floor in the space exceeds 5°, one bilge suction may be fitted near the centre line. If the rise of floor is less than 58, at least two suctions shall be fitted, one at each side of the hold.

7.6.6 Where the length of a hold exceeds 35 m, the bilge suctions shall be fitted in the fore and after parts of this hold, with the requirements of 7.6.1 to 7.6.5 being complied with.

7.6.7 At narrow ends of cargo spaces, one bilge suction may be allowed.

7.6.8 The drain pipes from spaces located below the bulkhead deck and communicating with the cargo space in the same compartment may be laid into the wells of that hold.

Drainage into the wells of cargo spaces from spaces located in other watertight compartments below the bulkhead deck is not permitted.

The requirements for drainage into the bilges of refrigerated cargo spaces are given in **7.8**.

7.6.9 Where a ceiling or removable covers is fitted over the bilges or wells in cargo spaces, provision shall be made for free access of water into the bilges or wells.

7.6.10 Branch bilge suctions shall be fitted with strum boxes or strainers having perforations 8 to 10 mm in size.

The total area of these perforations shall not be less than twice the clear area of the given suction pipe.

The strum boxes and strainers shall be removable, or provision shall be made for cleaning them without having to disassemble the suction.

7.6.11 In bulk carrier cargo spaces the bilge system shall be so designed that its operability may not be affected when bulk cargo is carried.

7.6.12 For the drainage of enclosed cargo spaces located on the bulkhead deck of a passenger or cargo ship that is assigned a subdivision distinguishing mark in its class notation, and on the freeboard deck of other cargo ships, the arrangements specified under **7.6.12.1** and **7.6.12.2** shall be provided.

For drainage of special category spaces located below bulkhead deck arangements specified in **7.6.12.2** shall be provided.

7.6.12.1 Where the freeboard up to the bulkhead deck or the freeboard deck height is such that the deck edge is immersed when the ship heels more than 5°, the drainage shall be by means of scuppers discharging directly overboard.

The scuppers and drain pipes shall be arranged and fitted according to **4.3.2.6** or **7.12.4**.

The scuppers from spaces of a special category passenger ships with signs **B-R3-S**, **B-R3-RS**, **C-R3-S**, **C-R3-RS** та **D-R3-S**, **D-R3-RS**, fitted with reliable closing devices, which are controlled from a place above the bulkhead deck shall be open, when the ship is at sea.

7.6.12.2 Where the freeboard is such that the edge of the deck is immersed when the ship heels 58 or less, the drainage of the enclosed cargo spaces on this deck shall be laid to suitable spaces of adequate capacity having a high water level alarm and suitable arrangements for dis-charge overboard. In such cases it shall be ensured that:

.1 the number, size and disposition of the scuppers are such as to prevent unreasonable accumulation of free water;

.2 the pumping arrangements for the drainage of cargo spaces provide water drainage with any fixed water fire extinguishing systems, including spraying systems, that are required, respectively, for passenger and cargo ships.

The bilge system (refer to 7.1) shall have a capacity not less than 125 % of the total capacity of the water fire main and water-spraying system pumps with due regard for the required number of fire nozzles and be calculated considering the requirements of IMO circular MSC.1/Circ.1320[5];

.3 valves of the drainage arrangements shall be controlled from a position outside the space protected, located nearby the water-spraying system controls.

Bilge wells shall have sufficient capacity and be arranged in the vicinity of the side plating not more than 40 m apart in each watertight compartment.

Water contaminated with petrol or other dangerous substances shall not be drained to machinery spaces or other spaces containing sources of ignition;

.4 where the enclosed cargo space is protected by a fire smothering system the deck scuppers are fitted with means to prevent the escape of the gas.

7.6.12.3 On all ships, for closed vehicles and ro-ro spaces and special category spaces, where fixed pressure water-spraying systems are fitted, means shall be provided to prevent the blockage of drainage arrangements, taking into account the requirements of IMO circular MSC.1/Circ.1320.

An easily removable grating, screen or other means shall be installed over each drain opening in the protected spaces to prevent debris from blocking the drain. The total open area ratio of the grating to the attached drain pipe shall be at least 6 to 1.

The grating shall be raised above the deck or installed at an angle to prevent large objects from blocking the drain. No dimension of the individual openings in the grating shall be more than 25 mm.

[1] Refer to IMO MSC.1/Circ.1320: «Guidelines for the drainage of fire-fighting water from closed vehicle and ro-ro spaces and special category spaces of passenger and cargo ships»

A clearly visible sign or marking shall be provided not less than 1500 mm above each drain opening stating:

"DRAIN OPENING - DO NOT COVER OR OBSTRUCT".

The marking shall be in letters at least 50 mm in height.

7.6.13 The bilge system of cargo holds with weathertight hatch covers above the superstructure deck outside the positions 1 and 2 (refer to **7.1.4**, Part III "Equipment, Arrangements and Outfit" of the present Rules and **3.2.1** of the Load Line Rules for Sea-Going Ships) shall have the pumps of an increased capacity with regard to additional water ingress due to:

.1 the stable amount of precipitation equal to 100 mm/h, which penetrate through the total area of gaps between closures sections;

.2 the consumption of water by a sprinkler system (if fitted), whichever is greater.

The internal diameter of a bilge main shall be increased in compliance with an increased pump capacity.

Each cargo hold shall be fitted with an alarm on a limiting water level in bilge wells.

7.6.14 On container ships, holds fitted with weathertight closures and intended for carrigate of dangerous cargoes shall be considered as open-type container holds in accordance with paragraphs **10** and **11** of IMO circular MSC/Circ.608/Rev.1.

7.6.15 The cargo spaces of bulk carriers and single-hold cargo ships shall be provided with alarms complying with the requirements of **2.4**, Part XV "Automation", located on the navigating bridge, as well as 7.10, Part XI "Electrical Equipment".

The alarm system detectors shall be positioned at two levels:

at a height of 0,5 m above the inner bottom;

at a height of 15 % of the depth of cargo space but not more than 2 m above the inner bottom.

The visual signals of each cargo space and each level shall be clearly distinguishable.

For cargo holds, which are used for water ballast, an alarm-overriding device may be installed to be activated when ballast is loaded thereinto.

7.7 DRAINAGE OF CARGO PUMP SPACES OF OIL TANKERS

7.7.1 The cargo pump rooms of oil tankers shall be drained by separate pumps or ejectors arranged in these rooms.

Stripping pumps may be used as bilge pumps, provided non-return shut-off valves are fitted at the open ends of the bilge suctions and a shut-off valve is arranged on a pipe connecting the valve box and the stripping pump.

The pump rooms in oil tankers of up to 500 gross tonnage may be drained by hand pumps.

Construction of the pumps shall preclude the possibility of spark formation to a maximum.

Arrangement of the driving machinery of the pumps shall meet the requirements of **4.2.5**, Part VII "Machinery Installations".

The cargo pump rooms shall be provided with a visual and audible high bilge water level alarm to give warning to the cargo control station and navigation bridge.

7.8 DRAINAGE OF REFRIGERATED CARGO SPACES

7.8.1 Provision shall be made for drainage of water from all the spaces, trays, chutes and other places, which may accumulate water.

7.8.2 Drain pipes from non-refrigerated spaces shall not be laid into the bilges of refrigerated spaces.

7.8.3 Each drain pipe of refrigerated cargo spaces shall be fitted with a liquid sealed trap or with another equivalent arrangement. The head of liquid shall be such that the arrangement will work effectively under any conditions of service.

The liquid sealed traps shall be placed in accessible positions outside the insulation. Where drain pipes from the 'tween-deck spaces and the hold are laid into a common bilge well, non-return valves shall be fitted to the open ends of the drains from the hold.

7.8.4 No shut-off valves shall be fitted on the drains from refrigerated spaces.

7.9 DRAINAGE OF FORWARD SPACES OF BULK CARRIERS

7.9.1 The present requirements apply to the means for draining and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces, any part of which extends forward of the foremost cargo hold, except the enclosed spaces the volume of which does not exceed 0,1 % of the ship maximum displacement volume and the chain lockers.

7.9.2 The means for draining and pumping ballast tanks forward of the collision bulkhead, and bilges of dry spaces, any part of which extends forward of the cargo hold, shall be capable of being brought in operation from the navigation bridge or propulsion machinery control position or from a readily accessible enclosed space, the location of which is accessible from the navigation bridge or propulsion machinery control position without traversing exposed freeboard or superstructure decks.

A pipe trunk or other similar means of access shall not be taken as being a "readily accessible enclosed space".

7.9.3 The drainage arrangements shall be such that when they are in operation, other systems essential for the safety of the ship including fire-fighting and bilge systems remain available and ready for immediate use.

The systems for normal operation of electric power supplies, propulsion and steering shall not been affected by the operation of bilge systems.

It shall be also possible to immediately start fire pumps and have a readily available supply of water and to be able to configure and use bilge system for any compartment.

7.9.4 The drainage arrangements shall be such that any accumulated water can be drained directly by a pump or eductor.

The drainage arrangements shall be designed to remove water at a rate of not less than 320xA, m^3/h, where A is the cross-sectional area, in m^2, of the largest air or venting pipe leading from the exposed deck to the space that is required to be drainaged.

7.9.5 Bilge wells shall be provided with gratings or strainers that will prevent blockage of the bilge system with debris.

7.9.6 Where pipes serving tanks or bilges mentioned in **7.9.2** pierce the collision bulkhead, as an alternative to the valve control specified in **5.1.3**, valve operation by means of remotely operated actuators may be accepted, provided that the location of such valve controls complies with **7.9.2**.

7.9.7 Where the piping of closed spaces bilge system is connected to the piping arrangements for the drainage of water ballast tanks, two non-return valves shall be provided to prevent the ingress of water into dry spaces from the water ballast tanks. One of these non-return valves shall be fitted with shut-off isolation arrangement.

The non-return valves shall be located in readily accessible positions.

The valve control position shall meet the requirements of **7.9.2**.

Moreover, the valve shall comply with the requirements of **4.1.1.2** and **4.1.2.2**.

7.9.8 Any dry spaces or cofferdams other than chain lockers, the volume of which does not exceed 0,1 % of the ship maximum displacement volume, fully or partly located forward of the foremost cargo hold, shall be fitted with water level detectors giving audible and visual alarms at a water level of 0,1 m above the deck.

7.9.9 The water ballast tanks forward of the collision bulkhead shall be provided with detectors giving an audible and visual alarms when the liquid in the tank reaches a level not exceeding 10 % of the tank capacity. An alarm overriding device may be installed to be activated when the tank is in use.

7.10 DRAINAGE OF COFFERDAMS

7.10.1 Cofferdams filled with water shall be provided with drainage means.

The location of branch suctions shall comply with the requirements of **7.6**.

In oil tankers and combination carriers, the filled cofferdams adjoining cargo tanks or slop tanks shall have automatic drain arrangements.

7.11 FORE AND AFT PEAK DRAINAGE

7.11.1 Where the peaks are not used as water ballast or other tanks, they may be drained by their own hand pumps or water ejectors.

For draining of fore compartments in oil tankers, other than cargo compartments, provision shall be made for a separate pump or ejector, which may also be used for filling and draining of the tanks intended only for water ballast.

7.12 DRAINAGE OF OTHER SPACES

7.12.1 Drainage of the chain lockers and boats-wain's stores may be carried out by means of hand pumps, water ejectors or other means.

7.12.2 Drainage of the steering engine rooms and other compartments situated above the after peak may be carried out by hand pumps or water ejectors, as well as through drain pipes laid into the bilges of shaft tunnel or engine room.

The drain pipes shall be fitted with readily accessible self-closing valves and shall be of not less than 39 mm in inner diameter.

In passenger ships, drain pipes shall not be used for drainage of the above-mentioned spaces..

7.12.3 Drain pipes shall not be laid into the bilges of the engine rooms and shaft tunnels from the spaces situated in other watertight compartments below the bulkhead decks (with the exception of cases specified by **7.12.2**).

Drain pipes from these spaces may be laid into the engine rooms and shaft tunnels only if terminating in closed drain tanks.

Where several watertight compartments have a common drain tank, the drain pipes from these compartments shall be fitted with non-return valves to prevent the passage of water from one compartment into another in the event of flooding.

The drain tank may be discharged through the bilge main, provided a non-return valve is fitted on the branch suction or the distribution chest.

7.12.4 Drain pipes from enclosed superstructures and deckhouses may be laid into the bilges (wells) of the engine room or the holds.

In ships having in the class notation a mark of subdivision, these pipes shall be fitted with valves controllable from a place above the bulkhead deck to prevent penetration of water in the above-mentioned spaces shall the engine room or hold become flooded.

7.12.5 Drain pipes for drainage of storerooms for explosives shall be fitted with valves controllable from locations outside these rooms.

7.12.6 Drainage facilities in way of helidecks shall be constructed of steel and shall lead directly overboard independent of any other system.

Drainage shall not fall onto any part of the ship.

7.12.7 Drainage of passenger and crew accommodation.

If passenger and crew accommodation in passenger ships are fitted with a sprinkler system and a water fire system, they shall be fitted with sufficient number of scuppers to provide drainage of water from the fire extinguishing systems, which enters the room through sprinklers and from two fire hoses.

The scuppers shall be located in places where their maximum efficiency is achieved, that is, in every corner.

7.13 DRAINAGE OF FLOATING DOCK COMPARTMENTS

7.13.1 Machinery spaces and dry compartments shall be provided with draining means.

The requirements of this Section, except **7.3.2** and **7.3.8**, are not applicable to the drainage system of floating docks.

7.14 DRAINAGE OF SPACES INTENDED FOR THE CARRIAGE OF DANGEROUS GOODS

7.14.1 Enclosed cargo spaces and cargo spaces of container ships of open type intended for the carriage of flammable liquids with flash point below 23°C or toxic liquids of subclass 6.1 specified in **7.2.4** and Table **7.2.4-3**, Part VI "Fire Protection" shall be equipped with the fixed drainage system located outside the machinery space.

The self-contained drainage system shall meet the following requirements:

.1 1 the capacity of the self-contained drainage system shall be not less than 10 m^3/h when one space is drained and not less than 25 m^3/h when two or more spaces are drained;

.2 the use of pipelines of the ship's main drainage system located in these spaces is allowed, if measures are taken to prevent pumping of flammable or toxic liquids through the pipelines and pumps of the engine room through installation of a blank flange or a shut-off valve;

.3 cargo spaces may be drained by gravity overboard or into a closed drainage tank located outside the engine room.

The tank shall have an air pipe led to the safe position on the open deck and be protected by flame screen;

.4 cargo spaces may be drained into bilge wells located below spaces intended for the carriage of dangerous goods;

.5 enclosed spaces with pumps of the self-contained drainage system shall be provided with ventilation arrangements complying with the requirements of **12.7.1**.

7.14.2 The drainage and pumping arrangements servicing spaces intended for the carriage of explosives shall prevent the build-up of free water surfaces when fire-extinguishing systems are used.

The capacity of the drainage system shall be 1,25 times greater the combined capacity of both water spraying system pumps and fire hose nozzles specified in **3.2**, Part VI "Fire Protection".

The drainage system valves shall be operable from outside the protected space at a position in the vicinity of the extinguishing system controls**.**

7.15 BILGE SYSTEM OF SHIPS EQUIPPED FOR USING GASES OR LOW-FLASHPOINT FUELS

7.15.1 Bilge systems installed in areas where gas or other low-flashpoint fuels may be present shall be segregated from the bilge system of spaces where fuel cannot be present.

7.15.2 Where fuel is carried in a fuel containment system requiring a secondary barrier, suitable drainage arrangements for dealing with any leakage into the hold or insulation spaces through the adjacent ship structure shall be provided.

The bilge system shall not lead to pumps in safe spaces.

Means of detecting such leakages shall be provided.

7.15.3 The hold or interbarrier spaces of type A independent tanks for liquid gas shall be provided with a bilge system suitable for handling liquid fuel in the event of fuel tank leakage or rupture.

8. BALLAST, HEEL AND TRIM SYSTEMS

8.1 PUMPS

8.1.1 The ballast system shall be served by at least one pump. The capacity of the ballast pump shall be such as to ensure the speed of water of not less than 2 m/s, with the suction pipe diameter taken from Formula (8.2.1) as for the largest ballast tank.

For each hull of a ship with twin hulls, an independent ballast system shall be provided.

8.1.2 General service pumps of sufficient capacity, as well as a bilge, fire or standby cooling pump, may be used for ballasting (refer to 8.1.3).

Fire pumps may be permitted subject to compliance with **3.2.3.2** and **3.2.3.4**, Part VI "Fire Protection".

8.1.3 Where the fuel oil tanks are generally used as ballast tanks, the standby cooling pump or a fire pump shall not be used for ballasting, nor shall the ballast pump be used as fire pump or standby cooling pump.

8.1.4 The pumps used for pumping out ballast water from the double-bottom tanks shall be of self-priming type and comply with **5.2.4**, Part IX "Machinery"..

8.1.5 In passenger ships, ballast tanks shall not, generally, be intended for the carriage of fuel oil.

8.1.6 In oil tankers emergency ballast discharge by stripper and cargo pumps is allowed, provided the requirements of 9.10.2 are complied with.

8.1.7 The ballast system of passenger ships having length, as defined in **1.2.1** of the Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones shall comply with the requirements of **2.2.6.7.5** and **2.2.6.8**, Part VI "Fire Protection".

8.2 PIPING DIAMETERS

8.2.1 The internal diameter d_i, in mm, of the ballast pipes for separate tanks shall be determined by the formula

$$d_i = 18\sqrt[3]{v} \qquad (8.2.1)$$

where: v – ballast tank capacity, m^3.

The diameter may be adopted by the nearest standard size.

8.2.2 The diameter of the ballast main shall not be less than the maximum diameter of the suction determined by Formula (8.2.1).

8.3 PIPING LAYING

8.3.1 The arrangement of the suctions shall be such as to ensure pumping of the water from any of the ballast tanks, whether the ship is on even keel or listed 5°.

8.3.2 In icebreakers and **Ice4** – **Ice6** ice class ships, the fore and after peaks, as well as structural wing tanks for water ballast, located above the waterline and in way of cargo holds, shall be provided with heating arrangements.

The double-bottom tanks in way of cargo holds, intended for water ballast, are recommended to be fitted with heating coils.

8.3.3 The suction and discharge pipes of segregated ballast tanks shall not communicate with sea chests and pipelines servicing cargo tanks.

8.4 BALLAST SYSTEM OF FLOATING DOCKS

8.4.1 The ballast system shall be so designed that at least two pumps are available at any ballast compartment.

8.4.2 In floating docks intended for service under negative temperatures, the pumps and valves shall be located in warmed spaces of the dock or shall be provided with local heating.

8.4.3 If the valves of the ballast system are controlled from a power source, then the sea inlet and discharge valves at side shall have manual emergency driving means laid to above the safety deck. In this case, the distributing valves are recommended to be fitted with a device automatically closing them, shall supply from the power source by interrupted.

8.5 HEEL AND TRIM SYSTEMS

8.5.1 The heel and trim systems shall be in compliance with **8.3.2** and **8.3.3**.

8.5.2 The design of the heeling system and the stabilization system shall exclude uncontrolled fluid flow.

Otherwise, a valve or shutter shall be provided on the cross-flow line, which is automatically locked in case of loss of power supply.

8.6 BALLAST SYSTEM OF BULK CARRIERS

8.6.1 Each water ballast tank forward of the collision bulkhead shall be provided with a water level detector giving audible and visual alarms when the liquid in the tank reaches a level not exceeding 10 % of the tank capacity.

8.6.2 On bulk carriers, the means for draining and pumping ballast tanks forward of the collision bulkhead shall comply with **7.9**.

8.7 BALLAST WATER TREATMENT SYSTEMS[5]

8.7.1 Permissible methods of ballast water exchange at sea:

.1 *refill method* is a process where a ballast tank or hold is first emptied of at least 95 per cent of its volume and then refilled with replacement ballast water;

.2 *flow-through method* is a process where replacement ballast water is pumped through the ballast tank or hold allowing the water to overflow or flow through other arrangements. At least 3 times the tank or hold volume shall be pumped through the tank or hold;

.3 *dilution method* is a process where replacement ballast water is filled in the ballast tank or hold through the tank top with simultaneous discharge of the same water quantity and maintaining a constant level in the tank or hold.

At least 3 times the tank or hold volume shall be pumped through the tank or hold.

8.7.2 Ballast water system shall provide pumping in and out any ballast tank and hold under any environmental conditions permitted by the Ballast Water Management Plan.

8.7.3 Where the flow-through method of water ballast exchange is used, overpressure in the tank or hold more than designed pressure shall be avoided.

8.7.4 Every ballast tank or hold shall be provided with shut-off valves for pumping in or out.

8.7.5 To prevent unauthorized flow of ballast shut-off valves for the ballast tanks or holds shall be permanently closed, except for the water ballast handling.

As a rule, the shut-off valves shall be of self-closing spring type or equivalent.

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[5] The requirements of this Chapter are mandatory for ships that have a ship's Manual for the safe exchange of ballast at sea and are not covered by the BWM Convention in accordance with the provisions of 2, Article 3 of that Convention.

8.7.6 The relative positions of ballast water intake and discharge openings shall be such as to preclude as far as practicable contamination of replacement ballast water by water that is pumped out.

8.7.7 The ballast system intended for ballast water exchange shall be served by at least two pumps. Where the ship's Ballast Water Management Plan permits the use of the r e f i l l m e t h o d , each pump shall be capable of providing ballast water exchange of the largest ballast water tank or group of tanks as per the ship's Ballast Water Management Plan within 3 h.

8.7.8 Ballast water exchange of cargo holds used for the carriage of water ballast may require an extended period of time but not more than 24 h by one pump.

8.7.9 The ballast system design shall permit the ballast water exchange operations with the minimum number of operational modes.

8.7.10 The internal arrangements of ballast tanks as well as ballast water piping inlet and outlet arrangements shall permit complete ballast water exchange and cleaning of any sediments.

8.7.11 The design of sea suction line strainers shall permit cleaning of strainers without interrupting the water ballast treatment.

8.7.12 Ballast pumps and all valves shall be remotely controlled from a central ballast control station.

Furthermore, the ballast pumps shall be provided with a means of local control.

8.7.13 A manually operated independent controls of all valves required for ballast water exchange shall also be provided for emergency operation in the event of main centralized remote control failure.

Where the valves are located inside tanks or other hard-to-reach spaces, the manually operated independent means of control may be achieved by connections to the control lines of individual valves.

8.7.14 The central ballast control station shall include the following:

valve position indicating system;

urrent tank level indicating system;

draught indicating system.

Means of communication between the central ballast control station and those spaces containing local controls for the ballast pumps and manually operated independent controls**.**

8.7.15 The centralized remote control system shall be arranged so that the failure of any one of the control system components does not cause the loss of operation to the pumps or valves or other systems.

8.7.16 The design of ballast tanks shall permit, where necessary, taking samples of the ballast water and sediments. Fitting of a tank hatch in addition to conventional manhole is recommended for this purpose.

Spaces below any tank opening shall be kept free of obstructions that could impede taking samples or free access.

8.7.17 Ballast water exchange by the f l o w - t h r o u g h m e t h o d without the risk of overpressure in the ballast tanks shall be demonstrated by calculations and testing on board.

8.7.18 The f l o w – t h r o u g h method with water flowing over the upper deck is not permitted.

The use of collecting pipes, internal overflow pipes or interconnecting pipe/trunk arrangements between tanks may be allowed to avoid water flowing over the upper deck.

8.7.19 Where d i l u t i o n m e t h o d is used, the following arrangements shall be provided:

special arrangements automatically maintaining the constant ballast water level. These arrangements shall provide for a manual emergency stop of the ballast pump in case of valve failure or incorrect control actions;

high and low water level alarms in tanks where the ballast water level changes significantly affecting the safety of the ship during water ballast treatment.

8.8 CONSTRUCTION OF BALLAST SYSTEMS, FACILITIES AND EQUIPMENT OF SHIPS FOR BALLAST WATER AND SEDIMENT MANAGEMENT

8.8.1 The requirements of this para are mandatory for ships which shall comply with the ballast water treatment standard in accordance with rule D2, Annex to the Convention and to which the symbol **BWM (D2)** is added to the character of class.

For the purpose of this Section the following definitions and explanations (in addition to those specified in this Part of the Rules and in **1.2**, Part I "Classification" of the Rules for the Classification and Construction of Ships) have been adopted:

Control equipment is an equipment installed for the purpose of maintaining and controlling ballast water treatment equipment.

Sediments means matter settled out of Ballast Water within a ship.

Ballast Water Management Plan (BWM Plan) a document describing the process and procedures for ballast water management performed on individual vessels. BWM Plan shall comply with regulation B-1 of the Annex to the BWM Convention and the requirements of IMO Resolution MERC 127 (53), as amended by IMO MERC Resolution 306 (73), be specific to each vessel.

Ballast Water Management System(BWMS) is a system designed to treat ballast water so that the quality of treated water at discharge meets or exceeds that specified in regulation D-2 of the Annex to the Convention.

It includes ballast water treatment equipment, all related control equipment, monitoring equipment and sampling facilities.

BWMS may include water treatment technologies based on a mechanical, physical, chemical or biological process, alone or in combination.

These technologies are used to remove and/or eliminate harmful aquatic and pathogenic organisms in ballast water and sediment, or to prevent their receiving or discharging.

Ship means a vessel of any type whatsoever operating in the aquatic environment and includes submersibles, floating craft, floating platforms, FSUs and FPSOs.

Ballast water tank is any tank, hold or compartment used to carry ballast water.

Ballast Water Management means mechanical, physical, chemical, and biological processes, either singularly or in combination, to remove, render harmless, or avoid the uptake or discharge of Harmful Aquatic Organisms and Pathogens within Ballast Water and Sediments.

Monitoring equipment is an equipment installed to assess the operational efficiency of ballast water treatment equipment.

Ballast water treatment equipment is an equipment which, by mechanical, physical, chemical or biological means, alone or in combination, carries out treatment to remove, dispose of harmful aquatic and pathogenic organisms contained in ballast water and sediments, or to avoid receiving or discharging them.

Ballast water treatment equipment may be operated when receiving or discharging ballast water during a voyage or in combination of these operations.

Harmful Aquatic Organisms and Pathogens means aquatic organisms or pathogens which, if introduced into the sea including estuaries, or into fresh water courses, may create hazards to the environment, human health, property or resources, impair biological diversity or interfere with other legitimate uses of such areas.

8.8.2 Unless expressly provided otherwise in Article 3 of the Convention, the ballast water discharge shall be carried out using Ballast Water Management System (BWMS) in accordance with the provisions of the Appendix of the Convention, taking into account the requirements of Rule A-3 and Rule A-5 of the said Appendix.

8.8.3 The ballast system, including BWMS, must comply with the applicable requirements of Part II “Hull”, part IV “Stability”, part VIII “Systems and Piping", Part X “Machinery”, Part X “Electrical equipment”, Part XV “Automation” of the Rules as well as the requirements of the Annex to the Convention.

8.8.4 All ships specified in 8.8.2 shall, without prejudice to safety or operational efficiency, be constructed in such a way as with a view to minimize the uptake and undesirable entrapment of sediments, facilitate removal of sediments, and provide safe access to allow for sediment removal and sampling.

8.8.5 Ballast system technical requirements in accordance with Regulation D-2 of the Annex to the Convention.

8.8.5.1 Ballast system in accordance with Regulation D-2 of the Annex to the Convention shall be equipped with an BWMS.

8.8.5.2 BWMS shall comply with the requirements of the Ballast Water Quality Standard of Regulation D-2 of the Annex to the Convention.

8.8.5.3 BWMS must be approved by the Flag State Administration.

8.8.5.4 Ballast water tanks and their internal structure should be designed to avoid the accumulation of sediment in a ballast tank, in accordance with the requirements of Resolution MEPC.209 (63) "Guidelines for the design and construction to facilitated sediment control on ship 2012 (P12)».

8.8.5.5 Emergency bypass or BWMS shutdown equipment must be installed in the event of an emergency to ensure the safety of the ship and personnel.

Triggering of bypass or shutdown appliances shall activate the alarm and shall be recorded by monitoring equipment.

The ship ballast system shall be fitted on each side of the ship with piping for discharge of ballast water into shore based receptacles in case of BWMS failure.

The discharge pipes must be installed in convenient places for connecting hoses and have distinctive strips, and must also be equipped with blind flanges.

8.8.5.6 Pipeline systems should be designed such that, when deballasting, disturbance of the water in the tank is as powerful as possible, so that the turbulence re-suspends sediment.

Any designs depending upon water flow to re-suspend sediment should, as far as possible, be independent of human intervention, in order that the workload of ships' crews is minimal when operating the system.

8.8.5.7 The design of all ships should provide safe access to allow for sediment removal and sampling.

8.8.5.8 The design of sea chests should be such shall prevent the formation of sediment traps.

8.8.5.9 The design of ballast water systems should, as far as practicable, facilitate installation of high sea suction points on each side of the ship.

8.8.5.10 Sampling facilities must be installed in a straight section of the outlet piping as close as possible to the side outlet.

8.8.5.11 BWMS may be installed in the Engine room or in a compartment equipped with a ventilation system according to the requirements of **12.9.1** and taking into account the requirements stipulated by the type of ballast water treatment equipment of installed BWMS.

8.8.5.12 If ballast water treatment equipment uses active substances or preparations, places / premises for their storage on the vessel must be provided.

8.8.5.13 If ballast water treatment equipment is intended to be installed in explosive areas of tankers, it shall comply with the applicable requirements of **19.2,** Part XI, "Electrical Equipment" of the Reules.

8.8.5.14 Any failure that threatens the proper operation of the ballast system must be accompanied by audible and visual alarms at all stations from which ballast water operations are controlled.

8.9 BALLAST SYSTEM OF SHIPS EQUIPPED TO ENSURE LONG-TERM OPERATION AT LOW TEMPERATURE

8.9.1 Ballast system onboard the ships with distinguishing marks **WINTERIZATION(DAT)** shall meet the requirements of **8.3.2**, Part VIII "Systems and Piping".

8.9.2 Discharge pipeline of ballast system shall be provided with heating.

8.9.3 Where submerged electrically-driven ballast pumps are used, their serviceability at design ambient temperature shall be ensured and documented; and the relevant information shall be introduced into the certificates issued by the Register.

8.9.4 Hydraulic liquids used as working media for ballast pumps driving and remotely controlled fittings shall be suitable for use at design ambient temperature.

9. SYSTEMS SPECIAL FOR CARRIAGE OF CARGOES IN BULK

9.1 APPLICATION

9.1.1 The requirements of the Section apply to ships intended for carriage of liquid cargoes in bulk and having the descriptive notation «**Oil tanker**», and «**Oil/bulk/ore carrier**», «**Oil recovery ship**», «**Oil/bulk carrier**», «**Oil/ore carrier**».

9.1.2 For the ships with the descriptive notation «**Oil tanker (>60°C)**» and «**Oil/bulk/ore carrier (>60ºC)», «Oil recovery ship (>60ºC)»**, «**Oil/bulk carrier (>60ºC)», «Oil/ore carrier (>60ºC)**» and «**Bilge water removing ship**» compliance with**9.2.1 – 9.2.8**, **9.3.1 – 9.3.3**, **9.3.5**, **9.3.6**, **9.4.1**, **9.4.4**, **9.4.5**, **9.5.1**, **9.5.2**, **9.5.6**, **9.6**, **9.7.1 – 9.7.3**, **9.7.5**, **9.7.7**, **9.7.9**, **9.7.13**, **9.7.15**, **9.7.17**, **9.10.1**, **9.10.2** is mandatory. Compliance with other paras of the Section is recommended for the above ships.

9.1.3 For supply vessels of MODU /FOP with the descriptive notation «**Supply vessel (OS)**» intended for the transport of limited amounts of flammable liquids in bulk with a vapour flashpoint 60°C and less the applicable requirements of the Section shall apply considering CODE FOR THE TRANSPORT AND HANDLING OF HAZARDOUS AND NOXIOUS LIQUID SUBSTANCES IN BULK ON OFFSHORE SUPPORT VESSELS (OSV Chemical Code), adopted by the IMO Resolution A.1122(30).

For offshore support vessels intended for the transport of limited amounts of flammable liquids in bulk with a vapour flashpoint more than 60°C the applicable requirements of paras listed in **9.1.2** shall apply.

The limited quantities of bulk liquids carried by offshore support vessels in the amount not exceeding a maximum shall be the lesser of 800 m^3 or a volume in cubic meters equal to 40 % of the vessel's deadweight calculated as a cargo density of 1000 kg/m^3.

In case where offshore support vessels of MODU/FOP are intended for carriage of more than the relevant maximum amount specified above, the requirements for such vessels shall be similar in full scale to the requirements for the bulk carriers.

9.2 GENERAL REQUIREMENTS FOR PIPING IN CARGO AREA

9.2.1 Remote-controlled valves shall comply with the requirements of **4.1.1.2 – 4.1.1.4**.

9.2.2 The spindles used to operate the valves placed inside the cargo tanks shall be carried to the open deck in gastight sealing glands.

Replacement of the sealing shall be made from the open deck.

The drives shall have arrangements showing whether the valve is open or closed.

The drive shall be constructed as to prevent accumulation of oil residues in them.

Where the rubbing parts of the valve drives pass inside cargo tanks and cofferdams, as well as on the cargo deck, precautions shall be such as to preclude spark formation.

9.2.3 In enclosed spaces inside the cargo area, the temperature of steam or heating medium shall not exceed 220°C.

9.2.4 The pipe flanges and fastening pieces intended for hose connections from shore installations shall be made of materials precluding spark formation.

9.2.5 The piping on deck and in cargo tanks shall be efficiently secured and fitted with thermal compensators.

Where thermal expansion is compensated by pipe bends, the radii of pipe bends shall comply with the requirements of **2.2**.

9.2.6 All the pipe lengths interconnected by flanges shall have reliable electric connection. At one place minimum, electric earthing to the hull shall be made as it is required in **2.5.3**, Part XI "Electrical Equipment".

9.2.7 To prevent the passage of flame into cargo holds, in the structure of valves of cargo pipes and venting arrangements, covers of manholes and hatches of cargo tanks, use of materials, which easily lose their properties under the effect of heat, is not permitted.

9.2.8 In combination carriers, provision shall be made for devices in the form of blank flange to isolate slop tanks from cargo tanks.

9.2.9 All piping on board, through which communication between liquid-free spaces of cargo tanks is possible, shall be equipped with a flame arrester.

9.2.10 To keep cargo spills within the cargo area, provision shall be made for a permanent continuous coaming on the upper deck, of at least 300 mm in height and extending from side to side.

9.3 CARGO OIL SYSTEM

9.3.1 Cargo piping shall not pass through the tanks not intended for cargo storage and shall not be connected to other tanks or piping including the fuel oil pipes of the propulsion plant.

Cofferdams shall have no connections to cargo tanks.

No by-pass valves are permitted in cofferdams.

The piping, by means of which hazardous mixing of different types of cargo or watering of cargo can take place, shall have a double number of shut-off valves.

9.3.2 The terminations of the filling pipes of cargo tanks shall be laid, as far as practicable, as near to the tank bottom as possible, but not nearer than 1/4 of the pipe inner diameter.

9.3.3 The slop tanks of oil tankers shall be generally served by independent piping systems.

Where such systems are not provided, all the suction and discharge pipes of slop tanks shall be equipped with spectacle flanges or other blocking arrangements.

9.3.4 In combination carriers, reliable means shall be provided for isolating the piping connecting the pump with the slop tanks.

The means of isolation shall consist of a valve followed by a spectacle flange or a spool piece with appropriate blank flanges.

This arrangement shall be located adjacent to the slop tanks, but where this is unreasonable or impracticable, it may be located within the pump-room directly after the piping penetrates the bulkhead.

In combination carriers, under deck cargo piping shall be located in special ducts provided with ventilating and draining arrangements.

9.3.5 In combination carriers where the ship is in the dry cargo mode, a permanently installed system shall be provided for discharging the contents of the slop tanks directly to the open deck.Use of spool pieces is permitted to connect the system for discharging the contents of the slop tanks to other systems.

The manifold for slop tank contents installed on the open deck shall be equipped with a shut-off valve and a blank flange.

9.3.6 Where cargo hoses are connected to cargo manifolds, provision shall be made for a tray, in which cargo oil residues would accumulate.

9.3.7 Irrespective of purpose, piping laid through dangerous zones and intended for hose connection from shore or from another ship, shall be provided with the following facilities to ensure intrinsical safety:

.1 insulating flange connections or nonconducting pipe lengths;

.2 insulating mats, pads and railing to prevent the contact between the metal components of hoses and the hull.

The measured resistance between the metal components of hoses and the hull shall not be less than 25 kOhm.

9.4 CARGO PUMPS

9.4.1 Cargo pumps and cargo stripping pumps shall serve only their direct purpose except as provided for in **7.7.1** and **9.10.2**. These pumps shall not have any connections to tanks other than cargo tanks.

Cargo pumps and cargo stripping pumps shall be either installed in a separate space or they shall be submersible pumps.

9.4.2 The arrangement of driving machinery of cargo pumps and cargo stripping pumps shall comply with the requirements of **4.2.5**, Part VII "Machinery Installations".

9.4.3 The design of pumps, valves and their drives shall be such as to preclude spark formation to maximum extent possible.

Structural measures shall be taken to limit the zero delivery time of submersible cargo pumps.

9.4.4 Devices shall be provided to stop cargo pumps and cargo stripping pumps from the top flat of the pump room at main deck level or from a readily accessible location on deck.

Where a cargo control station is provided, the pump stopping arrangements shall be installed at the cargo control station as well.

The stopping arrangements of electrically driven pumps shall comply with the requirements of **19.2.4.5**, Part XI "Electrical Equipment".

9.4.5 The pressure gauges of the cargo oil discharge and cargo stripping mains shall be fitted at pumps and on the top flat of the pump room, or at the cargo control station.

9.4.6 Where any machinery (both electric and hydraulic) used to drive cargo and ballast pumps, as well as the arrangements used to supply and control the pumps and valves of the cargo and ballast systems are integrated, the requirements of **19.2.7**, Part XI "Electrical Equipment" shall be met.

9.5 BOW AND AFT LOADING SYSTEM

9.5.1 Bow and aft cargo piping of an oil tanker shall be permanently installed.

Where necessary, the connections of such piping may be detachable.

9.5.2 Bow and aft cargo piping shall be laid outside accommodation and service spaces, and outside machinery spaces adjacent to accommodation spaces and control stations.

9.5.3 Bow and aft cargo piping shall be connected by welded joints.

If necessary, expansion joints may be used. Within the hazardous zone, piping may have detachable joints.

For pipe-to-valve connections, flange connections, as mentioned in **2.4**, may be used.

Cargo piping of this type shall be marked accordingly.

They shall be disconnectable from the principal cargo mains either with two valves in the cargo area, provided with devices for their sealing when shut, or with a single valve used alongside a spool piece or spectacle flange.

9.5.4 The pipe section used as shore connection shall be fitted with a shut-off valve and a blank flange, and provided with a tray.

In case a special coupling is used, the blank flange may be omitted.

The area of 3 m around the manifolds shall be considered a hazardous zone 1 (refer to **19.2.3**, Part XI "Electrical Equipment").

9.5.5 In cargo piping, arrangements for the discharge of cargo residues shall be provided.

Outside the hazardous zone, cargo piping shall be fitted with arrangements to make it clean of cargo and purge it with inert gas. Between cargo piping and inert gas system (IGS), isolating device shall be fitted.

For ships less than 8000 tons deadweight without IGS, it is possible to provide ventilation of pipelines with a portable fan or compressed air blowing instead of purging with an inert gas.

9.5.6 In oil tankers equipped with bow loading system intended for cargo-handling operations at point berths carried out to sea, an emergency high-speed device shall be installed for the cargo hose disconnection.

The design and location of such device shall comply with the applicable requirements of Part VIII "Requirements for the equipment of oil tankers for cargo operations at sea" of the Rules for the Prevention of Pollution from Ships.

9.6 CARGO HEATING SYSTEM

9.6.1 As a heating medium for heating of cargo in tanks, the use of steam, hot water and thermal oil is permitted.

9.6.2 Upstream from each steam heating coil, a non-return stop valve shall be fitted, and upstream to stop valves at the outlet the gauge valve for checking of the condensate quality shall be installed.

9.6.3 The return of condensate from the heating system shall be performed via the check tank.

The air pipes of the check tank for heating steam condensate from the cargo tanks containing the cargoes with the flash point below 60 8C shall be provided with flame arresters and be lead to a safe place.

9.6.4 Cargo heating systems using thermal liquid as a heating medium shall comply with **20.11**.

9.6.5 In ships with the descriptive notations «**Oil tanker (> 60°C)**» and «**Oil/ore carrier (> 60°C)**» in the class notation, the maximum heating temperature shall be lower than the flash point of the carrying cargo at least for15°C.

9.3.6 The cargo heating system shall be equipped with the facilites for cargo temperature control in the tanks.

Control of the current temperature in tanks, as well as light and audible alarms on exceeding of the maximum permissible cargo temperature or on cargo flow velocity loss when pumped through the heaters, shall be provided.

9.7 VENTING SYSTEM

9.7.1 The venting system shall ensure gas exchange and safe pressure in cargo tanks during the loading, discharging and carriage of liquid cargo. For this purpose, the system shall include one or more devices to limit the following:

.1 pressurization above cargo tank test pressure during loading or ballasting with the maximum specified output;

.2 pressure fall below 7 kPa during unloading with the maximum cargo pump delivery.

9.7.2 The venting systems of cargo tanks shall be entirely distinct from the air pipes of other compartments.

The design and arrangement of the outlets of venting arrangements shall be such as to minimize the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition or collecting in the vicinity of deck machinery and equipment.

9.7.3 The venting system shall include arrangements to provide for:

.1 free flow of small volumes of vapour, air or inert gas mixtures caused by thermal variations in the cargo tank;

.2 free flow of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

9.7.4 Vent outlets for free flow of vapour mixtures, intended for compensation of thermal pressure variations, shall be arranged:

.1 not less than 2 m above the cargo tank deck;

.2 not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment, which may constitute an ignition hazard, such as anchor windlass and chain locker openings.

9.7.5 The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

Where the arrangements are combined with other cargo tanks, pressure/vacuum, valves may be mounted on the inert gas mains.

9.7.6 Where the arrangements are combined with other cargo tanks, a stop valve and a flame arrester shall be provided to isolate each cargo tank.

Where stop valves are fitted, they shall be provided with locking arrangements which shall be under the control of the responsible ship's officer.

There shall be a clear visual indication of the operational status of the valves.

Where tanks have been isolated, it shall be ensured that relevant isolating valves are opened before cargo loading or ballasting or discharging of those tanks is commenced.

Flame arresters shall be located so as to render the penetration of cargo oil therein impossible under any navigational conditions, rolling included.

9.7.7 Any isolation of venting arrangements shall continue to permit the flow caused by thermal variations in a cargo tank in accordance with**9.7.3.1**.

9.7.8 The system for the venting of vapours displaced from the cargo tanks during loading, discharging and ballasting shall consist of either one or more mast risers, or a number of high-velocity vents permitting to discharge of the vapour mixtures with a velocity of not less than 30 m/s.

The vapour mixture shall be discharged vertically upwards.

9.7.9 The vent outlets of pipes required by **9.7.3.2** shall be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1,25.

When determining the capacity of venting systems equipped with flame arresters, the pressure drop as the gases pass through the flame arrester shall be considered.

In any case, the adopted pressure drop value shall be by 50 % greater than that for a flame arrester in the clean condition.

The internal diameter of vent pipes shall not be less than 80 mm, and that of mains, not less than 100 mm.

9.7.10 Where the method is by free flow of vapour mixtures, the vent outlets of the venting system pipes shall not be less than 6 m above the cargo tank deck or fore and aft gangway, if situated within 4 m of the gangway, and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, and equipment which may constitute an ignition hazard.

9.7.11 Where the method is by high-velocity discharge, the vent outlets shall be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to closed spaces containing a source of ignition and from deck machinery, which may include anchor windlass and chain locker openings, an equipment which may constitute an ignition hazard.

9.7.12 In each cargo tank a secondary means of allowing full flow relief of vapour, air or inert gas mixtures to prevent overpressure or underpressure in the event of failure of the arrangements mentioned in **9.7.3.2** shall be fitted.

Pressure/vacuum-breaking devices fitted on IGS main may be utilised as the required secondary means of allowing full flow relief of vapour, air or inert gas mixtures where the cargo is homogenous or for multiple cargoes where the vapours are compatible and do not require isolation.

Alternatively, pressure sensors may be fitted in each tank protected by the arrangement specified in **9.7.3.2**, with a monitoring system in the ship's cargo control room or the position from which cargo operations are normally controlled. Such monitoring equipment shall also provide an alarm and monitoring system which is activated by detection of over-pressure or underpressure conditions within a tank.

For ships that apply pressure sensors in each tank as an alternative secondary means of flow relief of vapour, air or inert gas mixtures, the overpressure alarm actuation setting shall be above the pressure setting of the pressure/vacuum-valve and the underpressure alarm actuation setting shall be below the vacuum setting of the pressure/vacuum-valve.

The alarm actuation settings shall be within the design pressures of the cargo tanks. The actuation settings of pressure and vacuum detectors in cargo tanks shall be fixed and not arranged for blocking or adjustment in operation. An exception is permitted for ships that carry different types of cargo and use pressure/vacuum valves with different settings, one setting for each type of cargo.

9.7.13 Permanent arrangements shall be provided to drain the venting arrangements and vent lines to a cargo tank.

9.7.14 The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks.

The design, testing and locating of flame arresters shall comply with the requirements based on ISO 15364, IMO circular MSC/Circ.677 considering amendments (IMO circulars MSC/Circ.1009 and MSC/Circ.1324).

9.7.15 The hatches and other openings of cargo tanks used for measuring temperature, ullage, sampling, gas analysis, except openings for permanently installed gauges, shall be provided with selfclosing covers or valves. Flame arresters and screens are not required in these openings.

The above covers and/or valves shall not be used for pressure equalization in the spaces above the cargo surface.

9.7.16 Arrangements, required in **9.7.1.1**, may be provided with a bypass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided, there shall be suitable indicators to show whether the bypass is open or closed.

9.7.17 In combination carriers, the arrangements for isolating venting systems of slop tanks containing oil or oil residues shall consist of blank flanges, which will remain in position at all times when cargoes other than liquid cargoes are carried.

9.7.18 The venting systems of oil tankers designed to carry boiling oily products, the Reid vapour pressure of which exceeds atmospheric pressure, shall be subject to special consideration by the Register in each case.

9.8 PURGING AND GAS FREEING OF CARGO TANKS

9.8.1 On the ships fitted with IGS arrangements may be provided for purging and gas freeing empty tanks in addition to the venting arrangements specified in **9.7.10** and **9.7.11**, which would ensure and exit vertical velocity of at least 20 m/s when any three tanks are being simultaneously supplied with inert gas.

Their outlets shall extend not less than 2 m above deck level.

9.8.2 On the ships not fitted with IGS, special fans, which may be portable, shall be provided for purging and gas freeing empty tanks.

During gas freeing operations, in addition to the arrangements specified in **9.7.10** and **9.7.11**, hydrocarbon vapours may be vented through special pipes, which shall comply with the following requirements:

the pipe outlets shall extend not less than 2 m above deck level;

gas exit velocity of at least 30 m/s in the vertical direction shall be maintained;

the pipe outlets shall be arranged horizontally not less than 10 m away from openings to enclosed spaces containing sources of ignition, from air intakes, deck machinery and other equipment which may present ignition hazard.

Gas exit velocity may be reduced to 20 m/s, provided the device is fitted to prevent the passage of flame, as required by **9.7.14**.

9.8.3 On individual cargo tanks, the gas outlet pipe shall be positioned as far as practicable from the inert gas/air inlet.

The inlet of such outlet pipes may be located either at deck level or at not more than 1 m above the bottom of the tank.

9.8.4 Each gas outlet shall be fitted with suitable blanking arrangements.

9.9 CARGO VAPOUR DISCHARGE SYSTEM

9.9.1 If a ship is equipped with the cargo vapour discharge system, the distinguishing mark **VCS** may be added to the character of classification (refer to **2.2.16**, Part I «Classification»).

In addition to the requirements of the present Chapter, in order to assign the distinguishing mark **VCS** to the ship, the requirements for the overflow prevention and cargo tank level control specified in **9.11.1** shall be complied with, and the level gauging system shall be closed as specified in **9.11.2**.

9.9.2 The cargo vapour discharge system shall be arranged in such a way that it cannot interfere with the normal operation of the venting system.

The cargo vapour discharge system shall be designed basing on the maximum loading capacity. The pressure drop in the cargo vapour discharge piping, obtained by means of hydraulic calculation, shall not exceed 80 % of the opening pressure of any venting system discharge valve specified in **9.7.1.1**.

9.9.3 The instructions approved by the Register shall be constantly kept on the ship, proceeding from which the allowable loading speed of different cargoes may be defined, taking into consideration the requirements of **9.9.1** and **9.9.2**.

9.9.4 Vapours of incompatible cargoes shall not be mixed when passing the vapour discharge system.

9.9.5 When the inert gas distribution piping is used to collect cargo vapours, measures shall be taken for insulating inert gas pipes from the cargo vapour discharge system.

9.9.6 Provision shall be made for elimination of condensate, which may be accumulated in the system.

9.9.7 Piping of the system shall be electrically continuous and have safety earthing.

9.9.8 Cargo vapour discharge manifolds shall be fitted with a pressure sensor and alarm system to produce alarm signals at high-pressure level (but not higher than that at which the high-speed venting device is actuated) and for vacuum (but not lower than the pressure, at which the vacuum valve is actuated).

The present requirement may be dispensed with if each cargo tank is fitted with overpressure/ underpressure sensor according to **9.7.12**.

9.9.9 In the area of the adapter sleeve of the cargo vapour discharge manifold, the easily accessible check valve with manual control shall be installed.

9.9.10 Hoses applied in the vapour discharge system shall comply with the requirements of 6.1.12.

9.9.11 To exlude false connection of vapour discharge piping to onshore terminal liquid cargo piping, studs with a diameter of 12,7 mm and the length not less than 25,4 mm shall be mounted on the vapour discharge manifold connecting flanges at the upper point of the coupling bolts line, as shown in Fig. **9.9.11-1**.

The vapour discharge manifold marking shall comply with Fig. **9.9.11-2**.

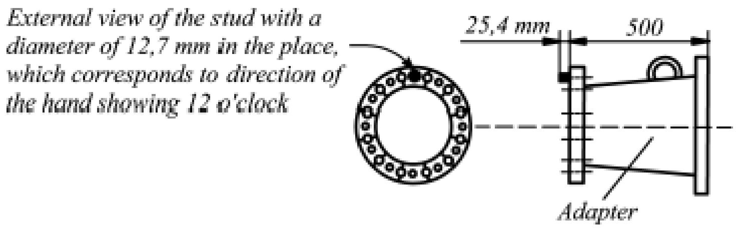

Fig. 9.9.11-1

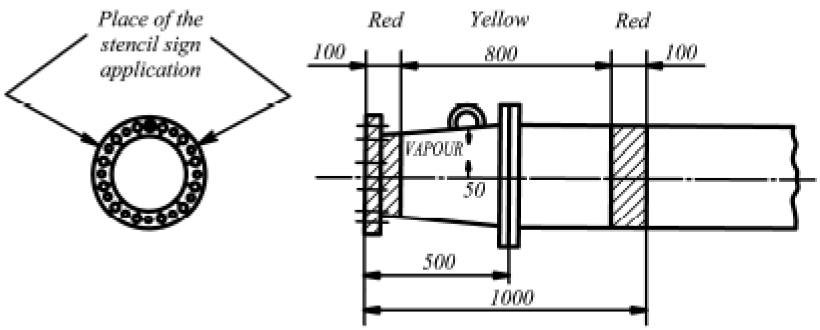

Fig. 9.9.11-2 The vapour discharge manifold marking

9.10 SHIP SERVICE SYSTEMS IN CARGO AREA

9.10.1 Ballast, sounding and air pipes of segregated ballast tanks shall not pass through cargo tanks.

Cargo and similar pipes intended to serve cargo and slop tanks shall not be laid through segregated ballast tanks.

This requirement may be dispensed with, in the case of shorter pipes, provided they are completely welded or equivalent, with thickened flanged connections, the number of which shall be kept to a minimum.

Thermal expansion of the pipes shall be compensated by the pipe bends.

The bend radii shall be in accordance with the requirements of **2.2.1**.

In Fig. 9.10.1, the recommended design of an air pipe is shown by way of an example. Piping shall be seamless and its material shall be steel.

The pipe wall thickness shall not be less than indicated in Table 9.10.1.

Table 9.10.1

Internal diameter, in mm	Minimal wall thickness, in mm
Up to 50	6,3
Up to 100	8,6
Up to 125	9,5
Up to 150	11,0
150 and above	12,5

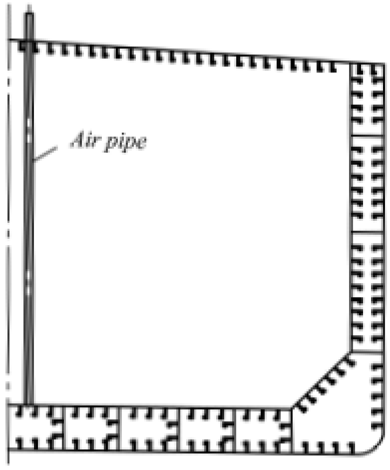

Fig. 9.10.1

9.10.2 Emergency ballast discharge may be affected by means of a connection to a cargo pump through a spool piece, which shall be mounted in a conspicuous, readily accessible position in the pump room.

To prevent the passage of petroleum products into the ballast tanks, a non-return valve shall be fitted on the segregated ballast connections.

The ballast pump shall be located in the cargo pump room or another space with the safety level equivalent to that of a cargo pump room not containing sources of ignition.

9.10.3 The fore peak tank can be ballasted with the system serving other ballast tanks within the cargo area, provided:

.1 the fore peak tank is considered as hazardous;

.2 the vent pipe openings are located on open deck 3 m away from sources of ignition or in accordance with **19.2.3**, Part XI "Electrical Equipment";

.3 means are provided, on the open deck, to allow measurement of flammable gas concentrations within the fore peak tank by a suitable portable instrument;

.4 the sounding arrangement to the fore peak tank is direct from open deck;

.5 the access to the fore peak tank is direct from open deck. Alternatively, indirect access from the open deck to the fore peak tank through an enclosed space may be accepted provided that:

.5.1 in case the enclosed space is separated from the cargo tanks by cofferdams, the access is through a gas tight bolted manhole located in the enclosed space and a warning sign shall be provided at the manhole stating that the fore peak tank may only be opened after it has been proven to be gas free; or any electrical equipment which is not certified safe in the enclosed space is isolated.

.5.2 in case the enclosed space has a common boundary with the cargo tanks and is therefore hazardous, the enclosed space can be well ventilated in accordance with **12.12** (at least as for the spaces of area 2 according to **12.12.6**).

9.10.4 In oil tankers, the open ends of air pipes of cofferdams, fuel oil and lubricating oil tanks adjoining cargo and slop tanks shall be laid to the open deck where the vapours displaced from the above tanks do not present a fire hazard and where flame arresting fittings of a Register-approved type are available.

The flow area of the fittings shall not be less than the air pipe flow area.

9.10.5 Steaming pipes of cargo tanks shall be equipped with non-return/shut-off valves.

9.11 LEVEL AND OVERFLOW CONTROL OF CARGO TANKS

9.11.1 Provision shall be made to guard against liquid rising in the venting system to a height, which would exceed the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems.

The overflow control system shall be two-level and independent of tank level gauging devices, it shall give visible and audible high- and limit-level alarms in cargo tanks to the ship operator and to the cargo control room (if any), give and alarm for deenergization of the system or level sensors, have the possibility of checking the alarm circuit prior to cargo operations.

For the purpose of this regulation, spill valves are not considered equivalent to an overflow system.

9.11.2 Each oil tanker equipped with a fixed IGS shall be provided with closed measurement devices for taking ullages of cargo and slop tanks.

In oil tankers, semiclosed or closed measurement devices for taking ullages of cargo and slop tanks shall be applied.

Open sounding devices are admitted in oil tankers with the descriptive notation «**Oil tanker (> 60°C)**» and as a reserve means in oil tankers not equipped with IGS.

9.11.3 The cargo tanks sounding pipes shall be so designed as to include hermetic self-closing valves and covers fitted on pipes laid to the open deck; the pipe laid to the deck shall be as high as to prevent cargo spillage onto the deck during sounding.

9.11.4 In oil tankers intended for the carriage of cargoes with flash point below 60 8C , the sounding rods shall be made of a non-sparking material.

9.11.5 In oil tankers each cargo tank shall be provided with overflow prevention system to meet the following requirements:

.1 be separated of sounding system of cargo tanks;

.2 give visible and audible high- and limit-level alarms in cargo tanks to ship's operator and to cargo handling room;

.3 give an alarm on de-energization of system or level sensors;

.4 have the possibility of checking the alarm circuit prior to cargo operations;

.5 give a code signal for sequential switch-off of shore pumps and valves, or both, and valves shall be switched off by ship's operators.

Application of ship's automatically closed valves is allowed only upon the permission and under the agreement with Port Administration.

9.12 CARGO TANK WASHING SYSTEM

9.12.1 Every crude oil tanker of 20000 t deadweight and above shall be provided with the crude oil washing system. This system shall fully comply with the requirements of regulation 33 of Annex I to MARPOL 73/78.

If a ship is provided with the crude oil washing system complying with the requirements of the above regulation, regardless of its deadweight, the distinguishing mark **COW** shall be added to the character of classification (refer to **2.2.18**, Part I "Classification").

When the crude oil washing system is provided on board, the ship shall be fitted with IGS complying with the requirements of **9.16**.

The crude oil washing system pipelines and associated equipment and arrangements (piping, tank washing machines, pumps, stripping system) shall comply with **3.2.3**, Chapter 3, Part I «Requirements for the ships design and their equipment for oil pollution prevention» Rules for the prevention of pollution from ships.

9.13 STATIC ELECTRICITY PROTECTION

9.13.1 Cargo hoses, compressed air hoses, tank washing hoses and other hoses used in the cargo area shall comply with the requirements of Section 6, conduct electricity through their whole length, including connections and flanges (with the exception of shore connections), and shall be earthed to remove electrostatic charges.

9.13.2 Portable pumps and ventilators to be used in the cargo area shall be equipped with devices for electrostatic earthing prior to operation.

9.13.3 The cargo system shall make it possible to regulate the intensity of loading each particular tank so that the flow velocity would not exceed 1 m/s at suction pump outlet in the tank at the initial stage of loading. The above flow velocity can be increased, if cargo tanks are fitted with special suction wells to reduce the level of tank atmosphere electrization, which design shall be approved by the Register.

For maximum loading intensity, the flow velocity shall not exceed 7 m/s.

The requirements of this paragraph may be waived, if cargo tanks are inerted during cargo-handling operations.

9.14 MONITORING THE COMPOSITION OF ATMOSPHERE IN CARGO AREA

9.14.1 Oil tankers and combination carriers shall carry at least two portable instruments for measuring oxygen and flammable vapour concentrations (refer to item **15** of Table 5.1.2, Part VI "Fire Protection").

9.14.2 Structural measures shall be taken to facilitate flammable vapour concentration measurements in all spaces of the cargo area. The above measurements shall be possible from open deck or readily accessible locations.

Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines. Where plastic pipe material are used, they shall be electrically conductive.

9.14.3 3 In cargo pump rooms and in ballast pump rooms fitted with the equipment containing cargo or pumps to pump fuel with a flash point below 60°C, a system for continuous monitoring of the concentration of hydrocarbon gases shall be fitted. Sampling of atmosphere for analysis shall be carried out in succession (including the exhaust vent).

The interval between measurements shall be as short as possible. Detector heads of gas analyzers shall be located in the areas with limited air circulation (at recesses and remote angles).

When the hydrocarbon gas concentration reaches a pre-set level, which shall not be higher than 10 % of the lower flammable limit, a continuous audible and visual alarm signal shall be automatically effected in the pump-room, main machinery control room, cargo control room and navigation bridge to alert personnel to the potential hazard.

In combination carriers, such system, in addition to the cargo pump-rooms, shall be installed in cofferdams and pipe tunnels adjacent to the settling tanks.

9.14.4 Where fixed gas analysers are fitted outside the cargo area, the following conditions shall be met:

.1 sampling pipes shall be provided with flame arresters and gas samples shall be vented to the atmosphere through a special pipe mounted at a safe location;

.2 sampling pipe assemblies at gastight bulkhead penetrations shall be type-approved and their fire resistance shall be equal to that of the bulkhead;

.3 each sampling pipe shall be provided with a manual insulation valve fitted on the gas-safe side of the gasight bulkhead;

.4 instruments and equipment for gas analysis shall be arranged inside a special hermetic steel cabinet and one of the sampling points shall be located in the cabinet. When the dangerous gas concentration inside the cabinet reaches 30 % of the lower flammability limit, the gas supply to the gas analyzer shall be automatically stopped;

.5 sampling lines shall not generally be laid through spaces outside the hazardous area.

Where it is not possible to install the gas analysis cabinet on a gastight bulkhead, the sampling pipes shall be as short as practicable, they shall be made of steel or an equivalent material and shall not have detachable joints except joints with the gas analysis cabinet and insulating valves on the gastight bulkhead.

9.14.5 In oil recovery ships and bilge water removing ships the sampling arrangements or the atmosphere monitoring system detectors shall be located as follows:

.1 near the forced ventilation openings;

.2 at least at two locations at the open deck at a height not more than 1m above the deck;

.3 in machinery spaces of category A;

.4 in air locks;

.5 in cofferdams adjacent to cargo tanks.

9.16.6 Oil tankers of 20 000 t deadweight and above shall be provided with a fixed hydrocarbon gas detection system of all double hull spaces complying with the Fire Safety Systems Code and IMO circular MSC.1/Circ.1370.

.1 the above system shall perform periodical measurements of hydrocarbon gas concentrations in all ballast tanks and void spaces adjacent to the cargo and slop tanks (inter alia to those, which form a cruciform (corner to corner) contact), including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks. However, this is not required for fuel tanks.

.2 as a rule, the gas detection system shall be arranged with single sampling lines from each sampling point.

Sampling lines in the same space may be combined art deck level with a manually operated threeway valve arrangements provided with clear local indication of which sampling point is active. In ballast/ partially ballast condition valve to be set so that upper sampling point is active; for empty tank the lower sampling point is to be active;

.3 hydrocarbon gas concentration measurement systems should also be provided in ballast pump rooms and bow thruster rooms located under the bulkhead decks as well as in any void spaces adjacent to cargo and slop tanks.

In such spaces it is permitted to arrange one sampling point at the lower part;

.4 it is not required to install fixed hydrocarbon gas detection equipment in the spaces of oil tankers fitted with permanently operated IGS for such spaces;

.5 cargo pump rooms complying with the requirements of **9.14.3** and **9.14.4** are not covered by the requirements of this paragraph.

9.15 OIL RECOVERY SYSTEM OF OIL RECOVERY SHIPS

9.15.1 The system and devices for the recovery and transfer of oil shall be installed outside machinery spaces and accommodation spaces.

9.15.2 The system shall ensure both the recovery and transfer of oil being recovered.

9.15.3 Where, in multi-purpose ships, a permanently installed oil recovery system is incompatible with the cargo of the cargo system installed, relevant isolating arrangements shall be provided.

9.15.4 Where the ship is fitted with portable oil recovery equipment, not more than two suctions connected by piping to all oil collecting tanks shall be provided on the upper deck for connecting to the discharge hoses of the oil recovery equipment.

The arrangement of suctions on the upper deck shall make it possible to simultaneously connect two oil recovery systems installed on the opposite sides of the oil recovery ship.

Pipe connecting suctions to tanks shall not pass through accommodation, service spaces and other enclosed safe-type spaces (refer to **19.2.3.4**, Part XI "Electrical Equipment"), located as high as the open deck and above.

9.16 INERT GAS SYSTEM (IGS)

9.16.1 General.

9.16.1.1 Oil tankers of 8000 t deadweight and above, intended for the carriage of flammable liquids with a flash point of 60°C and below, as well as oil tankers provided with the crude oil washing system shall be equipped with the fixed IGS complying with the requirements of the International Code for Fire Safety Systems with IMO resolution MSC.367(93), **9.16.8**, **9.16.9** or **9.16.12** with a capacity specified in **9.16.2**.

Where a ship is equipped with IGS complying with the requirements of the present Chapter, the distinguishing mark **IGS-IG**, **IGS-NG** or **IGS-Pad** may be added to the character of classification as specified in 2.2.17, Part I "Classification".

.1 IGS-IG - if an inert gas generator operating on the basis of fuel combustion is used as a source of inert gas in the system, and the requirements of **9.16.9** are met;

.2 IGS-NG - if a nitrogen generator is used as a source of inert gas in the system and the requirements of **9.16.12** are met;

.3 IGS-Pad - if the inert gas system is intended only to create an insulating layer in cargo tanks and the requirements of **9.16.11** are met.

9.16.1.2 IGS may be used for fire prevention by generating and continually maintaining the nonflammable atmosphere in cargo tanks, except when such tanks shall be degassed.

The system shall be capable of:

.1 maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding 8% by volume and at a positive pressure at all times in port and at sea except when it is necessary for such tank to be gas free;

.2 eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;

.3 purging empty cargo tanks with inert gas and air;

9.16.1.3 Inert gas with an oxygen content of not more than 5 % by volume shall be delivered to the cargo tanks.

9.16.1.4 The inert gas supply may be treated flue gas from main or auxiliary boilers or separate gas generators. The Register may accept systems using flue gases from other sources or any combinations thereof provided an equivalent standard of safety is achieved.

Each source of flue gas shall be provided with automatic combustion control to provide for the fulfilment of the requirement of **9.16.1.3**.

Carbon dioxide smothering system due to the risk of ignition of the mixture of vapours of flammable liquids with air from discharges of static electricity generated at carbon dioxide supply shall not be used for the purpose of inertization.

9.16.2 Capacity.

9.16.1.2.1 For ships specified in **9.16.1.1** and having the distinguishing mark **IGS-IG** or **IGS-NG**, IGS shall have a capacity of not less than 125 % of the maximum total capacity of cargo pumps during discharging the ship.

9.16.2.2 For ships not specified in **9.16.1.1** and having the distinguishing mark **IG-Pad**, IGS shall have capacity sufficient for producing pad in cargo tanks, inerting, where necessary, of spaces adjacent to cargo tanks, replacing the inert gas loss during voyage, or the appropriated quantity of the inert gas in cylinders shall be provided on board the ship.

9.16. 3 Equipment.

9.16.3.1 A flue gas scrubber shall be fitted which will effectively cool the volume of gas and remove solids and sulphur combustion products. The cooling water shall be delivered by an independent pump. Provision shall be made for an alternative supply of cooling water from a stand-by pump without interfering with any essential services on the ship.

9.16.3.2 The gas scrubber shall be designed so that the capacity of the system will not drop for more than 3 % and the gas temperature at the outlet will not rise more than 3°C as against the design values under all normal conditions of heel and trim.

9.16.3.3 Provision shall be made in the gas scrubber housing for inspection holes and sight glasses made of impact-, and heat-resisting material for inspections and maintenance.

9.16.3.4 At least two blowers shall be fitted which together are capable of delivering at least the volume of gas required by **9.16.2**; and where possible there shall be established equal supply for each blower, but at any rate for each of them it shall not be less than 1/3 of aggregate required supply.

9.16. 3.5 Provision shall be made in the blower casing for maintenance devices.

9.16.3.6 Interior surfaces of the scrubber and blowers shall be made of corrosion-resistant materials or lined with a coating material.

9.16.3.7 Filters or equivalent devices shall be fitted to minimize the amount of water and solid particles carried over to the inert gas blowers.

9.16.4 Cargo tank protection against pressure/vacuum.

9.16.4.1 IGS shall be so designed that the maximum pressure which it can exert on any cargo tank will not exceed the test pressure of any cargo tank.

9.16.4.2 One or more devices for braking pressure/vacuum in cargo tanks shall be provided on the inert gas supply main if they are not fitted on the gas venting system or individually in each tank. Control and location of these arrangements shall comply with the requirements of **9.7**.

9.16.4.3 A positive pressure not exceeding 21 kPa shall be maintained in the cargo tanks when they are filled or being filled with inert gas under normal working conditions.

9.16.5 Non-return devices.

9.16.5.1 At least two non-return devices shall be fitted in the inert gas supply main in the cargo area on deck. One of them shall be a deck water seal, and the other - a non-return valve or an equivalent device fitted forward of the deck water seal. They shall be located between the automatic valve required by **9.16.6.5** and the aftermost connection to any cargo tank or cargo pipeline.

9.16.5.2 The deck water seal shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times and automatically starting each pump feeding the water seal and automatically filling the seal with water upon inert gas supply failure (for half-dry and dry water seals).

A drain pipe of the deck water seal shall not pass through machinery spaces.

Discharge pipes shall be laid directly overboard.

9.16.5.3 Provision shall be made to ensure that the water seal is protected against freezing in such a way that the integrity of seal is not impaired by overheating.

9.16.5.4 The deck water seal and all loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks.

9.16.5.5 The non-return valve (refer to 9.16.5.1) may be of non-return shut-off type or of non-return type with a shut-off valve being additionally fitted in the inert gas supply main forward of the non-return valve.

9.16.5.6 A water loop or other approved arrangement shall be fitted to each associated water supply and drain pipe and each venting or pressure-sensing pipe leading to gas safe spaces[6].

[6] Gas safe space is a space in which the entry of hydrocarbon gases would produce hazards with regard to flammability or toxicity.

Means shall be provided to prevent such loops from being emptied by vacuum

9.16.5.7 Provision shall be made in the deck water seal for sight holes and glases for monitoring the water level and making inspections.

9.16.5.8 Materials used in non-return devices shall be resistant to the effect of acids generated during cooling, cleaning and by gases coming through the pipes.

9.16.6 Pipes.

9.16.6.1 The inert gas main may be divided into two or more distributing pipes forward of the non-return devices required by **9.16.5.1**.

9.16.6.2 The distribution inert gas supply pipes shall be fitted with branch piping leading to each cargo tank. Branch piping for inert gas shall be fitted with either shut-off valves or equivalent means of control for isolating each tank.

Where shut-off valves are fitted, they shall be provided with locking arrangements to prevent the control of the valves by unauthorized persons.

The control system operated shall provide positive indication of the operational status of the shut-off valves.

Unambiguous information regarding the operational status of stop valves in branch piping leading from the inert gas main to cargo tanks means position indicators providing open/intermediate/closed status information in the control panel. Limit switches shall be used to positively indicate both open and closed position. Intermediate position status shall be indicated when the valve is in neither open nor closed position.

The operational status of IGS shall be based on indication that inert gas is being supplied downstream of the gas regulating valve and on the pressure or flow of the inert gas mains downstream of the non-return devices.

However, the operational status of the IG system shall not be considered to require additional indicators and alarms other than those specified in **9.16.7.2**.

9.16.6.3 In combination carriers the arrangement to isolate IGS from the slop tanks shall consist of blank flanges.

9.16.6.4 Pipe outlets discharging inert gas into the cargo tanks shall be located in the upper part.

9.16.6.5 A gas regulating valve shall be fitted in the inert gas supply main. It shall be capable of automatically regulating the flow of inert gas to the cargo tanks as referred to in **9.16.8.8** unless means are provided to automatically control the speed of the inert gas blowers.

9.16.6.6 If a connection is fitted between the inert gas supply main and the cargo system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference which may exist between the systems. It shall consist of two shut-off valves, the valve on the cargo main being of a non-return type, and an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks.

9.16.6.7 Piping systems shall be so laid as to prevent the accumulation of cargo or water in the pipelines under all normal conditions.

9.16.6.8 Suitable arrangements shall be provided for the safe venting of the section of the line between the valves referred to in **9.16.5.5** and **9.16.6.5** in case when the first of these valves is closed.

9.16.6.9 The diameter of the pipes shall be such as to ensure the gas flow rate in any section of the piping to be not more than 40 m/s.

9.16.6.10 The piping from the gas scrubber to the blowers and recirculation lines as well as drain pipe of gas scrubbing and cooling system shall be lined with corrosion-resistant coating.

9.16.6.11 An arrangement shall be provided to connect the inert gas main to the external supply of inert gas. The arrangement shall consist of a branch with a flange joint DN 250 mm fitted forward of the non-return valve specified in **9.16.6.5**.

Flange design shall comply with the requirements of **2.4.3**.

Since 01.01.2024[6]. «**9.16.6.11** An arrangement shall be provided to connect the inert gas main to the external supply of inert gas. The arrangement shall consist of a branch with a flange joint DN 250 mm fitted forward of the non-return valve specified in **9.16.6.5**, and shut-off valve, який установлюється на патрубкуfitted on the branch, to separate the inert gas main from the external supply of inert gas.

Flange design shall comply with the requirements of **2.4.3**.»

9.16.6.12 The inert gas supply main may be used for the venting of the cargo tanks.

[6] Refer to IMO MSC.457(101)

9.16.7 Instruments and alarms.

9.16.7.1 On the discharge side of gas blowers, instruments shall be provided for continuous indication of the inert gas temperature and pressure.

9.16.7.2 Instrumentation shall be fitted for continuously indicating and permanently recording, when the inert gas is being supplied:

.1 the pressure of the inert gas supply main forward of the non-return devices required by **9.16.5.1**;

.2 the oxygen content of the inert gas in the inert gas supply main on the discharge side of the gas blowers.

Since 01.01.2024[9]: «**.2** the oxygen content of the inert gas in the inert gas supply main».

These devices shall be placed in the cargo control room; but where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

9.16.7.3 In addition to the requirements of **9.16.7.2**, the following meters shall be fitted:

.1 in the navigation bridge to indicate at all times the pressure (refer to **9.16.7.2.1**) and the pressure in the slop tanks of combination carriers, wherever those tanks are isolated from the inert gas supply main;

.2 in the main machinery control room or in the machinery space to indicate the oxygen content (refer to **9.16.7.2.2**).

9.16.7.4 Suitable arrangements shall be provided on each cargo tank for measuring oxygen and hydrocarbon vapour concentration using portable instruments.

9.16.7.5 Suitable means shall be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments referred to in **9.16.7.2** and item **15** of Table 5.1.2, Part VI "Fire Protection".

9.16.7.6 Audible and visual alarms shall be provided to indicate:

.1 low water pressure or low water flow rate to the flue gas scrubber (except for the nitrogen generator systems, refer to **9.16.12**);

.2 high water level in the scrubber (except for the nitrogen generator systems, refer to **9.16.12**);

.3 increase of gas temperature, this alarm being operated when the temperatures referred to in **9.16.1.4** are reached;

.4 failure of inert gas blowers;

.5 oxygen content more than 14 % by volume in cargo holds;

.6 oxygen content in the inert gas main more than 5 % by volume;

.7 failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices referred to in **9.16.7.2**;

.8 low water level in the deck water seal referred to in **9.16.5.1**;

.9 gas pressure less than 1 kPa in the inert gas main. The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times;

.10 high gas pressure (when the pressure reaches 10 kPa);

.11 insufficient fuel feeding (if inert gas generators are available);

.12 failure of power supply to the generator (if inert gas generators are available);

.13 failure of power supply to automatic generator control system (if inert gas generators are available).

9.16.7.7 Indicating units of the alarms required in **9.16. 7.6.3**, **9.16. 7.6.4**, **9.16.7.6.6** and **9.16.7.9**, shall be placed in the machinery space and in the cargo control room, where provided, but in any case they shall be placed in a position where the alarm may be im-mediately received by responsible members of the crew.

9.16.7.8 Audible and visual alarms indicating the low water level in the water seal of half-dry and dry type shall operate on failure of the inert gas supply.

9.16.7.9 Additional audible alarms independent of the alarms required in **9.16.7.6.9** or automatic shut-down of the cargo pumps shall be provided to operate when the pressure in the main drops to 0,5 kPa.

9.16.8 Systems using flue gas of boilers (these requirements are additional to those of **9.16.1** to **9.16.7**).

9.16.8.1 The flue gas scrubber and blowers shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of category A.

The design and location of scrubber and blowers with relevant piping and valves shall prevent the gas leakages into enclosed spaces.

9.16.8.2 Suitable shut-off arrangements shall be provided on the suction and discharge connections of each blower.

Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge.

9.16.8.3 Shut-off valves shall be fitted in the inert gas supply mains between the boiler uptake and the flue gas scrubber. The valves shall be provided with an indicator to show whether they are open or shut.

Precautions shall be taken to maintain them gastight and keep the seatings clear of soot. Arrangements shall be provided to ensure that boiler soot blowers cannot be operated when the corresponding flue gas valve is open.

9.16.8.4 If the blowers shall be used for gas freeing, their air inlets shall be provided with blanking arrangements.

9.16.8.5 A shut-off valve (refer to **9.16.8.3**) shall be made of materials capable of withstanding the flue gas temperature and resistant to the corrosive action of the gas.

9.16.8.6 The piping between the shut-off valve and the scrubber shall be made of corrosionresistant steel.

9.16.8.7 An additional water seal or other effective means of preventing flue gas leakage shall be fitted between the shut-off valve (refer to **9.16.8.3**) and the scrubber.

9.16.8.8 The valve referred to in **9.16.6.5** shall be located at the forward bulkhead of the forwardmost gas safe space through which the inert gas supply main passes.

9.16.8.9 Automatic shutdown of the inert gas blowers and gas regulating valve shall be arranged on predetermined limits being reached in respect of **9.16.7.6.1**, **9.16.7.6.2** and **9.16.7.6.8**.

Automatic shut-down of the gas regulating valve shall also be arranged in case of blower failure.

9.16.9 Inert gas generator system (the requirements for this system stated below are additional to those given in **9.16.1** to **9.16.7**).

9.16.9.1 For inert gas generator (the machinery including blower, combustion chamber, scrubber, fuel oil pump, burner, automatic combustion control and supervisory equipment) use shall be made of fuel oil meeting the requirements of **1.1.2**, Part VII "Machinery Installations".

9.16.9.2 The generators shall be located in the space referring to machinery spaces of category A.

9.16.9.3 In ships in whose tanks toxic substances may be carried the gas generators shall not be located in the machinery spaces and shall be located in a compartment reserved solely for their use according to the requirements of **9.16.8.1**.

Such a compartment shall be separated from the machinery spaces at least by a gastight steel bulkhead, having no doors or other openings, and from the accommodation spaces and cargo area by open decks, cofferdams or similar spaces.

Adequate positive pressure type mechanical ventilation shall be provided for such a compartment. Access to such compartments shall be only from an open deck outside the cargo area. Access shall be provided on the end bulkhead of the superstructure or deckhouse, not facing the cargo area and/or on the outboard side of the superstructure or deckhouse at a distance of at least L/25, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area.

The inert gas supply main shall not be located in, or have any connection with systems located in machinery spaces, accommodation spaces and service spaces.

9.16.9.4 Despite the provisions of **9.16.3.4**, the Register may permit only one blower if it is capable of delivering to the protected cargo spaces the total volume of gas required by **9.16.2**, provided sufficient spares for the air blower and its prime mover are carried on board to enable any failure of the air blower and its prime mover to be rectified by the ship’s crew.

9.16.9.5 Two fuel oil pumps shall be fitted to the inert gas generator. The Register may permit only one fuel oil pump, provided sufficient spares for the fuel oil pump and its prime mover are carried on board to enable any failure of the pump and its prime mover to be rectified by the ship's crew.

9.16.9.6 Where more than one inert gas generator is provided, suitable shut-off arrangements shall be fitted on the discharge outlet of each generator plant.

9.16.9.7 Arrangements shall be made to vent the inert gas to the atmosphere during starting-up or in case of equipment failure.

9.16.9.8 Where the inert gas generator is served by positive displacement blowers, a pressure relief device shall be provided to prevent excess pressure being developed on the discharge side of the blower.

9.16.9.9 Audible and visual alarms shall be provided to indicate:

.1 insufficient fuel oil supply;

.2 failure of power supply to the generator;

.3 failure of power supply to the automatic control system for the generator.

9.16.9.10 The gas regulating valve shall be automatically controlled to close and to interrupt the fuel oil supply to the generator on predetermined limits being reached in respect of **9.16.7.6.1** and **9.16.7.6.2**.

Automatic shut-down of the gas regulating shall also be arranged in respect of **9.16.9.9.2**.

9.16.10 Inertization of oil tankers double hull spaces.

9.16.10.1 On tankers, where IGS is provided, inertization of space in double hull may be accomplished through detachable branch pipes connected with IGS of cargo tanks or via stationary pipelines. If detachable branch pipes are used, connection arrangements on the system main shall be provided.

9.16.10.2 If stationary pipelines are used, measures shall be provided to mitigate inert gases return from the protected space into IGS like two non-return devices compliant to **9.16.5**.

It is recommended that a separate deck gate and shut-off valve shall be provided.

9.16.10.3 Inert gas by-pass is prohibited from cargo tanks into other protected spaces including ballast tanks and back.

9.16.10.4 Measures shall be provided to avoid the ingress of water into IGS pipes from ballast tanks in case of their overfilling.

9.16.10.5 At the inert gas supply piping to a ballast tank or another protected space an isolation stop valve shall be provided.

9.16.10.6 Special measures shall be taken to prevent overpressure or vacuum in ballast tanks both as a result of the system of inert gas, and as a result of the ballast pump.

9.16.10.7 If IGS is an alternative for a fixed hydrocarbon gas detection system as required in **9.14.6.4**, then IGS shall be permanently operated.

Its capacity shall be not less than 125 % of the maximum total supply of cargo and ballast pumps if in compliance with the ship procedures simultaneous ballast and cargo discharging is provided. In case combination of such operations is not provided, IGS capacity shall be at least 125 % of the maximum total supply.

If an individual IGS is provided for ballast tanks onboard, its capacity shall be at least 125 % of the maximum consumption during ballast discharging. In the event of failure of the onboard system portable concentration measurement devices in protected spaces.

All ballast tanks and void spaces of double hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under the bulkhead deck adjacent to cargo tanks, except cargo pump-rooms and ballast pump-rooms, shall be fitted with suitable connections for the supply of inert gas.

9.16.11 System for producing pad in cargo tanks.

9.16.11.1 To produce pad in cargo tanks, use may be made of the system with the inert gas supplied from cylinders, as well as the system using inert gas generators and nitrogen generators, if their capacity is less tan that specified in **9.16.2.1**.

The quantity of gas in the cylinders shall be sufficient for producing pad in cargo tanks, inerting, where necessary, of spaces adjacent to cargo tanks and for replacing the inert gas loss during voyage.

9.16.11.2 The inert gas shall be stored in special cylinders or pressure vessels complying with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

The pressure vessels may be installed on the open deck or in a special space complying with the requirements of **3.1.3.2**, Part VI "Fire Protection", located aft of the collision bulkhead and provided with ventilation complying with the requirements of **12.9**.

9.16.11.3 Pipelines from pressure vessels and from each group of cylinders shall be fitted with reducing valves downstream of which safety valves shall be provided. Besides, two non-return valves placed in tandem shall be provided.

Otherwise, all connections of the system to protected spaces and pipelines shall be provided with detachable components.

Shut-off valves shall be provided upstream and downstream of these components.

9.16.11.4 Cargo tanks and the spaces to be inertized (specified in **9.16.10.1**) shall be equipped with devices for measuring pressure and gas atmosphere.

9.16.12 Nitrogen generator system.

9.16.12.1 The present requirements cover the system in which the inert gas (nitrogen) originates at separation of compressed air to the basic gases while passing through the nitrogen generator (group of empty fibres of semipermeable membranes or through adsorbent placed in hermetic casing).

In addition to the requirements of the present paragraph, the system shall also comply with requirements of **9.16.2.1**, **9.16.4**, **9.16.6.1** – **9.16.6.3**, **9.16. 6.12** (applicable to **9.16.12.8**), **9.16.7.4**, **9.16.7.5**, **9.16.7.9** (applicable to **9.16.12.14.7**) and **9.16.8.8** (applicable to **9.16.12.8**).

9.16.12.2 Air compressor and nitrogen generator shall be placed in the engine room or in a separate room which is then referred to other engine rooms (refer to **2.4.2**, Part VI "Fire Protection").

It shall be located outside the cargo area and it shall have no direct access to the accommodation, service spaces and control stations.

9.16.12.3 The system shall produce inert gas with at least 95 % content of nitrogen and no more than 5 % of oxygen. The system shall be fitted with an automatic device which would enable emission of gas into the air while preparation of the system for the specification level and even during its faults.

9.16.12.4 The system shall have two air compressors of equal capacity. The system may have one compressor provided there are enough spare parts for it aboard to repair by the crew.

9.16.12.5 Equipment for processing of air ingoing into generator (air cooler, air heater, separator, filters) shall clean it from moisture, particles and oil and maintain specification temperature.

9.16.12.6 The nitrogen receiver may be installed in the cargo area. The room where it is installed shall have exit to the open deck, the door is to open outwards.

9.16.12.7 The oxygen-enriched air from the nitrogen generator is to extend outside rooms to the safe locations on the open deck outside of hazardous area, situated not within 3 m of areas traversed by personnel and not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets.

The nitrogen-product enriched gas from the protective devices of the nitrogen receiver is to extend outside rooms to the safe locations on the open deck, situated not within 3 m of areas traversed by personnel and not within 6m of air intakes for machinery (engines and boilers) and all ventilation inlets/outlets.

9.16.12.8 On the outlet from the nitrogen generator there shall be installed devices which maintain permanent pressure of the inert gas.

9.16.12.9 A shut-off valve shall be installed between the nitrogen generator and receiver.

9.16.12.10 At least two non-return shut-off devices shall be fitted in IGS. One of them shall have double blocking and blowoff arrangement, another - the local locking device.

They shall be installed on the main in the cargo area before branch pipes specified in **9.16.6.2**.

9.16.12.11 There shall be mounted instruments for the permanent temperature and pressure indication: on the compressor delivery side; on the intake side of the nitrogen generator.

9.16.12.12 There shall be mounted instruments for the permanent indication and registration during system operation:

.1 oxygen content in the inert gas at the output of nitrogen generator;

.2 pressure in the main before the retaning sealing valves required by **9.16.12.10**.

9.16.12.13 Instruments specified in **9.16.12.12** shall be fitted in the cargo control room, if any. If there is no cargo control room onboard the instruments shall be fitted in such a place where alarm may be received by the responsible crew members.

9.16.12.14 Audible and visual alarm shall be provided to indicate:

.1 low air pressure in the compressor specified in **9.16.12.11**;

.2 high air temperature specified in **9.16.12.11**;

.3 high level of water in the separator specified in **9.16.12.5**;

.4 breakdown of electrical heater (if fitted) specified in **9.16.12.5**;

.5 high oxygen content specified in **9.16.12.3** and **9.16.12.12**;

.6 stop of energy supply of instruments specified in **9.16.12.12**;

.7 drop of gas pressure referred to in **9.16.12.12**;

.8 increase of gas pressure referred to in **9.16.12.12**.

9.16.12.15 Automatic stop of compressor shall take place if alarm turns on as specified in 9.16.12.14.1 – 9.16.12.14.5 and 9.16.12.14.8. Automatic compressor protection shall comply with the requirements of 4.5, Part XV "Automation".

For the purposes of this paragraph, an independent audible alarm means that a second pressure sensor should be provided, independent of the low pressure, high pressure and pressure sensors / pressure recorder. However, a common software and logic control unit may be used in the control system to provide an audible alarm. An independent sensor is not required for a system designed to stop cargo pumps. If a system for stopping cargo pumps is fitted, an automatic stopping system for all cargo pumps shall be provided. The audible stop signal shall be heard in the control station. The stop shall not interfere with the operation of the ballast or bilge pumps in the cargo pump room.

9.16.12.16 Automatic locking of arrangements specified in **9.16.12.8** shall take place if power is disconnected from the compressor.

9.16.12.17 Alarm required by **9.16.12.14** shall be installed in the engine room and cargo control room if such post is provided but in any case in such a room where alarm may be immediately received by the responsible crew member.

9.17 SYSTEMS OF TANKERS AND COMBINATION CARRIERS TO ENSURE LONG-TERM OPERATION AT LOW TEMPERATURE

9.17.1 Cargo system of ships with distinguishing mark WINTERIZATION(DAT).

9.17.1.1 Where submerged electrically-driven ballast pumps are used, their serviceability at design ambient temperature shall be ensured and documented and the relevant information shall be introduced into the certificates issued by the Register.

9.17.1.2 Hydraulic liquids used as working media for ballast pumps driving and remotely controlled fittings shall be suitable for use at design ambient temperature.

9.17.1.3 The Register certificates issued for cargo hoses of oil and chemical tankers shall contain an indication whether it is allowed to use them at design ambient temperature.

9.17.2 Bow loading system of ships with distinguishing mark WINTERIZATION(DAT).

9.17.2.1 Materials of components of the bow loading system shall meet the requirements to materials for ships with distinguishing mark **WINTERIZATION(DAT)**.

9.17.2.2 Hydraulic liquids and lubricating oils shall be suitable for use at design ambient temperature.

9.17.2.3 The Register certificates issued for bow loading system to be installed onboard the ships with distinguishing marks **WINTERIZATION(-40)** and **WINTERIZATION(-50)**, shall contain an indication whether it is allowed to use it at appropriate design ambient temperature.

9.17.3 Inert gas system of ships with distinguishing mark WINTERIZATION(DAT).

9.17.3.1 Sea water supply pipeline for deck water seal, a gas scrubber and other equipment of inert gas system shall be fitted with heating.

10. AIR, OVERFLOW AND SOUNDING PIPING

10.1 AIR PIPES

10.1.1 Each tank intended for the storage of liquid and each filled cofferdam, as well as the ice boxes and sea chests, shall have air pipes.

The air pipes of ice boxes and sea chests shall have shut-off valves fitted directly on the them.

Air pipes of double-bottom tanks and of tanks adjoining the shell plating, as well as the air pipes of ice boxes and sea chests, shall be carried to above the bulkhead deck.

10.1.2 The air pipes shall be fitted at the highest part of the tank and, as a rule, at a place that is at maximum distance from the filling pipe.

The number and arrangement of the pipes shall be selected depending on the shape and size of the tank, and shall also preclude the formation of air pockets.

If the air pipes of fuel tanks are used as overflow (air/overflow) pipes, the requirements of **10.2.4** shall be complied with.

10.1.3 The tanks extending from side to side of the ship shall be fitted with air pipes at either side.

The air pipes shall not be used as filling pipes, except when the tank is fitted with more than one air pipe.

The air pipes of tanks carrying liquids of different kinds are not permitted to be laid into a common line.

10.1.4 The height of the air pipes laid to the open deck measured from the deck to the point where water may have access below shall not be less than:

760 mm on the freeboard deck;

450 mm on superstructure decks.

Where such a height is an obstacle to operations on board a smaller height may be approved, provided the availability of closing arrangements or other circumstances make this substitution reasonable.

Besides, in ships of restricted areas of navigation **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN, A-R2, A-R2-S**, **A-R2-RS, B-R3-S, B-R3-RS C-R3-S, C-R3-RS**, **D-R3-S**, **D-R3-RS** the above pipe heights may be reduced. However, they shall not be less than 600 and 380 mm, accordingly.

Minimum wall thicknesses of the air pipes above deck shall be:

6 mm for $d \leq 80$ mm,

8,5 mm for $d \geq 165$ mm.

Intermediate sizes shall be determined by linear interpolation.

Air pipes shall be located in protected places, to exclude their damage during cargo operations.

10.1.5 The upper end of each air pipe shall be made as a bend, with its opening facing downwards or shall have another construction agreed upon with the Register.

10.1.6 The open ends of air pipes of fuel oil and lubricating oil tanks shall be laid to positions on the open deck where the vapours issuing from the mentioned tanks cannot incur a fire hazard.

Location and arrangement of air pipes for fuel oil service, settling and lubricating oil tanks shall be such that in the event of a broken air pipe this will not directly lead to the risk of ingress of sea water splashes or rainwater.

On oil tankers and combination carriers the open ends of air pipes of these tanks shall be in compliance with the requirements of **9.10.4**.

The air pipes of fuel oil tanks with heating arrangements shall meet the requirements of **13.3.5**.

10.1.7 The air pipes of independent lubricating oil storage tanks, may terminate in spaces where the tanks are installed if precautions are taken that will preclude spillage of oil onto electrical equipment or heated surfaces in case the tank is overflowing.

10.1.8 The outlets of air pipes situated on the open freeboard deck and superstructure deck of the first tier (refer to **1.2.5**, Part III "Equipment, Arrangements and Outfit"), as well as the outlets of the air pipes on the decks of higher tiers within the area limited by the angle of flooding (refer to **1.2**, Part IV "Stability") shall have permanently attached self-closing covers preventing the sea water from getting into the tanks, but allowing a free access of air and liquids.

Closing devices shall meet the requirements of **4.4**.

10.1.9 The total cross-sectional area of the air pipes in tank filled by gravity shall not be less than the total sectional area of the filling pipes of these tanks.

10.1.10 The total cross-sectional area of the air pipes of a tank filled by the ship's pumps or shore pumps, shall not be less than 1,25 times the cross-sectional area of the filling pipe of that tank.

The cross-sectional area of a common air pipe from several tanks shall be at least 1,25 times the area of the common filling pipeline of these tanks, the requirements of **10.2.3** being complied with.

10.1.11 Where a tank filled by shipboard pumps or from shore pumps is fitted with an overflow pipe, the total cross-sectional area of the air pipes of the tank shall not be less than one-third of the filling pipe area.

Where the air pipes from several tanks fitted with overflow pipes are combined, the cross-sectional area of the common air pipe shall be at least one-third of the area of the common filling pipe of these tanks, the requirements of **10.2.3** being complied with.

10.1.12 The air pipe nominal diameter shall be in any case at least 50 mm.

This requirement does not apply to the air pipes indicated in **10.1.9**.

10.1.13 The arrangement of the air pipes shall preclude the formation of hydraulic seals in the pipes.

10.1.14 The air pipes of fuel oil and lubricating oil tanks in way of accommodation and refrigerated cargo spaces shall not have detachable connections.

10.1.15 Nameplates shall be affixed to the upper ends of all air pipes.

10.1.16 The air pipes from crankcases of internal combustion engines shall comply with the requirements of **2.3.4**, Part IX "Machinery" and **11.1.9** of the present Part.

10.1.17 The air pipes from ballast compartments of floating docks shall be laid to a height not less than 300 mm above the margin line.

It is permitted to lay air pipes through the plating of wing walls.

Other requirements of the present Chapter are not applicable to the air pipes of the ballast compartments in floating docks.

10.1.18 In passenger ships the open ends of air pipes terminating in the superstructure, shall be located at a height of 1 m above the waterline of the ship inclined up to 15° or the maximum angle of heel determined by calculations during intermediate flooding, whichever is the greater.

As an alternative to this air pipes of tanks, other than fuel oil and lubricating oil tanks, may be laid through the superstructure side.

10.1.19 The open ends of the cargo tanks air pipes of oil recovery ships shall be laid to positions on the open deck where the issuing vapours cannot incur a fire hazard and shall be protected with flame-arresting fittings.

The clear area through the fitting shall not be less than open flow area of the air pipe.

10.1.20 Test tank air pipes of cargo heating system condensate shall meet the requirements of **9.6.3**.

10.1.21 Upper ends of air pipes in in expansion tanks within the ethylene glycol water solution systems shall be arranged to discharge to the open deck.

10.2 OVERFLOW PIPES

10.2.1 Fuel oil tanks shall be provided with overflow pipes directing fuel to an overflow tank or storage tank, the capacity of which shall be increased by a value not less than the overflow tank capacity as stipulated by **10.3.1**, and which shall be equipped in accordance with **10.3.2**.

No overflow pipes may be fitted where the fuel oil system is so designed that no spilling overboard can occur during the loading and transfer of fuel.

Besides fuel oil tanks, the overflow pipes shall be fitted on lubricating oil tanks specified in **14.4.4** and **20.4.3**.

10.2.2 The cross-sectional area of overflow pipes shall not be less than 1,25 of the filling pipe area.

The cross-sectional area of the common overflow pipe of several tanks shall not be less than 1,25 of common filling pipe area.

10.2.3 Where the overflow pipes from several integrated tanks located in different watertight compartments are laid to a common header or pipe, this header or pipe shall be located above the deepest damage waterline in ships having a subdivision mark in the class notation and above the deepest load waterline in other ship.

10.2.4 Where air pipes are simultaneously used as overflow pipes, they shall not be connected to the air pipes of overflow tanks. In this case, the overflow pipes or a common overflow pipe shall be connected directly to the tank.

10.2.5 Where a tank is used alternatively for the carriage of fuel oil, water ballast or liquid and dry cargoes, then in the case of a common overflow system the overflow pipes shall be so arranged as to preclude the possibility of liquid flowing from one tank into another and liquid cargo vapours entering tanks containing dry cargo.

In such cases, subject to the Register approval the overflow pipes may be fitted with shut-off valves, provided such pipes are not used as air pipes.

10.2.6 The overflow pipes of daily tanks and of fuel oil and lubricating oil settling tanks shall be laid to overflow tanks located below the tanks mentioned above.

10.2.7 A sight glass shall be fitted on vertical overflow pipes at a readily visible and accessible location, or an alarm device shall be provided to give warning when the predetermined level is reached in the overflow tank (refer also to **10.3.2**).

10.2.8 Minimum overflow pipe bore shall be 50 mm.

10.2.9 Overflow pipes shall be extended up to the bottom of the overflow tanks with a minimal clearance.

The flow area in the clearance shall not be less than the sectional area of the overflow pipe.

10.3 OVERFLOW TANKS

10.3.1 The capacity of an overflow fuel tank shall not be less than the maximum capacity of the fuelling and fuel transfer system within 10 min.

10.3.2 An overflow tank shall be provided with audible and visual alarms operating whenever the tank filling reaches 75 %.

10.4 SOUNDING ARRANGEMENTS

10.4.1 Each tank intended for the storage of liquid, cofferdams and void spaces with bilge connections, as well as bilges and bilge wells in spaces, which are not accessible at all times, shall be provided with sounding pipes for level management generally extended to the open decks.

In tanks, other sounding arrangements may be used, which design is approved by the Register.

Sounding pipes of independent tanks are not required to be laid to the open deck.

Upper ends of the sounding pipes of the fuel oil and lubricating oil tanks shall not be laid to the spaces which may present the risk of ignition of leakage from the sounding pipes.

Laying of the sounding pipes of the fuel tanks to accommodation and service spaces is prohibited.

10.4.2 Other oil-level gauges may be used instead of the sounding pipes, provided that they meet the following requirements:

.1 in passenger ships the installation of such means shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel;

.2 in cargo ships the failure or overfilling of the above measuring instruments shall not permit release of fuel. The level indicators may be used with flat glass and self-closing cocks fitted between the level indicators and the fuel tanks.

When the upper part of the indicator is connected to the top of the tank, the upper self-closing valve may be not installed.

The use of glass pipes in the level indicators is not permitted.

10.4.3 Where the double bottom forms bilges at the wings, or the ship has a flat bottom, the sounding pipes shall be installed at each side.

These pipes shall be laid to positions above the bulkhead deck, which are at all times accessible for taking soundings.

The sounding pipes shall be as straight as practicable and shall not interfere with taking soundings with a sounding rod.

10.4.4 As a rule, the sounding pipes of fuel and oil tanks shall not terminate in machinery spaces.

Where this requirement is impracticable, termination of sounding pipes in machinery spaces may be permitted on condition the following requirements are met:

.1 in passenger ships, such pipes shall not require penetration below the top of the tank and their failure or overfilling of the tanks shall not permit release of fuel;

.2 in cargo ships, the failure of such pipes or overfilling of the tank shall not permit release of fuel;

.3 the sounding pipes shall terminate in locations remote from ignition hazards or they shall be screened;

.4 terminations of sounding pipes shall be fitted with self-closing blanking devices and with a smalldiameter self-closing control cock located below them;

.5 structural measures shall be taken to prevent the spillage of fuel or oil on heated surfaces from the blanking device;

.6 the pipes shall terminate at least 0,5 m above the plating.

10.4.5 The sounding pipes of the double-bottom water storage tanks are permitted to be laid into spaces below the bulkhead deck that are located above them and are accessible at all times. Such pipes shall not be used as air pipes and shall be fitted with self-closing cocks.

10.4.6 Provision shall be made under the open ends of the sounding pipes for welded striking plates or other strengthening to protect the bottom plating from damaging by a sounding rod. In case of slotted sounding pipes with closed ends, adequately strong closing plugs shall be provided.

10.4.7 The internal diameter of the sounding pipes shall be at least 32 mm and for ships of the restricted area of navigation **R3-S**, **R3-RS**, **R3**, **R3-IN, C-R3-S, C-R3-RS**, **D-R3-S, D-R3-RS** it shall not be less than 25 mm. Sounding pipes, which pass through refrigerated cargo spaces, in which the temperature may be reduced to 0°C and below, as well as sounding pipes of oil storage tanks in oil recovery ships shall have a internal diameter of not less than 50 mm.

10.4.8 Nameplates shall be affixed to the upper ends of the sounding pipes.

10.4.9 The ends of the sounding pipes laid to the exposed decks shall be fitted with tight plugs complying with the requirements of **2.1.8**.

If the sounding pipes project above the open deck, they shall be located at such positions where they cannot be damaged, otherwise they shall have appropriate guards.

10.4.10 In floating docks the sounding pipes of ballast compartments shall be laid to the top deck of the side walls.

11. EXHAUST GAS SYSTEM

11.1 EXHAUST GAS PIPING

11.1.1 The exhaust gas pipes shall, as a rule, be laid to the open decks.

11.1.2 Where the exhaust gas pipes are laid through the shell plating in the vicinity of load waterline or below it, provision shall be made for arrangements precluding the possibility of sea water entering the engine.

11.1.3 In oil tankers, oil recovery tankers, supply vessels, ships adapted for the carriage of explosive and fire hazardous cargoes and on ships servicing or towing the above-mentioned ships, the uptakes of boilers, exhaust pipes of main and auxiliary engines, incinerators shall be fitted with spark arresters of the construction approved by the Register.

11.1.4 The exhaust gas pipes shall be laid at a distance not less than 450 mm from the fuel oil tanks.

11.1.5 Each main engine shall have an individual exhaust gas pipe. Where three or more auxiliary engines are fitted, their exhaust gas pipes may be connected to a common exhaust line provided that the engine with the greatest output has an autonomous exhaust pipe.

Besides, the common exhaust line shall be fitted with reliable devices which will preclude:

gases of the common line entering the pipes of the engines not actually at work;

damage of any of the engines when started.

In ships of restricted areas of navigation **R2**, **R2-SN**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN, A-R2**, **A-R2-S**, **A-R2-RS**, **B-R3-S, B-R3-RS**, **C-R3-S**, **C-R3-RS**, **D-R3-S**, **D-R3-RS** the exhaust gas pipes of the main and auxiliary engines may be permitted to connect to a common exhaust line, provided the foregoing precautions are taken. The exhaust gas pipes from DF-engines shall comply with the requirements of **9.7**, Part IX "Machinery".

11.1.6 The waste boilers and the composite waste heat/oil fired boilers, which by reason of structural features cannot be left without water while heated by exhaust gases, as well as the boilers mentioned in **3.2.16**, Part X "Boilers, Heat Exchangers and Pressure Vessels" shall be provided with a by-pass line and dampers disconnecting the boilers from exhaust gas supply, when necessary.

11.1.7 The uptakes of boilers incinerators and the exhaust gas pipes of internal combustion engines shall be thermally insulated by means of suitable insulating material, double walls or screens.

Where an insulating material is used for thermal insulation, the requirements of **2.1.1.5**, Part VI "Fire Protection" shall be taken into consideration.

Double walls or screens are not required only in such positions where the possibility of their coming into contact with fuel or lubricating oil leaks is precluded.

11.1.8 When the uptakes of main and auxiliary boilers are arranged to discharge into a common uptake, dampers are permitted, provided they have arrangements to be locked open.

When required, manholes and vertical ladders shall be provided for inspection and cleaning of the uptakes and air ducts of boilers.

11.1.9 In oil recovery ships, the outlets of exhaust gas piping of main and auxiliary engines, uptakes of boilers, incinerators and other equipment containing sources of ignition as well as air pipe vent openings of crankcases in internal combustion engines shall be located at least 6 m above the deepest waterline, but in any case outside the hazardous zones as defined in **19.2.3**, Part XI "Electrical Equipment".

11.1.10 The exhaust gas piping of main and auxiliary internal combustion engines shall be fitted with non-disconnectable draining devices to prevent the entry of water into the engine.

The devices shall be readily accesible for maintenance and clearing and shall have a drain pipe bore not less than 25 mm.

11.1.11 The exhaust gas pipes of engines shall be fitted with thermal compensators.

The exhaust gas piping shall have, handholes and, when necessary, drain cocks.

11.1.12 Where waste heat boilers are available on board, structural arrangements shall be provided to prevent the ingress of water into the exhaust gas duct of the internal combustion engines during washing.

The draining pipes for the cleaning water shall be laid to the machinery space bilges and be provided with hydraulic seals.

11.2 SILENCERS AND SPARK ARRESTERS

11.2.1 The silencers and spark arresters shall be so arranged as to permit cleaning and shall be fitted with appropriate handholes or drain cocks.

11.2.2 Where spark arresters of the wet type are used, the requirements of **11.1.12** shall be met.

11.3 SYSTEMS FOR REDUCING NO_X EMISSIONS

11.3.1 The present requirements shall apply when Selective Catalyst Reduction (SCR) is used on board. SCR requires the use of a redundant which may be a urea/water solution, acquerous ammonia or even ahydrous ammonia.

The efficiency in the plant operation shall be measured along with the engines as part of the ship's propulsion plant.

11.3.2 Where urea based ammonia (e.g. 40 %/60 % urea/water solution) is introduced as a reductant, the following requirements shall be complied with:

.1 where aqueous urea solution based ammonia is introduced, the storage tank shall be arranged so that any leakage will be contained and prevented from making contact with heated surfaces.

All pipes or other tank penetrations shall be provided with manual closing valves attached immediately to the tank;

.2 storage tank may be located both on exposed deck areas and in closed spaces including the engine room;

.3 to ensure that the contents of the aqueous urea tank are maintained to avoid any impairment of the urea solution during storage, the storage tank shall be protected from excessively high or low temperatures considering concentration of the solution.

Heating and/or cooling systems shall be fitted, if necessary;

.4 if a urea storage tank is installed in a closed compartment, the area shall be served by an independent mechanical exhaust ventilation system providing at least 6 air changes per hour.

The ventilation system shall be maintained in operation continuously and capable of being controlled from outside the compartment. A warning notice requiring the use of such ventilation before entering the compartment shall be provided outside the compartment adjacent to each point of entry;

.5 each urea storage tank shall be provided with temperature and level monitoring arrangements.

High and low level alarms together with high and low temperature alarms shall also be provided;

.6 where urea based ammonia solution is stored in integral tanks, the following shall be considered during the design and construction:

.6.1 these tanks may be designed and constructed as integral part of the hull (e.g. double bottom, wing tank);

.6.2 these tanks shall be coated with appropriate anti-corrosion coating and shall not be located in closed proximity of fuel oil or fresh water tanks;

.6.3 these tanks shall be designed and constructed in compliance with the structural requirements applicable to hull and primary support members for a deep tank construction;

.6.4 these tanks shall be fitted with level detectors, temperature detectors, high temperature alarm, low level alarm, etc.

.6.5 these tanks shall be included in the ship's stability calculation;

.7 reductant piping and venting systems shall be independent of other ship service piping.

Reductant piping systems shall not be located in accommodation, service spaces, or control stations.

The vent pipes of the storage tank shall terminate in a safe location on the weather deck and the tank venting system shall be arranged to prevent entrance of water into the urea tank;

.8 reductant storage tanks and piping systems that may come in contact with the reductant solution shall be made of a non-combustible material recognized as suitable for use;

.9 for the protection of crew members, the ship shall have on board suitable personnel protective equipment.

Eyewash shall be provided, the location and number of eyewash stations shall be derived from the detailed installation arrangements;

.10 urea storage tanks shall be arranged so that they can be emptied of urea and vented by means of portable or permanent systems.

11.3.3 Reductants using aqueous ammonia (28 % or less concentration of ammonia).

11.3.3.1 Aqueous ammonia shall not be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant.

Where an application is made to use aqueous ammonia as the reductant then the arrangements for its loading, carriage and use shall be derived from a risk based analysis.

11.3.4 Reductants using anhydrous ammonia (99,5 % or greater concentration of ammonia by weight).

11.3.4.1 Anhydrous ammonia shall not be used as a reductant in a SCR except where it can be demonstrated that it is not practicable to use a urea based reductant and where the Flag State MA agrees to its use.

Where it is not practicable to use a urea reductant then it is also to be demonstrated that it is not practicable to use aqueous ammonia.

Where an application is made to use anhydrous ammonia as the reductant then the arrangements for its loading, carriage and use shall be derived from a risk based analysis.

12. VENTILATION SYSTEM

12.1 GENERAL REQUIREMENTS FOR VENTILATION SYSTEMS

12.1.1 Generally, ventilation ducts shall not be laid through watertight bulkheads below the bulkhead deck.

Where it is not practicable to avoid laying ventilation ducts through watertight bulkheads below the bulkhead deck, means of closure shall be provided at the penetrations ensuring watertightness and strength equal to that of local ship's structures and operated from a position above the bulkhead deck.

Where ventilation ducts are laid through more than one watertight bulkhead, the means of closure of such openings shall be operated by power and be capable of being closed from the main machinery control room situated above the bulkhead deck.

The design of closures shall be such as to ensure strength equivalent to the strength of ship's structures in places where these closures are installed.

12.1.2 Where trunkways and vertical ducts of the ventilation system pass through watertight decks, they shall be watertight and equivalent in strength to adjacent hull structures within a single watertight compartment below the bulkhead deck.

12.1.3 Ventilation ducts shall be adequately protected against corrosion or constructed of corrosion-resistant materials.

12.1.4 Ventilation ducts for removal of explosion and fire-dangerous vapours and gases shall be gastight and shall not communicate with the ducts of other spaces.

12.1.5 Ventilation ducts laid to cargo spaces, machinery spaces and other spaces fitted with smothering facilities shall have closures complying with **3.1.2.3**, Part VI "Fire Protection".

12.1.6 In places of possible sweating the ventilation ducts shall be properly insulated. Drain plugs shall be provided for the portions of ducts where water is likely to accumulate.

12.1.7 The inlets and outlets of the ventilation systems shall be provided with closing appliances fitted with drives for closing them from positions outside these spaces. The closures shall be watertight in a closed position and the means of closing shall be easily accessible as well as prominently and permanently marked and shall indicate whether the shutoff is open or closed. The ventilator heads of supply ducts and the air inlets of ventilation systems shall be so located that the risk of drawing in air contaminated by gas, oil vapours, etc., is minimized, and admission of sea water (including water splashing) into the ventilation ducts is precluded.

In icebreakers and ice class ships with ice strengthening precautions shall be taken to prevent admission of snow into the ventilation ducts. It is recommended to arrange the air intakes on both sides of the ship and to provide for heating arrangements.

12.1.8 The ventilator coamings shall have a height in accordance with **7.8**, Part III "Equipment, Arrangements and Outfit".

12.1.9 The arrangement of ventilator heads in cargo spaces, special category spaces, open and closed spaces of ro-ro ships shall comply with the requirements of **2.1.4.7**, Part VI "Fire Protection".

12.1.10 Access routes to the controls for closure of the ventilation system, mentioned in **12.1.5** shall permit a rapid shutdown without regard to weather and sea conditions. For this routes:

.1 are clearly marked and at least 600 mm clear width;

.2 are provided with a single handrail or wire rope lifeline not less than 10 mm in diameter, supported by stanchions not more than 10 m apart in way of any route which involves traversing a deck exposed to weather; and

.3 are fitted with appropriate means of access (such as ladders or steps) to the closing devices of ventilators located in high positions (i.e. 1,8 m and above).

Alternatively, remote closing and position indicator arrangements from the bridge or a fire control station for those ventilator closures are acceptable.

12.1.11 Ventilation ducts, including single and double wall ducts, shall be of steel or equivalent material except flexible elements of short length not exceeding 600 mm used for connecting fans to the ducting in air-conditioning rooms. Unless expressly provided otherwise in **12.1.21**, 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:

.1 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. Calorific value is calculated according to the recommendations of ДСТУ Б EN ISO 1716:2011 «Reaction to fire tests for products - Determination of the gross heat of combustion (calorific value)» or the relevant international standard EN or ISO;

.2 the ducts are only used at the end of the ventilation device; and

.3 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 (refer to **2.1.2**, Part VI «Fire Protection»);

.4 flexible components of combustible material with length not exceeding 600 mm may be used for connection of fans to the ducting in air conditioning room.

12.1.12 Ducts passing through "A" class divisions shall meet the following requirements:

.1 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 a bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated;

.2 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; and;

.3 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 **12.1.21** and insulted to "A-60" class standard.

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.

12.1.13 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 bulkheads unless the duct is of steel for this length.

12.1.14 Where ventilation ducts of accommodation and service spaces or control stations pass through machinery spaces of category A, galleys, cargo spaces of ro-ro ships, vehicle spaces or special category spaces, as well as if ventilation ducts of machinery spaces of category A, galleys, cargo spaces of ro-ro ships, vehicle spaces or special category spaces pass through accommodation and service spaces or control stations, such ducts shall meet the requirements of **12.1.15** or **12.1.16**.

12.1.15 According to **12.1.14** ducts shall be:

.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 0,45 m^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-60" class standard from the boundaries of the spaces they serve to a point at least 5 m beyond each fire damper.

12.1.16 According to **12.1.14** ducts as alternative to **12.1.15** shall be:

.1 constructed of steel in accordance with **12.1.15.1** and **12.1.15.2**;

.2 insulated to "A-60" class standard throughout the spaces (refer to **12.1.14**) they pass, except for ducts that pass through spaces of category **(9)** or **(10)** as specified in **2.2.1.3**, Part VI "Fire Protection".

12.1.17 When the ventilation duct specified in **12.1.16.2** or **12.1.15.4** is contiguous to accommodation or service spaces, fire insulation of the duct shall comply with Figs. 12.1.17-1 – 12.1.17-4.

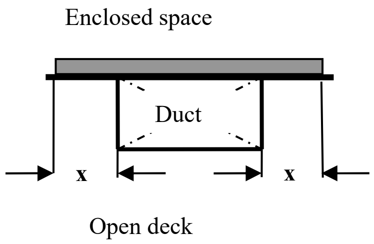

Fig.12.1.17-1

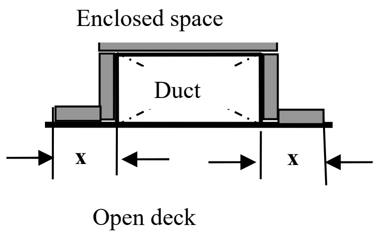

Fig.12.1.17-2

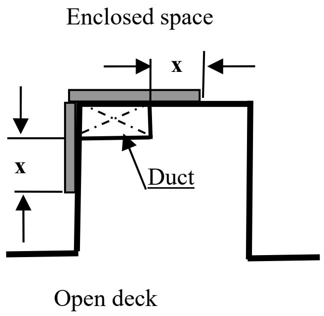

Fig.12.1.17-3

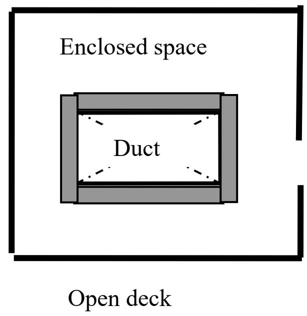

Fig.12.1.17-4

where:
- Fire insulation
X = 450 mm

12.1.18 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. 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.

12.1.19 The following arrangements shall be tested in accordance with the FTP Code (refer to **1.2** Part VI «Fire Protection»):

.1 fire dampers, except for specified in **12.2.4** and **12.3.6**;

.2 duct penetrations through "A" class divisions.

However, the test is not required where steel sleeves are directly joined to ventilation ducts by means of riveted or screwed connections or by welding.

12.1.20 Fire dampers fitted on the ventilation ducts from galley ranges in compliance with **12.2.5** and **12.3.6** do not need to pass the test according to the FTP Code, but shall be of steel and capable of stopping the draught, if necessary.

The requirements to "A" class division s apply only to the part of the duct outside the galley.

12.1.21 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.

12.1.22 Ventilation system of ships with distinguishing mark WINTERIZATION(DAT).

12.1.22.1 In addition to the requirements of this Section the ventilation system of ships with distinguishing mark **WINTERIZATION(DAT)** shall meet the requirements of **10.4,** Part III «Equipment, Arrangements and Outfit».

12.2 VENTILATION SYSTEMS OF CARGO SHIPS OF 500 GROSS TONNAGE AND UPWARDS, OIL TANKERS AND COMBINATION CARRIERS CARRYING PETROLEUM PRODUCTS WITH FLASH POINT 60°C AND MORE, PASSENGER SHIPS CARRYING NO MORE THAN 36 PASSENGERS, SPECIAL PURPOSE SHIPS CARRYING NO MORE THAN 240 PERSONS AND BERTH-CONNECTED SHIPS

12.2.1 Ventilation system of accommodation and service spaces as well as control stations shall comply with the requirements of this Chapter and ensure that in all conditions of the ship's service there is an adequate supply of fresh air necessary for the safety and convenience of the operating personnel and reliable operation of the installed equipment.

12.2.2 The ventilation systems for machinery spaces of category A, vehicle spaces, ro-ro spaces, galleys, special category spaces and cargo spaces shall, in general, be separated from each other and from the ventilation systems serving other spaces.

However, the galley ventilation systems on cargo ships of less than 4000 gross tonnage and in passenger ships carrying not more than 36 passengers 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.

12.2.3 All necessary measures shall be taken for permanent ventilation of the control stations outside the machinery spaces, to ensure visibility and absence of smoke to the extent required for normal operation of the equipment in control stations and working of the attending personnel.

For the ventilation of these control stations two alternative and separate means of air supply shall be provided.

The air supply ducts shall be fitted with fire or smoke dampers capable of being easily closed from within the control station so that, in the event of fire, smoke is kept from penetrating into the spaces.

These requirements need not be applied to the control stations situated on the open deck, to which they have a direct exit or where there are equally effective local closures of the control stations.

12.2.4 Galley ventilation systems shall be separate from the ventilation systems serving other spaces.

The exhaust ducts from galley ranges shall be constructed of "A" class divisions where they pass through accommodation spaces or spaces containing combustible materials.

Each galley ventilation duct passing through accommodation spaces or other spaces containing combustible materials shall be fitted with:

.1 grease trap readily removable for cleaning;

.2 a fire damper located in the lower end of the duct and, in addition, a fire damper located in the upper end of the duct;

.3 fixed means for extinguishing fire within the duct;

.4 arrangements, operable from within the galley, for shutting off the exhaust fans (refer also to **5.8.2**, Part XI "Electrical Equipment").

12.2.5 Where in passenger ships it is necessary that a ventilation duct passes through a division of the main vertical fire zone, a failsafe automatic closing fire damper shall be fitted adjacent to the division. The damper shall be also capable of being manually closed from each side of the division.

The position for operating the damper shall be readily accessible and be marked in red light-reflecting colour.

The duct between the division and damper shall be made of steel or other equivalent material and, bulkhead, shall be provided with insulation corresponding to the degree of fire integrity of the division.

At least at one side of the bulkhead the damper shall be fitted with a readily visible indicator showing whether the damper is ope.

12.2.6 Provision shall be made for closing the inlets and outlets of all ventilation systems from outside the ventilated spaces.

Manual closing arrangements shall be readily accessible and have indelible, readily visible marking, which shows whether the duct is open or closed.

12.2.7 The ventilation ducts and their passages through "A" or "B" class divisions in ships of less than 500 gross tonnage shall, generally, be constructed in compliance with the requirements of the Chapter.

12.2.8 Power ventilation of accommodation spaces, service spaces, cargo spaces, control stations and machinery spaces shall be capable of being stopped from an easily accessible position outside the space being served. This position shall not be readily cut off in the event of a fire in the spaces served. However, it is not required for the ventilation fans and air-conditioners intended for air recirculation inside these spaces without air intake, for which only the local control may be provided.

The ventilation fans servicing power ventilation systems shall be switched off in compliance with the requirements of **5.8.1** to **5.8.3**, Part XI "Electrical Equipment".

12.2.9 In passenger ships with signs **B-R3-S**, **B-R3-RS, C-R3-S, C-R3-RS, D-R3-S** and **D-R3-RS,** where ventilation ducts pass through "A" class divisions or decks, they shall comply with the following requirements:

.1 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 a bulkhead or, in the case of a deck, wholly laid on the lower side of the decks penetrated;

.2 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 protection of passageways that meets the requirements of the Register may be provided.

12.2.3 In passenger ships with signs **B-R3-S**, **B-R3-RS, C-R3-S C-R3-RS, D-R3-S** and **D-R3-RS,** duct with a free cross sectional area over 0,02 m^2, other than made of steel, which pass through “B” class divisions, shall be protected either by:

.1 a device tested for fire resistance, which corresponds to the fire resistance of the grillage and the type of duct used; or

.2 a steel sheet sleeve having a thickness of at least 1,8 mm and a length of at least 900мм - for ducts with diameter 150 mm and over;

And at least 600 mm – for ducts with diameter below 150 mm (preferably this length shall be divided in half by the division).

The ducts shall be connected to the sheet sleeves by flanges or other couplings.

12.3 VENTILATION SYSTEMS OF PASSENGER SHIPS CARRYING MORE THAN 36 PASSENGERS AND SPECIAL PURPOSE SHIPS CARRYING MORE THAN 240 PERSONS

12.3.1 The ventilation systems of accommodation spaces, service spaces and control stations shall comply with the requirements of **12.2**, besides meeting the requirements of the Chapter.

12.3.2 In general, the ventilation fans and ducts shall be disposed within the main vertical fire zone, which they serve.

12.3.3 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.

If necessary, the vertical ducts shall be insulated providing fire integrity as required by **2.2.1.3**, Part VI "Fire Protection".

12.3.4 Except in cargo spaces, ventilation ducts shall be constructed of the following materials:

.1 ducts with a cross-sectional area more than 0,075 m^2 and all vertical ducts serving more than a single ’tween-deck space shall be constructed of steel or other equivalent material;

.2 ducts with a cross-sectional area less than 0,075 m^2 other than the vertical ducts mentioned in **12.3.4.1** shall be constructed of steel or equivalent material; where such ducts penetrate "A" or "B" class divisions, due regard shall be given to ensuring the fire integrity of the divisions;

.3 short lengths of ducts not, in general, exceeding 0,02 m^2 in sectional area nor 2 m in length - of materials mentioned in **12.2.2**.

12.3.5 Ventilation systems of stairway enclosures shall be independent of other systems.

12.3.6 Exhaust ducts from galley ranges, in which grease or fat is likely to accumulate, shall meet the requirements of **12.2.4** and shall be fitted with:

.1 a grease trap readily removable for cleaning unless an alternative approved by the Register grease removal system is fitted;

.2 a fire damper located in the lower end of the duct, which is automatically and remotely operated, and in addition a remotely operated fire damper located in the upper end of the duct (the lower end of the duct means position where the duct is connected to exhaust hood at the galley range; the upper end of the duct means position where the duct is closed as it leaves the galley);

.3 fixed means for fire extinguishing within the duct;

.4 remote control arrangements for shutting off the exhaust fans and supply fans, for operating the fire dampers mentioned in **12.3.6.2** and for operating the fire-extinguishing system, which shall be placed in a position close to the entrance to the galley.

Where a multi-branch system is installed, means shall be provided to close all branches exhausting through the same main duct before an extinguishing medium is released into the system;

.5 hatches for inspection and cleaning arranged close to the fire dampers. One hatch shall be located nearby the exhaust fan, other hatches - in the lower part of ducts;

.6 exhaust ducts from ranges for cooking equipment installed on open decks shall conform to **12.3.6.1-5**, as applicable, when passing through accommodation spaces or spaces containing combustible materials.

12.3.7 Where public spaces span three or more decks and contain combustibles such as furniture and enclosed spaces such as shops, bars and restaurants, such spaces shall be equipped with a ventilation activated by a smoke detection system and capable to ventilate the entire volume during not more than 10 min.

Provision shall be made for manual control of the fans.

12.3.8 Power ventilation, except cargo holds and machinery space ventilation, 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. However, it is not required for the ventilators and conditioners intended for air recirculation inside these spaces without air intake, for which only the local control may be provided.

Fans serving power ventilation systems to cargo spaces shall be capable of being stopped from a safe position outside such spaces.

Power ventilation of machinery spaces shall be fitted with controls so grouped that they may be controlled from two separate positions one of them to be located outside the machinery space.

Fans serving mechanical ventilation systems shall be capable of being stopped in accordance with the requirements of **5.8.1** to **5.8.3**, Part XI "Electrical equipment".

12.3.9 Ventilation systems of passenger ships shall comply with the requirement of **2.2.8.6**, Part VI "Fire Protection".

The ventilation systems of safety zones of passenger ships having length, as defined in **1.2.1** of the Load Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones, shall additionally comply with the requirements of **2.2.6.10**, Part VI "Fire Protection".

The ventilation system serving safety centers may be derived from the ventilation system serving the navigation bridge, unless located in an adjacent main vertical zone.

12.3.10 Exhaust ducts from ranges for cooking equipment installed on open decks shall comply with the requirements of 12.3.6, as applicable, when passing through accommodation spaces or spaces containing combustible materials.

12.3.11 Exhaust ducts from main laundries shall be fitted with:

.1 filters readily removable for cleaning purposes;

.2 a fire damper located in the lower end of the duct which is automatically and remotely operated;

.3 remote-control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating the fire damper mentioned in **12.3.11.2**;

.4 suitably located hatches for inspection and cleaning.

12.4 VENTILATION SYSTEMS OF OIL TANKERS AND COMBINATION CARRIERS CARRYING CRUDE OIL AND PETROLEUM PRODUCTS WITH FLASH POINT 60°C AND BELOW

12.4.1 In addition to requirements of **12.1**, **12.2**, **12.6** and **12.9**, the ventilation systems shall comply with the requirements of the Chapter.

12.4.2 The ventilation inlets of accommodation spaces, service spaces and control stations shall be located on the aft transverse bulkhead not facing cargo tanks, or on the side of the superstructure or deckhouse at a distance equal, at least, to 4 % of the ship's length, but not less than 3 m from the end of the superstructure or deckhouse facing cargo tanks. This distance, however, need not exceed 5 m.

The inlets and outlets of ventilation ducts for machinery spaces shall be situated as far aft as practicable. Special consideration shall be given to location of these vents in oil tankers equipped to load and discharge at the stern.

12.4.3 Cargo pump rooms shall be mechanically ventilated and discharges from the exhaust fans shall be laid to a safe place on the open deck.

The ventilation of these rooms shall have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of air changes shall be at least 20 per hour, based upon the gross volume of the space.

The air ducts shall be arranged so that all of the space is effectively ventilated.

The suction ventilation shall be of mechanical type using fans of the non-sparking type.

Input ventilation may be self-ventilation.

Lighting shall be interlocked with ventilation in accordance with **19.2.4.4**, Part XI "Electrical Equipment".

12.4.4 The inlets of exhaust ducts shall be situated so as to provide extraction of air from below the floor plates. The bottom framing, as well as the floor plates and gratings of the pump room shall be so constructed as not to impede the free flow of air to the inlets of the exhaust ducts.

Outside the pump room these ducts shall be gastight and, generally, shall not communicate with the ducts of other spaces.

The pump rooms shall have also an emergency ventilation operating in the event of lower inlets being flooded. For this purpose an emergency intake about 2 m above the lower grating shall be provided on the exhaust duct. This intake shall have a damper capable of being operated from the main deck and lower grating level. The damper may be omitted if the areas of the inlets are chosen such that at least 20 air changes per hour will be ensured through the lower inlets, and at least 15 air changes per hour through the upper inlets in case of the lower inlets being flooded.

Where the ventilation system of the pump room is used for ventilating the cargo line and the communicating cargo tanks, duplicate shut-off fittings shall be provided at the connections of the ventilation duct to the cargo line.

12.4.5 The construction of the ventilation fans in cargo pump rooms shall comply with the requirements of **5.3**, Part IX "Machinery" and the location of their driving motors shall meet the requirements of **4.2.5**, Part VII "Machinery Installations".

12.4.6 The outlets of exhaust ducts for cargo pump rooms shall not be less than 2 m remote from any opening leading into ship spaces, which may contain a source capable of ignition oil vapours, and shall be so located that no contamination of air entering the inlets of ventilation systems will occur.

The outlets of exhaust ducts shall be fitted with flame-arresting fittings.

The inlets of ventilation ducts shall be protected in accordance with 5.3.3.2 of Part IX "Machinery".

The air intakes shall be situated at least 2,4 m above the cargo deck and at least 5,0 m from any openings of the cargo tanks and outlets of the pressure/relief valves, and at least 10 m from the outlets of vent pipes that expel freely the vapour/air mixture or are fitted with high-speed devices.

12.4.7 In combination carriers, all cargo spaces and all enclosed spaces adjacent to the cargo spaces shall be capable of being mechanically ventilated. This ventilation may be provided by portable fans.

12.4.8 On oil tankers:

.1 double hull and double bottom spaces shall be fitted with suitable connections for the supply of air;

.2 if IGS is required, spaces mentioned in **12.4.8.1** shall be connected to the fixed inert gas distribution systems; provision shall be also made for arrangements to prevent leakage of the hydrocarbon gas from the cargo tanks into such spaces through the inert gas distribution system.

Where these spaces are not connected constantly to the inert gas distribution sources arrangements shall be provided to ensure such connection

12.5 VENTILATION OF MACHINERY SPACES AND TUNNELS

12.5.1 The ventilation of machinery spaces of category A shall be such as to ensure that when the machinery and boilers therein are operating at full load in all service conditions including heavy weather, a supply of air is maintained to the spaces sufficient for the safety and comfort of the personnel and the operation of machinery.

The ventilation shall ensure removal of gases heavier than air from the lower zones of those spaces, from below floor plates, from where fuel system equipment, settling and supply tanks are installed.

Any other machinery spaces shall be adequately ventilated appropriate to the purpose of the machinery space.

The requirements for the ventilation of refrigerating machinery spaces are given in **3.1.6** and **3.1.7**, Part XII "Refrigerating Plants".

12.5.2 Shaft tunnels shall be properly ventilated. The pipe tunnels laid in the double bottom shall have mechanical exhaust ventilation.

12.5.3 In the space containing emergency diesel-generator (automatically started), provision shall be made for an automatic arrangement to ensure an air supply sufficient for the emergency dieselgenerator to run under full load in any service conditions when the space is closed.

12.5.4 In spaces mentioned under **4.2.7**, Part VII "Machinery Installations", independent mechanical exhaust ventilation or a ventilation device separable from the machinery space ventilation shall be installed.

The construction of fans shall comply with the requirements of **5.3**, Part IX "Machinery".

12.5.5 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.

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.

12.5.6 Emergency generator rooms are provided with ventilation openings for the admission of combustion air to engines and the removal of heat.

These openings are usually provided with louvers which can be closed (when fire breaks out in emergency generator rooms).

The louvers may be handoperated or power-operated.

Alternatively, the louvers may be of fixed type with a closing door which may be hand-operated or automatic.

The following requirements apply to ventilation louvers for emergency generator rooms and to closing appliances where fitted to ventilators serving emergency generator rooms:

.1 ventilation louvers and closing appliances may either be hand-operated or power-operated (hydraulic/ pneumatic/electric) and are to be operable under a fire condition;

.2 hand-operated ventilation louvers and closing appliances shall be kept open during normal operation of the ship. Corresponding instruction plates shall be provided at the location where hand-operation is provided;

.3 power-operated ventilation louvers and closing appliances shall be of a fail-to-open type. Closed ventilation louvers and closing appliances are acceptable during normal operation of the ship.

Power-operated ventilation louvers and closing appliances shall open automatically whenever the emergency generator is starting/in operation;

.4 It shall be possible to close ventilation openings by a manual operation from a clearly marked safe position outside the space where the closing operation can be easily confirmed. The louver status (open/closed) shall be indicated at this position.

Such closing shall not be possible from any other remote position.

12.6 VENTILATION OF SPECIAL CATEGORY SPACES, CARGO SPACES INTENDED FOR THE CARRIAGE OF MOTOR VEHICLES WITH FUEL IN THEIR TANKS AND CLOSED RO-RO CARGO SPACES

12.6.1 These spaces shall have mechanical exhaust ventilation system independent from other ventilation systems, which shall function during the whole period the motor vehicles are carried in such spaces.

If individual spaces have effective closures, ventilation ducts shall be separate for each of them.

The fans shall be operated from outside the ventilated spaces and to be capable of ensuring at least:

.1 10 air changes per hour:

in cargo spaces for the carriage of motor vehicles with fuel in their tanks in passenger ships carrying more than 36 passengers;

in special category spaces in all passenger ships;

in closed ro/ro cargo spaces with electrical equipment in accordance with **19.3.4**, Part XI "Electrical Equipment" in all ships;

.2 6 air changes per hour in all other ships;

.3 in cargo spaces for the carriage of motor vehicles, where an air quality control system is provided based on IMO circular MSC.1/Circ.1515, the ventilation system may be operated at a decreased amount of ventilation. This relaxation does not apply to spaces to which at least ten air changes per hour is required by **19.3.4.1**, of Part XI "Electrical Equipment".

12.6.2 The ventilation shall be such as to provide even distribution of air supply and shall prevent formation of trapped zones.

12.6.3 The ventilation system shall be equipped with devices indicating any loss or reduction of theventilating capacity and operation of the fans.

These devices shall be installed in the wheelhouse. Instead of them, the following means may be provided:

.1 visual signal indicating the operation of each fan;

.2 interlock to permit the electric motor of the fan to start only if the ventilation duct is open;

.3 audible signal for spontaneous stop of the electric motor.

12.6.4 The construction of the fans shall comply with the requirements of **5.3**, Part IX "Machinery".

12.6.5 Arrangements shall be provided for effective closure of the ventilation system in case of fire and shall meet the requirements of **12.1.10**.

12.6.6 The ventilation ducts and their closures shall be made of steel.

12.6.7 Ducts intended for ventilation of special-category spaces, which pass through other special-category spaces, shall be constructed of steel.

Where such ventilation ducts pass through special-category spaces, which do not form part of the of the same main horizontal zone, the ducts shall be insulated to A-60 standard.

Ventilation ducts shall not pass through machinery spaces unless they are constructed of "A-60" class divisions.

12.7 VENTILATION OF CARGO SPACES ADAPTED FOR THE CARRIAGE OF DANGEROUS GOODS[7]

12.7.1 Closed cargo spaces in cases mentioned in **7.2.4**, Part VI "Fire Protection" shall have mechanical exhaust ventilation, separate for each such space, sufficient to give at least 6 air changes per hour, based upon the volume of an empty hold.

Supply ventilation of these spaces may be natural**.**

In agreement with the Register, mechanical supply and natural exhaust ventilation may be allowed..

The number of air changes may be reduced with regard to the method of transportation (refer to Note 1 to Table 7.2.4-1, Part VI "Fire Protection").

12.7.2 For closed cargo spaces intended for the carriage of dangerous goods in bulk at least natural ventilation in accordance with **7.2.8.3**, Part VI "Fire Protection" is required.

However, when conditions of carriage require a mechanical ventilation system, a stationary system may be dispensed with, provided that portable fans ensuring adequate effectiveness of the ventilation are used.

12.7.3 The ventilation shall be such as to provide uniform change of air within the cargo space and to prevent formation of trapped zones.

The ventilation system shall be such that vapours of dangerous goods are removed from upper or lower part of the space, with regard to density of the vapours in relation to air..

12.7.4 The construction of ventilation fans shall comply with the requirements of 5.3, Part IX "Machinery".

The electric motors of the fans shall be of flameproof design. It is not recommended to arrange them in way of gas exhaust.

The inlets and outlets of ventilation systems shall be protected by screens with mesh size of 13x13 mm.

12.7.5 The ventilator heads of exhaust ducts from cargo spaces adopted for the carriage of dangerous goods emitting readily flammable and toxic vapours or gases shall be so located that the issuing vapours or gases will not enter other ship spaces.

12.7.6 Rooms containing bilge pumps servicing cargo spaces for carriage of dangerous goods shall be provided with separate artificial exhaust ventilation sufficient to give at least 6 air changes per hour.

12.7.7 During carriage of, dust-forming goods capable of emitting vapours and/or gases producing explosive mixtures with air, provision shall be made for two fixed or portable fans of flameproof design with a total capacity sufficient to provide 6 air changes per hour.

[7] For dangerous goods, refer to 7.1.2, Part VI "Fire Protection".

12.7.8 Ventilation system of ships carrying packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes (INF cargo, refer to 7.3, Part VI "Fire Protection") shall comply with the following requirements:

.1 provision shall be made for adequate ventilation or cooling of closed cargo spaces so that at any time the mean ambient temperature within these spaces does not exceed 55°C;

.2 ventilation or cooling systems serving cargo spaces intended for carriages of INF cargo shall be independent from similar systems serving other spaces; and;

.3 equipment indispensable for operation, such as fans, compressors, heat exchangers, cooling liquid supply systems shall be duplicated for each cargo space.

12.7.9 The open top container holds shall be mechanically ventilated by means of special ducts from the lower parts of cargo holds.

The ventilation capacity shall be at least 2 air changes per hour based on the empty hold volume below weather deck.

12.7.10 If the International Maritime Solid Bulk Cargoes Code (IMSBC Code) requires continuous ventilation of holds for the carriage of dangerous goods, the inlet and outlet ventilation openings not requiring the means of closure according to the Load Line Rules for Sea-Going Ships shall be used only. Means of closure for ventilation openings as required for fire protection purposes under **12.1.6** shall be provided and the minimum height to ventilation openings allowed not to have means of closure shall be in accordance with **7.8.2**, Part III "Equipment, Arrangements and Outfit".

12.7.11 If enclosed spaces adjacent to cargo hold are not separated from cargo spaces by sealed cover then they are considered as part of the enclosed cargo hold and the ventilation requirements shall apply to the adjacent space as for the enclosed cargo space itself.

Where the IMSBC Code requires 2 fans per each hold, a common ventilation system with 2 fans connected is acceptable.

12.8 VENTILATION OF REFRIGERATED CARGO SPACES

12.8.1 The requirements to the ventilation of refrigerated cargo spaces are set out in **3.3.5** to **3.3.8**, Part XII "Refrigerating Plants".

12.9 VENTILATION OF FIRE EXTINGUISHING STATIONS

12.9.1 The foam fire extinguishing and smothering stations, located below the upper deck or not accessible from the weather deck shall be equipped with efficient independent ventilation system with capacity sufficient to provide not less than 6 air changes per hour.

The carbon dioxide fire extinguishing stations shall be provided with an exhaust and supply ventilation independent from other ventilation systems. The inlets of exhaust ducts shall be located in lower part of the station.

12.9.2 The high-expansion foam fire extinguishing stations shall be equipped with devices ensuring air supply in an amount sufficient for the operation of foam generators.

12.10 VENTILATION OF ACCUMULATOR BATTERY ROOMS AND BOXES

12.10.1 The accumulator battery rooms and boxes shall be provided with independent ventilation system capable of removing air from upper part of the ventilated spaces.

The exhaust ducts shall be gastight.

12.10.2 The inlet air shall be supplied into the lower part of the ventilated space.

12.10.3 The outlets of ventilation ducts shall be so constructed as to preclude the admission of sea water, atmospheric precipitation and solids.

No flame-arresting fittings shall be installed.

The discharges of exhaust ducts shall be laid to places where the issuing gases do not present a fire hazard.

12.10.4 The boxes of accumulator batteries having a charging capacity not over $2,0 \times 10^2$ W may be ventilated through the openings in the lower and upper parts of the box to ensure removal of the gases.

12.10.5 The rate of air flow Q, in m^3/s, for the ventilation of an accumulator battery room or box shall not be less than that determined by the formula

$$Q = 3,06 \cdot 10^{-5} In, \qquad (12.10.5)$$

where:

I – maximum charging current during gas emission, but not less than 0,25 of maximum current of the charging device, A;

n – number of battery cells.

12.10.6 The cross-sectional area F, in m^2, of a duct, in case of natural ventilation of accumulator battery rooms and boxes, shall not be less than determined by the formula

$$F = 1{,}04\,Q, \qquad (12.10.6)$$

where: Q is the rate of air flow determined by Formula (12.10.5), but not less than 0,004 m^2.

12.10.7 Natural ventilation of the spaces may be used in the following cases: .1 the required amount of air, calculated by Formula (12.10.5), is less than $2{,}36 \cdot 10^{-2}$m^3/s;

.2 the angle of the duct deflection from the vertical is less than 45°;

.3 the number of bends of the duct does not exceed 2;

.4 the length of the duct does not exceed 5 m;

.5 the operation of ventilation system does not depend on the direction of the wind;

.6 the cross-sectional area of the duct shall be taken not less than that determined by Formula (12.10.6).

12.10.8 Where the rate of air flow determined by Formula (12.10.5) is $2{,}36 \cdot 10^{-2}$m^3/s and over, the accumulator battery room shall be provided with mechanical exhaust ventilation.

12.10.9 The internal surfaces of the exhaust ducts, as well as the ventilating fans shall be protected against the action of the electrolyte vapours.

12.10.10 The motors of the ventilating fans shall not be arranged in way of gas exhaust. The construction of the ventilating fans shall comply with the requirements of **5.3**, Part IX "Machinery".

12.10.11 Ventilation serving for battery rooms shall be equipped as follows:

.1 rursually, open ends of ventilation ducts from battery rooms shall not have outlets directly to the open decks and they shall be fitted with means of closing.

Closing devices shall be provided if it is required by the International Convention on Load Lines as well as 3.2.1 of Load Lines Rules for Sea-Going Ships or premises equipped with a fixed gas fire extinguishing system;

.2 where an open outlet of battery room ventilator is fitted with a closing device, then a warning notice stating, for example,

"This closing device shall be kept open and only closed in the event of fire or other emergency — DO NOT CLOSE! EXPLOSIVE GAS! ", shall be provided at the closing device to mitigate the possibility of inadvertent closing.

12.11 VENTILATION OF HANGARS FOR HELICOPTERS

12.11.1 Hangars and spaces where helicopter refuelling and maintenance facilities are located shall be provided with mechanical exhaust ventilation sufficient to give at least 10 air changes per hour.

12.11.2 Fans shall be of flameproof design and shall meet the requirements of **5.3.3**, Part IX "Machinery" and **19.3.4**, Part XI "Electrical Equipment".

12.12 VENTILATION OF SPACES IN OIL RECOVERY SHIPS

12.12.1 Ventilation systems serving dangerous and safe spaces shall be independent of each other.

Spaces in zones belonging to different classes as listed under **19.2.3**, Part XI "Electrical Equipment" shall be served by different systems.

12.12.2 Safe spaces and air locks shall be equipped with mechanical supply ventilation to ensure excessive pressure therein as compared to adjacent dangerous spaces.

12.12.3 Provision shall be made for automatic switch on of ventilators and signalling for loss of excessive pressure in safe spaces and air locks.

Alternatively, the following may be provided:

.1 light signalling of each ventilator operation;

.2 blocking to ensure the electric motor of the ventilator is switched on only when the vent duct cover is open;

.3 sound signalling of spontaneous stop of electric motor of the ventilator.

12.12.4 The suctions of supply ventilation ducts shall be located outside dangerous spaces on open decks.

12.12.5 Exhaust duct openings shall be fitted with flame aborting strainers.

12.12.6 Dangerous spaces in Zone 1 shall be provided with mechanical exhaust ventilation to ensure at least 20 air changes per hour.

Application of ventilation systems for 10 air exchanges per hour is allowed, provided the system is fitted with automatic switching for 20 air changes per hour, when the gas concentration of (20±10) % of the lower limit of the explosive range is reached in the atmosphere of the space.

Dangerous spaces in Zone 2 shall be provided with ventilation to ensure at least 10 air changes per hour.

12.12.7 In dangerous spaces, the exhaust ventilation ducts shall be gas-tight, rigid enough and shall not pass through safe spaces (except where the ducts of the pressure part of ventilation are laid through safe spaces in gas-tight tunnels).

12.12.8 In spaces and air locks, the ventilation systems shall be equipped with instruments to monitor the operation of ventilators and other devices mentioned under **12.12.3** and **12.12.6**.

12.13 VENTILATION OF SPACES INTENDED FOR INERT GAS EQUIPMENT

12.13.1 In spaces intended for the inert gas equipment of cargo tanks including generators, scrubbers, ventilators and their valves, provision shall be made for artificial exhaust ventilation which shall ensure at least six air changes per hour as determined proceeding from the empty space volume.

Forced ventilation may be natural ventilation.

When the above equipment is installed in machinery spaces, the requirements of **12.5** shall be complied with.

12.13.2 For ventilating spaces mentioned under **9.16.9.3**, Part VI "Fire Protection", provision shall be made for artificial forced ventilation, which shall ensure the number of air changes not less than stipulated under **12.13.1**.

12.14 VENTILATION OF SHIPS EQUIPPED FOR USING GASES OR LOW-FLASHPOINT FUELS

12.14.1 General.

12.14.1.1 Any ducting used for the ventilation of hazardous spaces shall be separate from that used for the ventilation of non-hazardous spaces.

The ventilation shall be operable at all temperatures and environmental conditions, specified in **2.3**, Part VII «Machinery Installations».

12.14.1.2 Electric motors for ventilation fans shall not be located in ventilation ducts for hazardous spaces unless the motors are certified for the same hazard zone as the space served.

12.14.1.3 Design of ventilation fans serving spaces containing gas sources shall comply with the following:

.1 ventilation fans shall not produce a source of vapour ignition in either the ventilated space or the ventilation system associated with the space. Ventilation fans and fan ducts, in way of fans only, shall be intrinsically safe defined as follows:

.1.1 for impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

.1.2 impellers and housings of non-ferrous metals;

.1.3 impellers and housings of austenitic stainless steel;

.1.4 impellers of aluminum alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non-ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing; or

.1.5 any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance;

.2 under no circumstances shall the radial air gap between the impeller and the casing be less than 0,1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm.

The gap need not be more than 13 mm;

.3 any combination of an aluminium or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is considered a sparking hazard and shall not be used in hazardous areas.

12.14.1.4 Ventilation systems required to avoid any gas accumulation shall consist of independent fans, each of sufficient capacity, unless otherwise specified in these requirements.

12.14.1.5 Air inlets for hazardous enclosed spaces shall be taken from areas that, in the absence of the considered inlet, would be non-hazardous.

Air inlets for non-hazardous enclosed spaces shall be taken from non-hazardous areas at least 1,5 m away from the boundaries of any hazardous area.

Where the inlet duct passes through a more hazardous space, the duct shall be gastight and have overpressure relative to this space.

12.14.1.6 Air outlets from non-hazardous spaces shall be located outside hazardous areas.

12.14.1.7 Air outlets from hazardous enclosed spaces shall be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

12.14.1.8 The required capacity of the ventilation plant is normally based on the total volume of the room.

An increase in required ventilation capacity may be necessary for rooms having a complicated form.

12.14.1.9 Non-hazardous spaces with entry openings to a hazardous area shall be arranged with an air lock and be maintained at overpressure relative to the external hazardous area.

The overpressure ventilation shall be arranged according to the following:

.1 during initial start-up or after loss of overpressure ventilation, before energizing any electrical installations not certified safe for the space in the absence of pressurization, it shall be required to:

.1.1 proceed with purging (at least 5 air changes) or confirm by measurements that the space is nonhazardous; and

.1.2 pressurize the space;

.2 operation of the overpressure ventilation shall be monitored and in the event of failure of the overpressure ventilation the following shall be performed:

.2.1 an audible and visual alarm shall be given at a manned location; and

.2.2 if overpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations shall be required.

12.14.1.10 Non-hazardous spaces with entry openings to a hazardous enclosed space shall be arranged with an air lock and the hazardous space shall be maintained at underpressure relative to the non-hazardous space.

Operation of the exhaust ventilation in the hazardous space shall be monitored and in the event of failure of the exhaust ventilation the following shall be performed:

.1 an audible and visual alarm shall be given at a manned location; and

.2 if underpressure cannot be immediately restored, automatic or programmed disconnection of electrical installations according to a recognized standard shall be required at a non-hazardous area.

12.14.1.11 As acceptable measures to confirm the ventilation capacity required in **12.14.1.10.1** may be adopted means of the following or equivalent:

.1 monitoring of the ventilation electric motor or fan operation combined with underpressure indication; or

.2 monitoring of the ventilation electric motor or fan operation combined with ventilation flow indication; or

.3 monitoring of ventilation flow rate to indicate that the required air flow rate is established.

12.14.2 Requirements for ventilation of tank connection spaces[8].

12.14.2.1 The tank connection space shall be provided with an effective mechanical forced exhaust ventilation system.

A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed.

The equivalence of alternative installations shall be demonstrated by a risk assessment.

12.14.2.2 Approved automatic fail-safe fire dampers shall be fitted in the ventilation duct for the tank connection space.

12.14.3 Requirements for ventilation of machinery spaces.

[8] Tank connection space means a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

12.14.3.1 The ventilation system for machinery spaces containing gas-fuelled consumers shall be independent of all other ventilation systems.

Spaces enclosed in the boundaries of machinery spaces (such as purifier's room, engineroom workshops and store rooms) are considered an integral part of machinery spaces containing gas-fuelled consumers and, therefore, their ventilation system does not need to be independent of the one of machinery spaces.

12.14.3.2 ESD[9] protected machinery spaces shall have ventilation with a capacity of at least 30 air changes per hour. The ventilation system shall ensure a good air circulation in all spaces, and in particular ensure that any formations of gas pockets in the room are detected.

As an alternative, arrangements whereby under normal operation the machinery spaces are ventilated with at least 15 air changes per hour are acceptable provided that if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 per hour.

12.14.3.3 For ESD protected machinery spaces the ventilation arrangements shall provide sufficient redundancy to ensure a high level of ventilation availability as defined in a standard agreed upon with the Register.

12.14.3.4 The number and power of the ventilation fans for ESD protected machinery spaces and for double pipe ventilation systems for gas-safe machinery spaces shall be such that the capacity is not reduced by more than 50 % of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

12.14.4 Requirements for ventilation of fuel preparation rooms.

12.14.4.1 Fuel preparation rooms[10] shall be fitted with effective mechanical ventilation system of the underpressure type providing a ventilation capacity of at least 30 air changes per hour.

12.14.4.2 The number and power of the ventilation fans shall be such that the capacity is not reduced by more than 50 %, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

12.14.4.3 Ventilation systems for fuel preparation rooms shall be in operation when pumps or compressors are working.

12.14.5 Requirements for ventilation of bunkering stations.

Bunkering stations that are not located on the open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside.

If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment as specified in **13.11.2.1**.

12.14.6 Requirements for ventilation of ducts and double pipes.

12.14.6.1 Ducts and double pipes containing fuel piping shall be fitted with effective mechanical ventilation system of the extraction type providing a ventilation capacity of at least 30 air changes per hour. This requirement is not applicable to double pipes in the machinery space if the requirements of **13.11.5.1** are complied with.

12.14.6.2 The ventilation system for double piping and for gas valve unit spaces in gas-safe machinery spaces shall be independent of all other ventilation systems.

Double wall piping and gas valve unit spaces in gas safe engine-rooms are considered an integral part of the fuel supply systems and, therefore, their ventilation system does not need to be independent of other fuel supply ventilation systems provided such fuel supply systems contain only gaseous fuel.

12.14.6.3 The ventilation inlet for the double wall piping or duct shall always be located in a non-hazardous area away from ignition sources. The inlet opening shall be fitted with a suitable wire mesh guard and protected from ingress of water.

[9] Gas-safe machinery space space means closed gas-safe space with gas fuel consumers, explosion safety of which is ensured by installation of gas-containing equipment in gastight enclosures (piping, ducting, partitions) for gas fuel bleed-off, and the inner space of partitions and ducting shall be considered gas-dangerous.

[10] Fuel preparation room means any space containing pumps, compressors or vaporizers for fuel preparation purposes.

12.14.6.4 The capacity of the ventilation for a pipe duct or double pipes may be below 30 air changes per hour if a flow velocity of minimum 3 m/s is ensured.

The flow velocity shall be calculated for the duct with fuel pipes and other components installed.

13. FUEL OIL SYSTEM

13.1 PUMPS

13.1.1 At least two pumps shall be provided for fuel transfer, one of which being a standby pump.

Any suitable pump, including the fuel oil separator pump, may be used for standby purpose.

Standby fuel pump should be started automatically regardless the automation class of the ship for any unattended engine rooms.

For cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** standby pump is not required.

In ships with a daily consumption of fuel less than 1t, a hand pump is admissible.

13.1.2 Where the fuel oil tanks, including the deep tanks, are used also for water ballast, provision shall be made for reliable arrangements disconnecting the ballast system from these tanks when carrying fuel oil and the fuel oil system, when containing water.

In addition, the requirements of MARPOL 73/78 shall be complied with.

13.1.3 The fuel oil and lubricating oil transfer pumps and the separator pumps, besides local hand control, shall be provided with stopping means operable from always accessible positions outside the space where the pumps are installed.

13.1.4 Shut-off valves shall be fitted on the pressure side and suction side of fuel oil and lubricating oil pumps.

Devices for measuring fuel oil temperature are recommended to be provided on the suction pipes of the fuel oil pumps.

This requirement is mandatory for installations with fuel oil flash point of less than60°C.

13.1.5 For ships intended to use heavy fuel oil (HFO) or marine diesel oil (MDO)[11] in non-restricted areas and marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 sSt in emission control areas, the following arrangements should be provided in addition to **13.1.1**.

.1 in non-restricted areas, ships provided with two fuel oil pumps that can each supply the fuel primarily used by the ship (i.e. HFO or MDO) in the required capacity for normal operation of the propulsion machinery.

.2 in emission control areas one of the following requirements shall be met:

.2.1 fuel oil pumps as in **13.1.5.1**, provided these are each suitable for marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 sSt in the required capacity for normal operation of the propulsion machinery;

.2.2 when the fuel oil pumps in **13.1.5.1** are suitable to operate on marine fuels with a sulphur content not exceeding 0,1 % m/m and minimum viscosity of 2 sSt, but one pump alone is not capable of delivering such fuel, then both pumps may operate in parallel. In this case, one additional (third) fuel oil pump shall be provided. The additional pump shall, when operating in parallel with one of the pumps in **13.1.5.1**, be suitable for and capable of delivering marine fuels at the required capacity for normal operation of the propulsion machinery;

.2.3 in addition to pumps as in **13.1.5.1**, two separate fuel pumps shall be provided, each capable of and suitable for supplying marine fuels with a sulphur content not exceeding 0,1% m/m and minimum viscosity of 2 sSt at the required capacity for normal operation of propulsion machinery.

If a marine distillate grade fuel with a different maximum sulphur content is specified by regulation for the area of operation of the ship then that maximum shall be applied.

Where electrical power is required for the operation of propulsion machinery, the requirements are also applicable for machinery for power generation when such machinery is supplied by common fuel supply pumps.

[11] Marine diesel oil (MDO) means distillate fuel used on ships for combustion purposes and which, in accordance with ISO 8217: 2010, has a kinematic viscosity at 40° C - less than 11.00 centistokes (mm^2/s).

13.2 PIPING LAYING

13.2.1 In general, the fuel oil pipeline shall have no communication with other piping systems.

Where the fuel oil tanks are used also for water ballast, the requirements of 13.1.2 shall be complied with.

13.2.2 Welded joints shall be generally applied for the assembly of piping for fuel oil with a flash point below 60°C and for oil heated above 60°C, whereas the number of detachable joints shall be reduced to a minimum.

Such pipes containing oil under a pressure of 0,18 N/mm^2 and above shall not be placed in a concealed position, they shall be readily accessible and their locations shall be adequately illuminated.

Note: Heated liquid fuel - means liquid fuel with a temperature higher than 60° C or higher than the flash point, if lower than 60°C.

When using fuel with a flash point below 60° C but not below 43° C, the following requirements must be additionally met:

.1 measurement of the fuel temperature in the suction pipe of the fuel pump shall be provided;

.2 fuel filters must be equipped with shut-off valves or cocks on the inlet and outlet side;

.3 piping shall be welded or with circular cone or spherical joints.

13.2.3 The fuel pipes shall not be laid above the internal combustion engines, turbines, exhaust gas pipes, steam pipes (except heating steam coils), steam boilers and boiler uptakes.

In exceptional cases, it is allowed to lay the fuel pipes above the said equipment provided that in these positions the pipes have no detachable joints or are shielded and that in necessary places provision is made for trays preventing the spillage of fuel on the equipment or other sources of ignition.

Provisions shall be taken to prevent fuel spillage on heated surfaces, which may be ejected under pressure from a pump, filter or heater.

13.2.4 The fuel pipes which damage may cause fuel leakage from tanks, slop and supply service tanks of 500 l and more located above double bottom shall be fitted with a cock or valve installed directly on a tank, which can be closed from a safe position outside such space if fire happens in a space where such tanks are located. Such a cock or valve may be fitted on straight branch pipes welded to the shell plating, provided they are rigid enough and have the minimum length.

In special cases when deep tanks are located in a propeller shaft tunnel, in pipe tunnel or any other similar space, the valves shall be located on deep tanks, however, there shall be an option to control the additional valve fitted on a pipeline or pipelines outside the tunnel or other similar space. If such additional valve is fitted in the machinery space, it shall be controlled from a position outside such space.

Remote control of the fuel tank for the emergency diesel generator shall be located in a separate space apart from the remote controls for other tank valves located in the machinery space.

13.2.5 Where the fuel oil system is fitted with flow metering devices or similar metering instruments, they shall be provided with a by-pass line and relevant shut-off valves for performing the maintenance and repair including cleaning of the built-in filters without interrupting the operation of the internal combustion engines (boilers).

13.3 HEATING ARRANGEMENTS OF FUEL OIL

13.3.1 For fuel oil heating the heat-carrying agents enumerated in **9.6.1** may be applied.

In case of using electric heating appliances for fuel oil heating, the requirements of 15.3, Part XI "Electrical Equipment" shall be complied with.

13.3.2 Heating coils and electric heating appliances shall be fitted as low as possible in the tanks.

13.3.3 In daily service tanks and settling tanks, the suction ends of fuel pipes shall be so positioned above the heating coils and electric heating appliances that the latter remain submerged as far as practicable.

13.3.4 When fuel oil and lubricating oil steam heaters or other heating medium heaters are used, except cases when the heated medium temperature does not reach a flash point, the system shall be fitted with an alarm on a high temperature or a flow drop in addition to the system for temperature monitoring.

13.3.5 The maximum temperature of fuel oil heating in storage tanks shall be 15°C below the fuel oil flash point.

Fuel oil in service tanks, settling tanks and any other tanks in the engine and boiler supply system may be heated above this limit, provided:

.1 the length of air pipes of these tanks or the use of cooling devices permits to lower the temperature of escaping vapours below 60°C or the outlets of air pipes are situated at least 3 m away from ignition sources;

.2 non-intrinsically safe electrical equipment is not located within a vapour space of fuel oil tanks;

.3 there are no openings from the vapour space of the fuel tanks into machinery spaces;

.4 enclosed spaces shall not be located directly over such fuel tanks, except for well-ventilated cofferdams;

.5 ends of air pipes shall be equipped with flame arresters.

13.4 DRAINAGE ARRANGEMENTS OF FUEL OIL TANKS

13.4.1 For draining water from the bottom of the daily service and settling tanks, these tanks shall be fitted with self-closing valves and pipes connected to drain tanks.

The drain pipes shall be fitted with sight glasses.

Where trays are available, open funnels may be used instead of sight glasses.

13.5 ARRANGEMENTS FOR COLLECTION OF LEAKAGE FUEL

13.5.1 Tanks, pumps, filters and other equipment shall be fitted with drip trays where there is a possibility of fuel oil leakage.

13.5.2 Drain pipes from the drip trays shall be laid into fuel oil drain tanks.

Drainage of fuel oil into the bilges and overflow tanks is not permitted.

13.5.3 The internal diameter of the drain pipes shall be at least 25 mm.

13.5.4 The ends of the drain pipes shall be laid to the tank bottom with a gap not less than 1/4 of the internal diameter of the pipe.

Where the drain tank is situated in the double-bottom space, structural measures shall be taken to prevent penetration of water into the machinery spaces through the open ends of the drain pipes in the event of damage to the shell plating.

Provision shall be made for an alarm device to give warning if the fuel oil reaches the upper predetermined level in the drain tank.

13.5.5 If drain pipes from drip trays fitted in different watertight compartments are laid into a common drain tank, structural precautions shall be made to prevent water from one flooded compartment to enter the other compartment via the open ends of drains.

13.6 FILLING OF STORAGE TANKS

13.6.1 The bunkering of the ship shall be carried out through a permanent pipeline, provided with the valves necessary for the filling of all the basic fuel storage tanks.

In ships with twin hulls, the filling pipes shall ensure the filling of the fuel tanks of any of the hulls as well as pumping of fuel from the tanks of one hull into the tanks of the other.

The end of the filling pipe shall be laid to the tank bottom with a gap not less than 1/4 of the internal diameter of the pipe or by other means excluding foaming when filling the tank.

13.6.2 In passenger ships provision shall be made for bunkering stations, which are separated from the other spaces, and fitted with drain pipes laid into fuel oil drain tanks.

13.6.3 The filling pipes of the tanks situated above the double bottom shall be connected to the tanks near the top.

Where this is impracticable, the filling pipes shall be fitted with non-return valves installed directly on the tanks.

Where the filling pipe is used as a suction pipe, the non-return valve shall be replaced by a remotecontrolled shut-off valve operable from accessible position outside the space, in which the tank is located.

13.7 FUEL OIL TANKS

13.7.1 The structural members of fuel oil tanks shall comply with the requirements of Part II "Hull".

13.7.2 The arrangement of the fuel tanks in the machinery spaces shall comply with the requirements of **4.3**, Part VII "Machinery Installations".

13.7.3 The fuel tanks situated on weather decks and superstructure decks, as shall be protected against the action of sunrays.

13.7.4 In glass-reinforced plastic ships (refer to **3.2.8**, Part XVI "Structure and Strength of Fiber-Reinforced Plastic Ships") the fuel tanks shall not directly adjoin the accommodation spaces.

The air gap between the fuel tank and accommodation space shall be efficiently ventilated. In general, the fuel tanks shall not be located in machinery spaces. If they are located in such spaces, they shall be constructed of steel or equivalent material (refer to **1.2**, Part VI "Fire Protection").

13.7.5 Fuel oil tanks shall be separated from the feed water and vegetable oil tanks by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

13.7.6 In ships of 400 gross tonnage and upwards, compartments situated forward of the collision bulkhead shall not be used for carriage of fuel oil or other flammable liquids.

13.7.7 In ships having distinguishing mark of provision with means for fire fighting on other ships in the class notation the fuel oil tanks shall contain fuel oil reserve sufficient to provide the operation of pumps of special fire-extinguishing systems during 24 h for ships with distinguishing mark **FF3WS** and 72 h for ships with distinguishing marks **FF1**, **FF1WS** , **FF2** or **FF2WS** .

13.7.8 On oil and chemical tankers, carrying liquid cargoes having a flashpoint not exceeding 60°C or toxic liquid cargoes, fuel tanks located with a common boundary to cargo or slop tanks shall not be situated within nor extend partly into the cargo tank block.

Such tanks may, however, be situated aft or forward of the cargo tank block. They may be accepted when located as independent tanks on open deck in the cargo area subject to spill and fire safety considerations.

The arrangement of independent fuel tanks and associated fuel piping systems, including the pumps, can be as for fuel tanks and associated fuel piping systems located in the machinery spaces.

For electrical equipment, requirements to hazardous area classification must however be taken into account met.

Cargo tank block is the part of the ship extending from the aft bulkhead of the aftmost cargo or slop tank to the forward bulkhead of the forward most cargo or slop tank, extending to the full depth and beam of the ship, but not including the area above the deck of the cargo or slop tank (refer to Fig. 13.7.8).

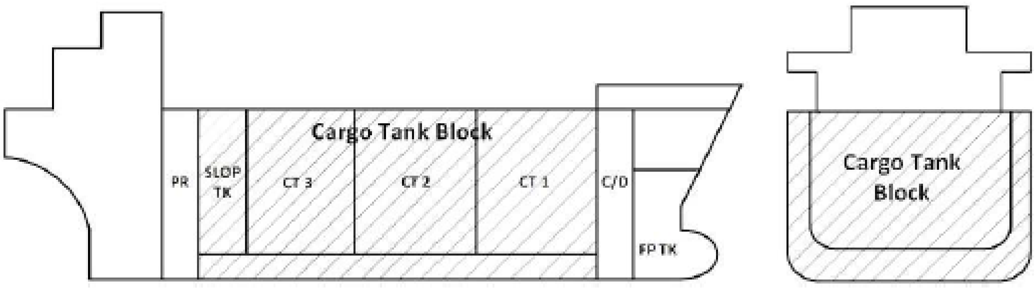

Fig. 13.7.8

13.8 FUEL OIL SUPPLY TO INTERNAL COMBUSTION ENGINES

13.8.I The equipment of fuel system shall be capable of supplying fuel oil duly prepared and cleaned to the extent required for the given engine.

The main and auxiliary engines shall be supplied with fuel oil from two fuel oil service tanks for each type of fuel used on board.

The fuel oil service tank is considered to mean a tank containing only the fuel oil prepared for use, i.e. the fuel oil the grade and properties of which meet the requirements specified by a manufacturer of the equipment.

The fuel oil service tank intended for a particular fuel oil grade shall be marked accordingly and need not be used for other purposes.

The capacity of each tank shall be sufficient for:

- 8 h operation of the main and auxiliary engines and boilers at maximum continuous rating;

- 4 h operation of the main and auxiliary engines and boilers at maximum continuous rating in passenger ships with signs **C-R3-S, C-R3-RS, D-R3-S** and **D-R3 -RS**.

The capacity of fuel oil service tanks in ships with an unattended machinery spaces and/or main machinery control room shall be sufficient for providing the machinery installation operation within the time period specified in **4.1.4** and **5.1.5**, Part XV "Automation", otherwise equivalents shall be provided to ensure compliance with the above requirements.

Use of slop tanks as the fuel oil service tanks is not permitted.

The equipment of the fuel oil system with two service tanks for each type of fuel used on board and equivalent arrangements complying with the requirements for the most commonly used fuel oil systems are shown in Figs. 13.8.1-1 and 13.8.1-2.

The scheme shown on Fig. 13.8.1-1*b*, is applied in cases when the main and auxiliary engines can operate at all loads on heavy fuel oil; as applied to the main engines, heavy fuel oil can be used when starting and reversing them.

The schemes shown on Fig. 13.8.1-1*b* and Fig. 13.8.1-2*b* are applied only in cases when arrangements and systems are used providing a quick switch from one fuel oil grade to another and capable of operating on two fuel oil grades at sea under all normal operating conditions.

Exemption from these requirements may be granted by the Register for fishing ships, ships of less than 500 gross tonnage, as well as for dredging ships, ships less than 24 m in length and berth-connected ships.

13.8.2 The filters fitted in the fuel oil supply lines to the engines shall be such that any filter can be cleaned without interrupting the operation of the engine.

The design and construction of filters shall meet the requirements of **4.2**.

13.8.3 When fuel oil is supplied to the engines, the following requirements shall be satisfied:

.1 where one booster pump is fitted to serve the main engines, except where the machinery installation comprises two or more engines, each having its own booster pump, the arrangements shall be such that the engines are supplied with fuel oil in the event of damage to the booster pump;

.2 where fuel oil is supplied to engines forming part of machinery installations comprising two or more main engines supplied with fuel oil from a single source, arrangements shall be provided to cut off fuel oil supply to each individual engine.

The cut off valves shall be remotely operated from the control station (refer also to 3.2.1.11, Part VII "Machinery Installations").

The Register may grant an exemption for cargo ships of less than 500 gross tonnage that navigate in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN.**

Heavy fuel oil service tank with a capacity for 8 h operation of main engine, diesel generators and auxiliary boilers	Heavy fuel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers	Diesel oil service tank for starting at low temperature or repairs of engines and boilers

a)

Heavy fuel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers	Diesel oil service tank with a capacity for 8 h operation of main engines, diesel generators and auxiliary boilers

b)

Fig.13.8.1-1. Heavy fuel oil service tanks for main and auxiliary engines and auxiliary boilers fuel supply: ***a*** – tanks required by SOLAS-74 Convention; ***b*** – tanks equivalent to those required by the Convention.

Note. Where pilot burners are used in auxiliary boilers, an additional diesel oil tank with a capacity for 8 h operation may be required.

Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Diesel oil service tank with a capacity for 8 h operation of auxiliary engines	Diesel oil service tank with a capacity for 8 h operation of auxiliary engines

a)

Heavy fuel oil service tank with a capacity for 8 h operation of main engines and auxiliary boilers	Diesel oil service tank with a capacity for 4 h operation of main engines, diesel generators and auxiliary boilers or for 8 h operation of diesel generators and auxiliary boilers, whichever is the greater	Diesel oil service tank with a capacity for 4 h operation of main engines, diesel generators and auxiliary boilers or for 8 h operation of diesel generators and auxiliary boilers, whichever is the greater

b)

Fig.13.8.1-2. Fuel oil service tanks for main engines and auxiliary boilers and diesel oil service tanks for auxiliary engines:
a – tanks required by SOLAS-74 Convention; ***b*** – tanks equivalent to those required by the Convention

13.8.4 Where the engines operate on different grades of fuel, precautions shall be taken to prevent auxiliary engines and other consumers from being supplied with fuel that is unfit for their operation.

13.8.5 The diesel-generating sets intended for use as emergency units shall be supplied with fuel from an independent daily service tank situated in the emergency diesel generator room.

Consumption of fuel from this tank by other consumers is not allowed, except cases specified in **9.4.2**, Part XI "Electrical Equipment" provided the requirements of **2.2.6**, Part IX "Machinery" are complied with.

The tank capacity shall be such as to ensure operation of the diesel generator for the period stated in **9.3.1**, **9.3.8** and **19.1.2.1**, Part XI "Electrical Equipment".

When emergency diesel generator is used for feeding consumers not in an emergency condition during the ship's moorage as well as in case of its use as a means to ensure that the machinery can be brought into operation from the dead ship condition (refer to **2.1.6**, Part VII "Machinery Installations"), provision shall be made of automatic refilling of emergency diesel-generator daily service tank and of low-level alarm corresponding to the volume of the emergency diesel-generator daily service tank.

Note: Service fuel tanks intended for direct fuel supply of diesel generators intended for use as emergency, shall be located separately from these machinery, excluding any possible transmission of voltages and vibrations from the operating machinery, providing a regulated supply of fuel properly prepared to the extent required for the engine.

13.8.6 The fuel oil system shall be provided with inspection and measuring instruments in accordance with **2.12**, Part IX "Machinery".

Sight glasses on pipelines shall be heat-resistant.

13.8.7 Fuel system components and connections within fuel supply lines shall be designed considering the maximum peak pressure to be experienced in service including any high pressure pulses and hydraulic impacts, which are generated and transmitted back into the fuel supply and spill lines by the action of fuel injection pumps.

13.9 FUEL OIL SUPPLY TO BOILERS

13.9.1 The fuel oil supply system with mechanical atomization, serving the main boilers and the auxiliary boilers for essential services (refer to 1.2, Part X "Boilers, Heat Exchangers and Pressure Vessels") shall include at least two sets of fuel pumps, suction and discharge filters.

Each set of machinery shall be calculated for the full steam generating capacity of the boilers served.

Apart from the local controls, the fuel pumps shall have means enabling them to be stopped from easily accessible positions outside the spaces, in which they are situated.

The main boilers shall generally be supplied from two fuel tanks.

13.9.2 The pumps supplying fuel oil to the boilers shall not be used for other purposes.

13.9.3 The pipes conveying fuel oil to the burners of each boiler shall be fitted with a quickclosing valve operated by hand.

This requirement is applicable to the boilers put into action by hand igniters and also to boilers with gravity feed of fuel oil to the burners.

13.9.4 Where fuel oil is fed to the burners by gravity, filters shall be fitted in the supply pipeline to the burners.

13.9.5 It shall be possible to bring the main boilers into operation without having to recourse to a source of power outside the ship.

13.9.6 If the fuel tanks of main and essential auxiliary boilers are used also as water ballast tanks, provision shall be made for settling tanks.

Where two daily service tanks are available, settling tanks need not be provided.

13.9.7 The oil burning installation of the boilers shall comply with the requirements of Section 5, Part X "Boilers, Heat Exhangers and Pressure Vessels".

13.10 FUEL OIL SUPPLY TO GAS TURBINES

13.10.1 The main gas turbine shall have at least two fuel feed pumps: main and standby, of which one may be driven from the main turbine.

The capacity of the standby pump shall not be less than that of the main pump. Where there are two gas turbines or more, one independent standby pump will suffice.

13.10.2 The fuel oil system of a gas turbine shall comply with the requirements of **13.8** of the present Part and **8.5.4**, Part IX "Machinery".

13.11 FUEL SYSTEM OF SHIPS, EQUIPPED FOR USING GASES OR LOW-FLASHPOINT FUELS

13.11.1 General.

13.11.1.1 The requirements of this section apply to the fuel piping of ships with the GFS mark in the ship's class notation that use natural gas as fuel (refer to 1.1.3).

13.11.1.2 Where tanks or piping are separated from the ship's structure by thermal isolation, provision shall be made for electrically bonding to the ship's structure both the piping and the tanks.

All gasketed pipe joints and hose connections shall be electrically bonded.

13.11.1.3 All pipelines or components which may be isolated in a liquid full condition shall be provided with relief valves.

13.11.1.4 Pipelines which may contain low temperature fuel shall be thermally insulated to an extent which will minimize condensation of moisture.

13.11.1.5 Wall thickness of pipes under internal pressure shall be at least equal to that determined by Formula (2.3.1), Part VII "Systems and Piping" of the Rules for the Classification and Construction of Sea-Going Ships with regard to additional requirements specified in **2.2.1 - 2.2.4**, Part VI "Systems and Piping" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

13.11.1.7 During manufacture of fuel system pipelines and selection of connections, requirements specified in **2.3** to **2.5**, Part VI "Systems and Piping" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk shall be complied with.

13.11.2 Bunkering stations.

13.11.2.1 The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment in accordance with IACS Recommendation No. 146 and in accordance with **1.1.11** IGF Code.

The bunkering station shall not be installed near the survival craft except for the liferafts required in compliance with **4.1.1.4**, Part II "Life-Saving Appliances" of the Rules for the Equipment of Sea-Going Ships.

The special consideration shall as a minimum include the following:

.1 segregation towards other areas on the ship;
.2 hazardous area plans for the ship;
.3 requirements for forced ventilation;
.4 requirements for leakage detection (e.g. gas detection and low temperature detection);
.5 safety actions related to leakage detection (e.g. gas detection and low temperature detection);
.6 access to bunkering station from non-hazardous areas through airlocks;
.7 monitoring of bunkering station by direct line of sight or by CCTV.

13.11.2.2 Connections and piping shall be so positioned and arranged that any damage to the fuel piping does not cause damage to the ship's fuel containment system resulting in an uncontrolled gas discharge.

13.11.2.**3** Arrangements shall be made for safe management of any spilled fuel.

13.11.2.4 Suitable means shall be provided to relieve the pressure and remove liquid contents from pump suctions and bunker lines.

Liquid shall be discharged to the LNG tanks or other suitable location.

13.11.2.5 The surrounding hull or deck structures shall not be exposed to unacceptable cooling in case of leakage of fue.

13.11.2.6 For CNG[12] bunkering stations, low temperature steel shielding shall be fitted to protect against low temperatures if the escape of cold jets impinging on surrounding hull structure is possible.

13.11.2.7 The bunkering manifold shall be designed to withstand the external loads during bunkering. The connections at the bunkering station shall be of dry-disconnect type equipped with additional safety dry break-away coupling/self-sealing quick release.

The couplings shall be of a standard type.

13.11.2.8 An arrangement for purging fuel bunkering lines with inert gas shall be provided.

13.11.2.9 The bunkering system shall be so arranged that no gas is discharged to the atmosphere during filling of storage tanks.

13.11.2.10 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve shall be fitted in every bunkering line close to the connecting point. It shall be possible to operate the remote valve in the control location for bunkering operations

[12]CNG station means compressed gas fuel station.

and/or from another safe location.

9.5.2.11 Means shall be provided for draining any fuel from the bunkering pipes upon completion of operation.

9.5.2.12 Bunkering lines shall be arranged for inerting and gas freeing. When not engaged in bunkering, the bunkering pipes shall be free of gas, unless the consequences of not gas freeing is evaluated and approved.

9.5.2.13 In case bunkering lines are arranged with a cross-over it shall be ensured by suitable isolation arrangements that no fuel is transferred inadvertently to the ship side not in use for bunkering.

9.5.2.14 A ship-shore link (SSL) or an equivalent means for automatic and manual ESD communication to the bunkering source shall be fitted.

9.5.2.15 The actuation time (from the trigger of the alarm to full closure) of the remote operated valve required by **13.11.2.10** shall be adjusted and be not greater than:

$$\tau \le 3600U/BR, \qquad (13.11.2.15)$$

where:

U – ullage volume at operating signal level, in m^3;

BR – maximum bunkering rate agreed between ship and shore facility, in m^3/h; or 5 s, whichever is the least.

The actuation time τ may be increased if the calculation demonstrates that it is required due to hydraulic impact hazard.

13.11.3 Requirements for redundancy of fuel supply systems.

13.11.3.1 For single fuel installations the fuel supply system shall be arranged with full redundancy and segregation all the way from the fuel tanks to the consumers so that a leakage in one system does not lead to an unacceptable loss of power.

13.11.3.2 For single fuel installations, the fuel storage shall be divided between two or more tanks.

The tanks shall be located in separate compartments.

13.11.3.3 For type C tank only, one tank may be accepted if two completely separate tank connection spaces are provided for the one tank.

13.11.4 Safety of gas supply systems.

13.11.4.1 Fuel storage tank inlets and outlets shall be provided with valves located as close to the tank as possible.

Valves required to be operated during normal operation and bunkering which are not readily accessible shall be remotely operated.

Tank valves whether accessible or not shall be automatically operated when the safety system required in **7.23**, Part XI «Electrical Equipment» is activated for automatic closure of the tank valve.

13.11.4.2 The main gas supply line to each gas consumer or set of consumers shall be equipped with a manually operated stop valve and an automatically operated master gas fuel valve coupled in series or a combined manually and automatically operated valve.

The valves shall be situated in the part of the piping that is outside the machinery space containing gas consumers, and placed as near as possible to the installation for gas treatment, if fitted.

The master gas fuel valve shall automatically cut off the gas supply to the machinery space with gas consuming engines when activated by the safety system required in **7.23**, Part XI «Electrical Equipment».

13.11.4.3 The automatic master gas fuel valve shall be operable from safe locations on escape routes inside a machinery space containing a gas consumer, the engine control room, if applicable; outside the machinery space, and from the navigation bridge.

13.11.4.4 Each gas consumer shall be provided with a double block and bleed valves arrangement[13].

These valves shall be arranged as specified in **13.11.4.4.1** and **13.11.4.4.2**, so that when the safety system required in **7.23**, Part XI «Electrical Equipment», is activated this will cause the shut-off valves that are in series to close automatically and the bleed valve to open automatically and:

.1 two shut-off valves shall be in series in the gas fuel pipe to the gas consuming equipment.

The bleed valve shall be in a pipe that vents to a safe location in the open air from that portion of the gas fuel piping that is between the two valves in series; or

.2 the functions of one of the shut-off valves in series and the bleed valve can be incorporated into one valve body, so arranged that the flow to the gas utilization unit will be blocked and the ventilation opened.

[13]Double block and bleed valves means a group of valves referenced in the following documents: **16.4.5** IGF Code

13.11.4.5 The two valves shall be of the fail-to-close type, while the bleed valve shall be fail-to-open.

13.11.4.6 The double block and bleed valves shall also be used for normal stop of the engine.

13.11.4.7 In cases where the master gas fuel valve is automatically shutdown, the complete gas supply branch downstream of the double block and bleed valve shall be automatically ventilated assuming possible reverse flow from the engine to the pipe.

13.11.4.8 There shall be one manually operated shutdown valve in the gas supply line to each engine upstream of the double block and bleed valves to assure safe isolation during maintenance of engines.

13.11.4.9 For single-engine installations and multi-engine installations, where a separate master valve is provided for each engine, the master gas fuel valve and the double block and bleed valve functions can be combined.

13.11.4.10 For each main gas supply line entering an ESD protected machinery space, and each gas supply line to high pressure installations means shall be provided for rapid detection of a rupture in the gas line in the machinery space.

When rupture is detected a valve shall be automatically shut off, the shutdown shall be time delayed to prevent blockout due to abrupt load variations. This valve shall be located in the gas supply line before it enters the machinery space or as close as possible to the point of entry inside the machinery space. It can be a separate valve or combined with other functions, e.g. the master valve.

13.11.4.11 Fuel pipes passing through enclosed spaces outside the machinery spaces shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically ventilated with 30 air changes per hour, and gas detection as required in **7.23.4**, Part XI «Electrical Equipment». This requirement may be omitted for fully welded fuel gas vent pipes passing through mechanically ventilated spaces.

Note. Refer to **13.11.4.12.**

13.11.4.12 Protection of fuel piping[14].

.1 Fuel pipes passing through enclosed spaces outside the machinery spaces shall be protected by a secondary enclosure. This enclosure can be a ventilated duct or a double wall piping system. The duct or double wall piping system shall be mechanically ventilated with 30 air changes per hour, and gas detection as required in **7.23.4**, Part XI «Electrical Equipment». The Administration may take other decisions that provide an equivalent level of security.

This requirement may be omitted for fully welded fuel gas vent pipes passing through mechanically ventilated spaces.

.2 Liquefied fuel pipes shall be protected by a secondary enclosure able to hold leaks. For piping passing through fuel preparation room or a tank connection space, the Register may not require compliance with this requirement.

The secondary enclosure shall withstand the maximum pressure possible due to leakage from the liquefied fuel pipi. For this purpose, a pressure relief system may be provided in the secondary enclosure, which prevents the pressure in the enclosure from rising above the calculated values..

13.11.5 Fuel supply in gas-safe machinery spaces.

13.11.5.1 Fuel piping in gas-safe machinery spaces shall be completely enclosed in external pipes or ducts fulfilling one of the following conditions:

.1 the gas piping shall be a double wall piping system with the gas fuel contained in the inner pipe.

The space between the concentric pipes shall be pressurized with inert gas at a pressure greater than the gas fuel pressure.

Suitable alarms shall be provided to indicate a loss of inert gas pressure between the pipes.

When the inner pipe contains high pressure gas, the system shall be so arranged that the pipe between the master gas valve and the engine is automatically purged with inert gas when the master gas valve is closed; or

.2 the gas fuel piping shall be installed within a ventilated pipe or duct.

The air space between the gas fuel piping and the wall of the outer pipe or duct shall be equipped with mechanical underpressure ventilation having a capacity of at least 30 air changes per hour.

This ventilation capacity may be reduced to 10 air changes per hour provided automatic filling of the duct with nitrogen upon detection of gas is arranged for.

[14] Refer to IMO MSC.458(101). In force since з 01.01.2024.

The fan motors shall comply with the required explosion protection in the installation area.

The ventilation outlet shall be screened and placed in a position where there are no flammable sources.

13.11.5.2 Pipes other than fuel pipelines including cable protection pipes may be made with double walls or enclosed in the ducts specified in **13.16.5.1.1** provided that they are not a flammable source and do not affect the integrity of double-wall pipes or duct.

Double-wall pipes or duct shall contain only pipes or cables required for operation of gas fuel supply installation and test devices.

13.11.5.3 The connecting of gas piping and ducting of internal combustion engines leading to the gas injection valves shall be completely covered by the ducting.

The arrangement of ducting shall facilitate replacement and maintenance of injection valves and cylinder covers.

The double ducting is also required for all gas pipes on the engine itself, until gas is injected into the chamber.

If gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space, double ducting may be omitted on the air inlet pipes.

13.11.6 Gas fuel supply in ESD protected machinery spaces.

13.11.6.1 The pressure in the gas fuel supply system pipelines in ESD protected machinery spaces shall not exceed 1 MPa.

13.11.6.2 The gas fuel supply lines shall have a design pressure not less than 1 MPa.

13.11.7 Regulations for the design of ventilated duct, outer pipe against inner pipe gas leakage.

13.11.7.1 The design pressure of the outer pipe or duct of fuel systems shall not be less than the maximum working pressure of the inner pipe.

Alternatively, for fuel piping systems with a working pressure greater than 1 MPa, the design pressure of the outer pipe or duct shall not be less than the maximum built-up pressure arising in the annular space considering the local instantaneous peak pressure in way of any rupture and the ventilation arrangements.

13.11.7.2 For high-pressure fuel piping, the design pressure of the ducting shall be taken as the higher of the following:

.1 the maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

.2 local instantaneous peak pressure in way of the rupture: this pressure shall be taken as the critical pressure determined by the following formula:

$$p=p_0[2/(k+1)]^{k/(k-1)}, \qquad (13.11.7.2.2)$$

where:

p_o – maximum working pressure of the inner pipe;

k = ***Cp/Cv*** – constant pressure specific heat divided by the constant volume specific heat.

k = 1,31 for CH_4 (methane).

The tangential membrane stress of a straight pipe shall not exceed the tensile strength divided by 1,5(R_m/1,5) when subjected to the above pressure.

The pressure ratings of all other piping components shall reflect the same level of strength as straight pipes.

As an alternative to using the peak pressure in accordance with Formula (13.11.7.2.2) the peak pressure resulted from the tests conducted can be used.

13.11.7.3 Verification of the strength shall be based on calculations demonstrating the duct or pipe integrity.

As an alternative to calculations, the strength can be verified by tests.

13.11.7.4 For low pressure fuel piping the duct shall be dimensioned for a design pressure not less than the maximum working pressure of the fuel pipe.

The duct shall be pressure tested to show that it can withstand the expected maximum pressure at fuel pipe rupture.

13.11.8 Requirements for compressors and pumps.

13.11.8.1 If compressors or pumps are driven by shafting passing through a bulkhead or deck, the bulkhead penetration shall be of gastight type.

13.11.8.2 Compressors and pumps shall undergo special tests to ensure their suitability for use within a marine environment.

The following, at least, shall be considered:

.1 environmental conditions;

.2 shipboard vibrations and accelerations;

.3 effects of pitch heave and roll motions;

.4 gas composition.

13.11.8.3 Arrangements shall be made to ensure that under no circumstances liquefied gas can be introduced in the gas control section or gas-fuelled machinery, unless the machinery is designed to operate with gas in liquid state.

13.11.8.4 Compressors and pumps shall be fitted with accessories and instrumentation necessary for efficient and reliable function.

13.12 APPLICATION OF NATURAL GAS (METHANE) AS FUEL

13.12.1 The requirements of this section are in addition to the general provisions of 13.11 in the case of the use of natural gas as a fuel for dual-fuel engines (DFEs), gas-fuel engines (GFEs) and gas-turbine engines (GTEs) that use natural gas (methane) as fuel (hereinafter - gas fuel).

13.12.2 Gas fuel piping shall not be laid through control stations, accommodation and service spaces.

Laying of gas fuel pipelines through other spaces is allowed in compliance with the requirements of **13.12.3.**

13.12.3 Gas fuel piping can be arranged in one of the ways specified in 13.12.3.1 та 13.12.3.2.

13.12.3.1 The pipeline represents a piping system with double walls containing gas fuel inside the internal pipe.

The following conditions shall be met:

.1 the space between the walls shall be filled with inert gas under pressure exceeding gas fuel pressure;

.2 inert gas pressure shall be constantly monitored by the alarm system;

.3 at the alarm system actuation the automatic valves mentioned in **13.12.5** and the main gas valve indicated in **13.12.6** shall be automatically closed prior the inert gas pressure drops lower than the pressure of gas fuel, and vent valve stated in **13.12.5** shall be automatically opened;

.4 the system shall be arranged so that the internal part of gas fuel supply pipeline between the main gas valve and engine be automaticaly purged with inert gas, when the main gas valve is closed.

13.12.3.2 Gas fuel pipelines shall be installed in the pipe or duct with artificial exhaust ventilation of the space between them.

The capacity of exhaust ventilation shall be calculated basing on the velocity of gas fuel flow, structure and location of protective pipes or ducts and provide at least 30 air changes per hour.

Therewith the following conditions shall be met:

.1 the pressure in the space between the external and internal walls of pipelines or ducts shall be kept lower than the atmospheric pressure;

.2 provision shall be made for the gas leakage detector and the cut-off of the gas supply to the engine room;

.3 electrical motors shall be of explosion-proof design and be located outside the pipes and ducts;

.4 when the required air flow is not maintained by the ventilation system, the main gas valve, mentioned in 13.12.6, shall be closed automatically.

Ventilation shall function every time when gas is supplied through the pipeline;

.5 air intakes of the ventilation system shall be provided with non-return devices.

These requirements are not compulsory when gas detectors are fitted in the air intakes;

.6 provision shall be made for inertization and degasification of gas fuel pipeline system section located in the engine room.

13.12.4 For the engine rooms of category A where gas fuel is used the additional requirements to ventilation shall be met.

13.12.4.1 Engine rooms shall be fitted with ventilation system precluding gas pockets. Ventilation shall be particularly effective in the area of electrical equipment installation, machinery or other possible sources of spark formation.

The ventilation system shall be separated from the ventilation of other slpaces and meet the requirements of **12.14**.

13.12.4.2 Engine rooms shall be equipped with the effective gas detection system in the places of possible gas lock and leakage.

When the concentration of gas is equal to 30 % of low flammability limit, the audible and visible alarms shall be actuated, and when the concentration of gas is equal to 60 % of low flammability limit, the supply of gas fuel to the engine room shall be cut off.

13.12.5 Installation of double block and bleed valves.

Gas fuel supply system shall be fitted with three automatic valves (refeer to **13.11.4**).

Two of them shall be installed in succession in the system of gas fuel supply to the engine.

The third valve (ventilation) shall be mounted for gas discharge from the pipe section located between two automatic valves installed in succession to the safe place on the weather deck.

the pressure in the gas fuel supply pipeline fluctuates from the set values;

loss of energy for valve driving;

violation of the conditions stated in **13.12.3.1** and **13.12.3.2**;

stop of the engine because of any reason, two valves installed in succesion shall be closed automatically and the third valve (ventilation) shall be opened automatically.

As an alternative, one of two valves installed in succession and the ventilation valve may be combined in one body, provided their performance of the above-mentioned functions.

All three valves shall be manually operated.

13.12.6 The main gas valve shall be installed outside the engine room and be equipped with remote control to enable its closing from the engine room.

This valve shall be automatically closed in the following cases:

leakage of gas fuel;

violation of the conditions stated in **13.12.3.1** and **13.12.3.2**;

actuation of oil mist concentration sensor in the engine crankcase or in the temperature control system of the engine bearings.

It is advisable, that the main gas valve is automatically closed at the actuation of interlocked gas valves (refer to Section 9, Part IX "Machinery").

13.12.7 Gas line shall have sufficient structural strength with regard to stresses caused by the mass of the pipeline, internal pressure, loads caused by bends of the ship's hull and accelerations.

13.12.8 The structure of protective pipes or ducts of the ventilation system mentioned in**13.12.3.1** i **13.12.3.2**, shall have strength sufficient to withstand fast increase of pressure in case of pipeline break. Requirements of **13.11.7** shall be taken into account.

A number of split connections in protective pipes or ducts shall be minimum.

13.12.9 As a rule, gas pipelines shall be connected with complete-penetration butt welds and special means for provision of weld root quality and completely radiographically tested (refeer to **1.5**).

All butt welds after welding are subjected to heat treatment depending on the material.

13.12.10 The installation for gas fuel supply and reservoirs for its storage shall comply with the following requirements:

.1 the construction, control and safety system of gas compressors, pressure vessels and heatexchangers incorporated in the gas fuel supply system, shall meet the requirements of the appropriate parts of the Rules;

.2 during the design work and calculation the possibility of fatigue failure of gas pipelines because of vibration as well as fluctuation of pressure when gas fuel is supplied by the compressors, shall be taken into consideration.

13.12.11 Gas supply to dual-fuel engines and gas turbines shall meet the requirements of **8.10** and Section **9**, Part IX "Machinery".

13.13 FUEL OIL SYSTEMS FOR HELICOPTERS

13.13.1 Helicopter refuelling systems.

13.13.1.1 Shipboard helicopter refuelling system shall comply with the requirements actual in the Civil Aviation of Flag State in part of bunkering, storage, cleaning, quality control and fuel filling.

Refuelling facilities shall be certified (approved) for compliance with the requirements of the Flag State aviation regulations.

13.13.1.2 All the equipment used in refuelling operations shall be effectively earthed.

All the equipment, arrangements, machinery and deck coverings shall be manufactured and installed so as to prevent spark formation.

13.13.1.3 The refueling pipeline shall be fitted with safety equipment that prevents the overpressure in the refueling hose.

13.13.1.4 As a rule, tanks used for storage of helicopter fuel shall be located on the open deck in specially designed area, which shall be:

.1 as remote as practicable from accommodation and machinery spaces, escape routes and embarkation stations, as well as from locations containing sources of ignition;

.2 isolated from areas containing sources of vapour ignition;

.3 the fuel storage area shall be provided with arrangements whereby fuel spillage may be collected and drained to off-grade fuel tank;

.4 where tanks for storage of helicopter fuel and off-grade fuel tanks are located in enclosed spaces, such tanks shall be surrounded by cofferdams filled with inert gas;

.5 in cofferdams referred to in **13.13.1.4.4** the length of oil fuel line and the number of its detachable joints shall be kept to a minimum, and its valves shall be located in easily accessible places, generally, on the open deck;

.6 cofferdams referred to in **13.13.1.4.4** shall not be connected to any piping system serving other spaces.

13.13.1.5 Provision shall be made for fuel jettisoning from tanks of the helicopter located on the helideck or in hangar to the off-grade fuel tank.

Provision shall be made for off-grade fuel delivery to the shore or ship's tanks.

13.13.1.6 Tanks used for storage of helicopter fuel and associated equipment shall be protected against physical damage and from a fire in an adjacent space or area. Tanks shall be protected against direct sunrays.

13.13.1.7 When equipping tanks for the storage of helicopter fuel with facilities for their emergency jettisoning precautions shall be taken to prevent the tank jettisoned from impact against ship's structures.

The tanks shall be as remote as practicable from survival craft muster and embarkation stations and survival craft launching stations.

13.13.1.8 The fuel tanks shall be made of materials which resist attacks by corrosion and helicopter fuel. Fuel may be stored both in transported and fixed tanks.

Tanks shall be efficiently secured, closed and bonded.

The tanks shall be readily accessible for inspection.

Tanks and piping for anti-crystallization fluids shall be made of stainless steels.

13.13.1.9 Each fuel oil tank shall be fitted with filling, outlet, sounding and air pipes. The end of a filling pipe shall not be more than 300 mm above a tank bottom. It is recommended to use closed-type flowmeters.

The sounding pipe shall end 30 to 50 mm above a tank bottom and shall be laid to the open deck.

13.13.1.10 Air pipes of fuel oil tanks shall be laid to a height of at least 2,4 m above the open deck.

Open ends of air pipes shall be spaced at a distance of at least 10 m from air intakes and openings of enclosed spaces with ignition sources, and from a deck machinery and equipment, which may present an ignition hazard, and shall be fitted with flame-arresting meshes or other fittings approved by the Register.

13.13.1.11 A fuel oil pump shall take in fuel oil simultaneously from one tank only.

Pipelines shall be made of steel or equivalent material, shall be short (where possible) and shall be protected against damages.

13.13.1.12 Fuel oil pumps shall be provided with shutdown means positioned in a remote safe place. Service tanks shall be provided with quick-closing valves driven from outside the tank area.

13.13.1.13 All pipelines and equipment of the system for bunkering, storage and fuelling shall be electrically continuous and shall be earthed to the ship hull.

13.13.1.14 Fuel pipelines shall have no stagnant sections.

Where it is structurally impossible to avoid stagnant sections, provision shall be made for pipe drainage by means of nitrogen purging or another way of pipeline emptying.

The lower parts of piping system shall be provided with drain cocks to remove sediment to off-grade fuel tank.

13.13.1.15 Helicopter refuelling system shall be so designed as to provide free access for its maintenance, fuel sampling and repair.

13.13.2 Ventilation system of hangars and spaces where helicopter refuelling and maintenance facilities are located shall meet the requirements of **12.11**.

13.13.3 Helicopter refueling station shall meet the requirements of **6.1.3.3**, Part VI "Fire Protection".

13.13.4 A helicopter operation manual shall be provided on board, including a description of the equipment, a list of inspections, safety requirements and equipment maintenance procedures. This Manual shall also include procedures and precautions to be followed during refueling operations designed in accordance with recognized safe practice.

13.14 LIQUEFIED GAS SYSTEM FOR DOMESTIC NEEDS

13.14.1 The use of gas meeting the requirements of current national standards is permitted.

13.14.2 Liquefied gas may be used for galley ranges, as also for straight-through liquid heaters (including provision refrigerators) consuming not more than 1 kg of liquefied gas per hour.

13.14.3 Only standard gas containers and gas-consuming appliances of type approved by competent technical supervision bodies may be installed on board the ship.

13.14.4 An automatic safety gas shut-off device shall be fitted on gas-consuming appliances, which operates in the event of flame failure.

For straight-through heaters this device shall have check flame.

13.14.5 Gas containers shall be stowed in a special compartment on the open deck, complying with the requirements of **2.1.5.3**, Part VI "Fire Protection" with direct access to the open deck.

Where provision is made for stowage of not more than two gas containers, they may be arranged in an enclosed recess in the superstructure or deckhouse, or in a steel locker.

Furthermore, the stowage compartment for gas containers shall meet the following requirements:

.1 efficient natural ventilation shall be provided, account being taken of the provisions of **12.1.4** and **12.4.6**.

In addition to natural ventilation, mechanical ventilation may be used, the requirements of **12.1.4** being taken into consideration;

.2 where necessary, structural arrangements shall be made to maintain the temperature in the compartment not exceeding +50°C;

.3 electric illumination and electrical equipment at a distance of 2 m from openings to the compartment shall comply with the requirements of **2.9**, Part XI "Electrical Equipment";

.4 a warning notice recalling of the risk of explosion and prohibiting the use of naked flame and smoking shall be displayed on the door.

13.14.6 The installation of gas containers in the compartment shall comply with the following requirements:

.1 cylinders shall be installed with stop valves upwards and be secured with quick-detachable arrangements. Other measures shall be taken to quickly release containers;

.2 a reducing valve shall generally be fitted on the container head; in this case, flexible hose of approved type may be used for connection of the reducing valve to the liquefied gas pipeline;

.3 if a group of containers is connected to the manifold, only one reducing valve shall be fitted between each container and the manifold; in this case, containers shall be connected to manifold by copper pipes;

.4 where more than one container is connected to the manifold, shut-off valve or cock shall be fitted between each container and the manifold. A notice prohibiting the simultaneous use of more than one container shall be displayed in the compartment.

13.14.7 Compartments containing gas-consuming appliances shall be equipped in compliance with **2.1.5.2**, Part VI "Fire Protection" and meet the following requirements:

.1 they shall not be arranged below the upper deck and be provided with efficient natural ventilation for extraction of combustion products and air taking from the lower part of the compartment;

.2 where the compartment is partially below the open deck, it shall be provided with mechanical ventilation;

.3 straight-through gas-consuming appliances shall be provided with separate lines for removal of combustion products.

13.14.8 Pipes shall be of seamless steel or copper. Steel pipes shall be protected against corrosion.

13.14.9 The thickness of pipe walls shall meet the requirements of column 2 or 8, Table 2.3.8.

13.14.10 Pipes from gas containers to gas-consuming appliances shall be laid over the open deck and be protected against mechanical damages.

13.14.11 Pipe joints shall be welded. Threaded or flange joints are permitted only in places of connection of instrumentation lines, gas-consuming appliances and valves.

13.14.12 A shut-off valve or cock shall be fitted on the pipe where it pierces the bulkhead of the container compartment, this valve or cock being operated from outside the compartment. The valve or cock shall be provided with a turning limiter and a plug position indicator.

13.14.13 Where more than one gas-consuming appliance is installed, a shut-off valve or cock provided with a turning limiter and a plug position indicator shall be fitted on branches from a common pipe line to each gas-consuming appliance.

Where these valves or cocks are fitted in the container compartment, provision shall be made for their operation from outside the compartment; in this case, the installation of a cock or valve on the common pipe line may be omitted (refer to **13.14.12**).

13.14.14 The reducing valve shall provide the pressure of not more than 5 kPa in the system.

13.14.15 The reducing valve or the pipe line after it shall be provided with a safety valve with a setting pressure less than 7 kPa with gas outlets piped to a safe place of the upper deck.

Where the reducing valve is so designed that gas outlet to a low pressure pipe line is closed in case of failure or break of the diaphragm, the safety valve need not be provided.

13.14.16 Valves shall be of bronze, brass or other corrosion-resistant material.

13.14.17 Liquefied gas pipe lines from containers to reducing valves shall be tested:

in ship, by hydraulic pressure of 2,5 MPa;

in ship, by air pressure of 1,7 MPa.

Pipelines from reducing valves to gas-consuming appliances shall be tested by air pressure of 0,02 MPa after installation on board.

13.15 FUEL OIL SUPPLY SYSTEM FOR GALLEY EQUIPMENT

13.15.1 It is permitted to use fuel oil with a flash point not less than 60 8C for galley equipment.

13.15.2 The capacity of fuel oil service tanks located in galleys shall not exceed the daily consumption requirement.

13.15.3 A shut-off valve on the supply pipe shall be remotely controlled from readily accessible place outside the galley. It is recommended to use quick-closing type valves.

13.15.4 Tanks, fuel oil pumps and heaters shall be placed at least 2 m from the nearest point on the heating equipment, and at a 0,5 m distance from the same in the plan view of the place.

13.15.5 If the galley space is sufficiently large, fuel oil tanks, pumps and other appliances of the fuel oil system shall be placed in special enclosures.

13.15.6 All oil-fired equipment, burners included, shall be fitted with trays underneath (or an equivalent protection provided directly on the steel deck), with beads not less than 75 mm in height, extending not less than 100 mm outside the equipment perimeter.

13.16 INERTING AND ATMOSPHERE CONTROL FOR SHIPS EQUIPPED FOR USING GASES OR LOW-FLASHPOINT FUELS

13.16.1 Inerting of fuel tanks.

13.16.1.1 A piping system shall be arranged to enable each fuel tank to be safely gas-freed, and to be safely filled with fuel from a gas-free condition.

The system shall be arranged to minimize the possibility of gas or air pockets remaining after changing the atmosphere.

13.16.1.2 The system shall be designed to eliminate the possibility of a flammable mixture existing in the fuel tank during any part of the atmosphere change operation by utilizing an inerting medium as an intermediate step.

13.16.1.3 Gas sampling points shall be provided for each fuel tank to monitor the progress of atmosphere change.

13.16.1.4 Inert gas utilized for gas freeing of fuel tanks may be provided externally to the ship.

13.16.2 Atmosphere control within fuel storage hold spaces (other than type C tanks)[15].

13.16.2.1 Interbarrier and fuel storage hold spaces associated with liquefied gas fuel containment systems requiring full or partial secondary barriers shall be inerted with a suitable dried inert gas and kept inerted with make-up gas provided by a shipboard inert gas generation plant, or by shipboard storage, which shall be sufficient for normal consumption for at least 30 days.

13.16.2.2 The spaces referred to in **13.16.2.1**, requiring only a partial secondary barrier may be filled with dry air provided that the ship maintains a stored charge of inert gas or is fitted with an inert gas generation plant sufficient to inert the largest of these spaces, and provided that the configuration of the spaces and the relevant vapour detection systems, together with the capability of the inerting arrangements, ensures that any leakage from the LNG tanks[16] will be rapidly detected and inerting effected before a dangerous condition can develop. Equipment to produce sufficient amount of suitable quality dry air shall be provided to satisfy the expected demand.

13.16.3 Environmental control of spaces surrounding type C tanks.

13.16.3.1 Spaces surrounding LNG tanks shall be filled with suitable dry air and be maintained in this condition with dry air provided by suitable air drying equipment. This requirement is only applicable for LNG tanks where condensation and icing due to cold surfaces is are possible.

13.16.4 Requirements for inerting.

13.16.4.1 Arrangements to prevent back-flow of fuel vapour into the inert gas system shall be provided. To prevent the return of flammable gas to any gas-safe spaces the inert gas supply line shall be fitted with two shutoff valves in series with a venting valve in between (double block and bleed valves). In addition, a closable non-return valve shall be installed between the double block and bleed arrangement and the fuel system. These valves shall be located outside gas-safe spaces.

13.16.4.2 Where the connections to the fuel piping systems are non-permanent, two non-return valves may be substituted for the valves specified in **13.16.4.1**.

13.16.4.3 The arrangements shall be such that each space being inerted can be isolated and the necessary controls and relief valves, etc. shall be provided for controlling pressure in these spaces.

13.16.4.4 Where insulation spaces are continually supplied with an inert gas as part of a leak detection system, means shall be provided to monitor the quantity of gas being supplied to individual areas and spaces.

13.16.5 Inert gas production and storage on board.

13.16.5.1 Inert gas generation plant shall be capable of producing inert gas with at no time greater than 5 % oxygen content by volume.

A continuous-reading oxygen content meter shall be provided at the inert gas generator output and shall be fitted with an alarm set at a maximum of 5 % oxygen content by volume.

13.16.5.2 An inert gas system shall be fitted with pressure controls and monitoring arrangements appropriate to the fuel containment system.

13.16.5.3 Where a nitrogen generator or nitrogen storage facilities are installed in a separate compartment outside the machinery space, this compartment shall be fitted with a mechanical extraction ventilation system with the capacity of at least 6 air changes per hour.

A low oxygen alarm shall be fitted

13.16.5.4 Inert gas pipelines shall only be laid through well ventilated spaces. Pipelines in enclosed spaces shall:

be fully welded;

have only a minimum of flange connections as needed for fitting of valves; and

be as short as possible.

13.17 USE OF CRUDE OIL OR OTHER FLAMMABLE LIQUIDS HAVING A FLASHPOINT OF 60°C OR LESS AS FUEL

13.17.1 Use of crude oil or other flammable liquids having a flash point of 60°C or less as fuel shall be allowed in compliance with the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).

13.17.2 Use of crude oil or cargo residues.

13.17.2.1 Crude oil or cargo residues may be used as fuel for main and auxiliary boilers on oil tankers in accordance with the provisions of **13.17.1** and the requirements of this Chapter.

Drawings of the general arrangement of the installation with the scheme of piping and safety devices shall be submitted to the Register for approval. Supply of crude oil or cargo residues shall be performed from cargo and special tanks installed in the cargo tanks area. They shall be separated from gas-safe areas by cofferdams with gas-tight bulkheads.

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[15] Type C tank means independent fuel storage tanks (FST) that meet the requirements for type C independent cargo tanks of gas carriers (refer to **2.10.1.2**, Part VII "Machinery Installations").

[16] LNG tank means liquefied gas fuel storage tank (LNG).

13.17.2.2 The design of boilers and burners shall be fit for use crude oil.

The outer casing of boilers shall be gas-tight relative to the engine room.

Boilers shall be tested for gas tightness before operation.

The entire system of pumps, filters, separators and heaters, if any, shall be installed in the cargo pump room or any other room which is considered dangerous and is separated from the engine-boiler room by gas-tight bulkheads.

If crude oil is to be heated by steam or hot water, the heating coil outlets must be routed to a separate control tank fitted with the above equipment.

This control tank shall be fitted with an air pipe laid to a safe positions on the open deck in accordance with **10.1.6**, as applicable to oil tankers.

The outlet of the air pipe shall be fitted with easily removable flame interrupting valves.

13.17.2.3 The arrengement of pumps, separators, etc. driving machinery shall comply with **4.2.5**, Part VII "Machinery Installations".

13.17.2.4 Pumps shall be fitted with safety valves for oil drainage into the suction cavity of the pump or the suction part of the pipe.

The pump shall be provided with stopping means operable from the station, located near the front of the boilers or CCR, as well as outside the engine room.

13.17.2.5 If crude oil or cargo residues need to be heated, their temperature shall be regulated automatically; at the same time, temperature excess alarm shall be fitted.

13.17.2.6 The thickness of crude oil or cargo residues pipe walls, as well as sewage pipes from the trays specified in **13.17.2.8**, shall comply with column 5 of table 2.3.8.

The number of connections of these pipes shall be minimal.

Detachable pipe connections shall be of flange type and meet the requirements of Table 2.4.3.3 for Class I pipes.

The above pipes along their entire length within the engine and boiler rooms shall be laid in a metal gas-tight duct, tightly connected to the the pump room bulkhead and then to trays specified in **13.17.2.8**.

Such a duct with a pipeline passing inside shall rise towards the boiler, so that when the fuel supply pressure drops or leaks, the fuel returns to the pump room by gravity.

In addition, the channel shall be installed at least one-fifth of the breadth amidship from the inner shell plating.

The duct shall have gas-tight inspection devices with gas-tight lids in the area of the pipe joints located inside the duct, as well as an automatically closing drainage arrangement located in the pump room and installed to direct crude oil to the pump room in case of leakage.

The sewage tank specified in **13.17.2.8** shall be equipped with level indicators with appropriate leak alarm.

The open ends of air pipe fitted at the top of this duct shall be laid to a safe positions on the open deck in accordance with **10.1.6**, as applicable to oil tankers. The outlet of the air pipe shall be fitted with easily removable flame interrupting valve.

The duct shall be permanently connected to the inert gas or steam system to provide the following:

supply of inert gas or steam in case of fire or leakage,

purge of the duct before starting work in case of fuel leakage.

13.17.2.7 Oil supply and return pipelines in the area of the bulkhead to which the duct specified in 13.17.2.6 is connected shall be fitted with shut-off valves on the pump-room side remotely-controlled from a station near the boiler front or CCR.

These valves shall be interlocked with the duct exhaust fans specified in **13.17.2.9** to ensure operation of the fans during the crude oil supply.

13.17.2.8 Boilers shall be fitted with trays or gutters not less than 200 mm high, to collect all possible fuel leaks from burners, valves and connections. Trays and gutters shall be fitted at the top with easily removable flame-breaking valves.

Fuel supply and return pipes shall pass through a tray or sewer with an impermeable sealing and then be connected to the fuel collectors. A quick-closing control valve shall be fitted on the pipeline to each collector.

The tray or gutter shall be fitted with a sewage pipe to drain fuel into the sewage tank in the pump room. This tank shall be fitted with an air pipe laid to the open deck.

The outlet of the air pipe shall be fitted with easily removable flame interrupting valve. The above sewage pipe shall be fitted with arrangement to prevent the return of fuel to the boiler or engine room.

13.17.2.9 The boilers shall be fitted with a suitable casing installed to contain as much as possible burners, valves and fuel pipes, without interfering with the supply of air to the burners nozzles.

If necessary, the casing shall be fitted with devices for inspection and access to the fuel pipes and valves located behind it.

The casing shall be fitted with a ventilation duct, laid to a safe place on the open deck and provided with easily removable flame-breaking valve.

At least two mechanical exhaust fans with intrinsically safe impellers shall be provided to maintain a lower pressure inside the casing than in the boiler room.

The above exhaust fans shall be fitted with an automatic device to switch on another fan in the event of a stop or failure of the working one.

Exhaust fan drives shall be located outside the duct, and shafts shall be fitted with gas-tight gasckets.

Electrical equipment installed in hazardous areas or areas that may become hazardous (e.g. inside crude oil piping casing or duct) shall be of explosion-proof design.

13.17.2.10 Supply of fuel to the boilers and return from them shall be provided; the boiler room shall be equipped in accordance with the requirements of **13.9** and **5**, Part X "Boilers, heat exchangers and pressure vessels".

Supply of fuel to burners and return from them shall be carried out by the mechanical blocking device which automatically stops supply of boiler fuel when using crude oil and vice versa.

13.17.2.11 Boiler room shall be fitted with mechanical ventilation, designed in to avoid stagnant zones.

Ventilation shall be especially effective in the area where electrical equipment, machinery and other devices that can be sources of sparking are fitted.

Such ventilation shall be separated from the ventilation of other spaces and meet the requirements of **12.4**.

13.17.2.12 A leak detection device shall be provided with sensors installed in the duct specified in 13.17.2.6, on the casing of the boiler front closure, in the jet from the exhaust fans and in all areas, where reduction in ventilation efficiency is possible.

Light and sound alarms shall be fitted near the boiler front and in the CCR.

13.17.2.13 Provisions shall be taken for automatic purging of the boiler before ignition.

13.17.2.14 Notwithstanding the fixed fire-extinguishing system required by Part VI "Fire Protection" for machinery spaces, an additional fire-extinguishing installation (refer to **3.1.2.8**, Part VI "Fire Protection") shall be provided for direct supply of the approved extinguishing agent to front of the boilers and on the tray specified in **13.17.2.8**.

The supply of extinguishing agent shall automatically stop the boiler casing exhaust fans (refer also to **13.17.2.7**).

13.17.2.15 A warning sign shall be installed near the boiler front in a clearly visible place, stating that in the event of explosive mixtures, as indicated by the alarm specified in **13.17.2.12**, service personnel shall immediately switch off the remotely operated valves installed in pump room on the crude oil supply and return pipelines, pumps, supply inert gas to the duct specified in **13.17.2.6**, and switch the boilers to run on conventional fuel.

13.17.2.16 The Register reserves the right to require the installation of an ignition nozzle in addition to the usual combustion control.

14. LUBRICATING OIL SYSTEM

14.1 LUBRICATING OIL PUMPS OF INTERNAL COMBUSTION ENGINES, GEARS AND COUPLINGS

14.1.1 For an installation with one main engine provision shall be made for not less than two lubricating oil pumps, main and standby, of the same capacity. One of these pumps may be driven from the main engine.

14.1.2 Where two or more main engines are installed, each of them shall have its own lube oil pump, with provision for one stand-by pump driven independently and having a capacity sufficient to ensure the operation of each engine. It is permitted to have on the ship a spare pump as stand-by provided that it is accessible for mounting in operational conditions.

14.1.3 In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** standby pumps may not be installed irrespective of the number of main engines.

This exception shall not apply to the tugs with one main engine of restricted navigation area **R2**.

14.1.4 Where the turbo-blowers of the main engine have an independent electrically driven lubricating oil pump, provision shall be made for a standby pump of adequate capacity and a gravity tank containing sufficient oil to maintain lubrication of the turbo-blowers during idle rotation if the oil pump stops working.

Warning alarms shall operate for low level in the tank and automatic start-up of standby pump shall be ensured at stoppage of the pump at work.

Means shall be provided to enable the oil flow in turbo-blower bearings to be controlled.

14.1.5 Lubricating oil pumps of main gearing, as well as the pumps supplying the main fluid couplings, shall comply with the requirements of **14.1.1** to **14.1.3** for the main engines.

14.1.6 Each auxiliary engine and each emergency diesel generator engine (refer to **2.2.5**, Part IX "Machinery") shall have a separate lubricating system.

14.1.7 The lubrication of oil-lubricated sterntube bearings shall comply with the requirements of **5.6.3** and **5.6.4**, Part VII "Machinery Installations".

14.2 LUBRICATING OIL SUPPLY TO INTERNAL COMBUSTION ENGINES AND GEARS

14.2.1 The design of a lubricating oil drain tank and the operating oil level in it, as well as the arrangement of pump suction pipes shall prevent a lubricating oil flow separation at the maximum static and dynamic heel and trim angles, which are probable for the given ship.

The lubricating oil drain pipes from the engine crankcase shall terminate in the oil drain tank so as to be submerged in oil all the time of the engine operation.

No communication is permitted between lubricating oil drain pipes of two or more engines.

14.2.2 The pipes of the lubricating oil system shall not communicate with other piping systems, except where they are connected to separators, which may be used for fuel oil separation. In the latter case, arrangements shall be fitted, which will preclude mixing of fuel oil and lubricating oil. While separating a lube oil, precautions shall be taken to prevent mixing of lubricating oils of different specifications.

14.2.3 The lubrication system shall provide effective cleaning of oil, for which purpose filters shall be fitted as follows:

.1 magnetic filter generally on the suction side of the pump of the gears;

.2 one coarse filter (strainer) on the suction side of the main engine pump; two parallel filters or one duplex filter or a self-cleaning filter on the discharge side of the main engine pump.

The design and construction of filters shall meet the requirements of **4.2** and **13.8.2**.

14.2.4 The capacity of each oil filter shall exceed by 10 % the maximum capacity of the pump.

14.2.5 The lubricating system shall be fitted with instrumentation in accordance with **2.12**, Part IX "Machinery".

The pressure gauge indicating the pressure after the oil cooler shall be placed at the control station.

14.2.6 Where a common lube oil system for the engine and turbochargers is used, upstream of the turbocharger bearings fine gage strainers shall be fitted; strainer design shall allow their cleaning without stopping the circulation of oil. A pressure gauge shall be fitted downstream of the strainers.

14.3 LUBRICATING OIL PUMPS OF STEAM TURBINES AND GEARS

14.3.1 The lubricating oil system of the main turbine set shall be serviced by two oil pumps, the capacity of each pump being sufficient to ensure lubrication of the turbine set for maximum output condition.

At least one of the pumps shall be independently driven.

Where two main turbine sets are arranged in the same space, one independent standby pump may be fitted for both turbine sets.

14.3.2 Lubricating oil pumps shall be of self-priming type and shall be so disposed that reliable start-up is always possible.

14.3.3 In general, the lubricating oil for main turbine sets shall be supplied from the gravity tank, with arrangements to be such that lubrication is supplied to the turbines also in the event of damage to the main oil pump, and until the turbines come to rest at failure in power supply from the main sources of power to the motors of oil pumps.

14.4 LUBRICATING OIL SUPPLY TO STEAM TURBINES AND GEARS

14.4.1 The circulating oil pipe line, including all branch pipes of consumers, shall be made of copper, bimetal, cupro-nickel or equivalent materials.

14.4.2 Oil may be taken from the main turbine lubricating system only for control, adjustment and protection needs, as well as for lubricating the main thrust bearing.

14.4.3 Each lubricating system shall be fitted with audible and visual alarms warning of oil pressure drop and placed at the main turbine control station.

In gravity lubrication system, the alarms shall operate at such level in the gravity tank as to enable the protection devices to cut in the standby pump during the time left before the tank is emptied.

14.4.4 The capacity of the gravity tank shall not be less than a 5-min consumption of oil, with the turbine running at rated output.

The tank shall be fitted with an overflow pipe with a sight glass well lighted and visible from the control station.

The cross-sectional area of the overflow pipe shall be at least 1,25 times that of the discharge pipe of the pump. It shall be possible to supply lubricating oil to consumers from the pump, excepting the tank.

14.4.5 The lubrication system of the main turbine set shall be fitted with two oil coolers, one of which is a standby cooler. Where two turbine sets are situated in the same space, one standby oil cooler may be installed for both turbine sets. Servicing of oil coolers shall be provided according to **15.1.7**.

14.4.6 The lubrication system of the main turbine sets and associated gearing shall comply with the requirements of **14.1.6**, **14.2.3** and **14.2.5**.

14.4.7 The branch pipes of the circulating oil pipeline shall be fitted with throttle valves for regulating the amount of oil supplied to each consumer.

14.5 LUBRICATING OIL TANKS

14.5.1 The lubricating oil tanks shall be separated from the feed water and vegetable oil tanks by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

14.5.2 The lubricating oil drain tanks in ships with main turbines shall in any case be separated from the bottom shell plating by a cofferdam, the structural members of which shall comply with the requirements of Part II "Hull".

For other ships, the arrangement of cofferdams is recommended. Where the cofferdams are not available, the drain pipes from crankcases shall have non-return or shut-off valves capable of being operated from above the engine room floor plating. In these cases lubricating oil drain tanks shall be provided with the relevant pipelines with valves for emergency lubricating oil suction by pumps from engines crankcases if tanks are holed. Valves shall have drives located above the engine room plating.

14.5.3 Provision shall be made for a lubricating oil storage tank with a capacity sufficient for filling the system with oil to the working condition.

This tank is recommended to be situated outside the double bottom. In ships of restricted areas of navigation **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** the lubricating oil storage tank need not be provided.

14.5.4 The suction pipes from the tank situated outside the double bottom shall be fitted with shut-off valves installed directly on the tanks.

Such cocks or valves may be fitted on straight branch pipes welded to the shell plating, provided they are rigid enough and have the minimum length.

In tanks of a capacity of more than 500 l which, with the exception of gravity lubrication systems, may be open in normal conditions, such valves shall be remote-controlled from always accessible positions outside the space containing the tank.

14.5.5 Arrangements for heating of the lubricating oil shall comply with the requirements of **13.3**.

14.5.6 For lubricating oil tanks arranged in machinery spaces of category A (refer to **1.2**, Part VII "Machinery Installations") and, whenever practicable, in other machinery spaces, the requirements of **10.4**, **13.5.1** and **13.6** of this Part and **4.3.3**, **4.3.4**, Part VII "Machinery Installations", shall be complied with, as far as lubricating oil tanks installed above heated surfaces of engines and machinery are concerned.

14.6 ARRANGEMENTS FOR COLLECTION OF LEAKAGE LUBRICATING OIL

14.6.1 The requirements of **13.5** apply to arrangements for collection of leakage lubricating oil.

14.7 LUBRICATING OIL SUPPLY TO GAS TURBINES

14.7.1 The lubricating oil system of a gas turbine plant shall comply with the requirements of **14.1** to **14.5** as far as these requirements are applicable to the given plant.

15. WATER COOLING SYSTEM

15.1 PUMPS

15.1.1 Water cooling systems of main engines shall comply with the following requirements:

.1 a sea water cooling system of one main engine shall include two cooling water pumps, one of which is standby.

The capacity of the standby pump shall not be less than that of the main pump.

At least, one pump shall be driven independently.

Ships with no automation mark shall be permitted to have one common standby pump.

A fresh water cooling system of the main engine shall also comply with these requirements.

One common independent standby pump may be used for both fresh and salt water cooling; the capacity of this pump shall not be less than that of the main pumps; precautions shall be taken to prevent mixing of fresh and salt water;

.2 one independent standby pump ensuring the operation of each engine running at maximum load shall be installed in a salt water cooling system of two and more main engines, each served by a separate cooling water pump.

No standby pump may be provided where a reserve pump is available, which may be assembled on board.

A fresh water cooling system shall also comply with these requirements.

Ships with no automation mark shall be permitted to have one common standby pump.

It is permitted to install one common independent standby pump, the capacity of which shall ensure fresh or sea water cooling of any engine; precautions shall be taken to prevent mixing of fresh and salt water;

.3 it is allowed to cool several engines by one independently driven pump. In this case, the capacity of the pump shall be sufficient for simultaneous cooling of all engines when running at maximum load.

One standby pump, the capacity of which shall not be less than that of the main pump cooling simultaneously all engines, shall be provided.

The cooling pipe shall have a water control valve at inlet to each engine;

.4 in installations of ships with an automation mark in the class notation the combination of the fresh water and the salt water standby pumps shall be not permitted.

.5 in ships of restricted areas of navigation special standby facilities are not compulsory, however, in the absence of redundancy, it shall be possible to cool the engine directly with salt water.

In ships of restricted areas of navigation **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** та **C-R3-S, C-R3-RS**, **B-R3-S, B-R3-RS, D-R3-S**, **D-R3-RS**, having two and more main engines direct standby sea water cooling is not compulsory.

15.1.2 The oil and air coolers of the electric propulsion motors shall have standby means of cooling, equivalent to the main means.

15.1.3 Where each of the auxiliary engines is provided with an independent cooling water pump, the standby pumps for these engines are not required.

Where, however, a group of auxiliaries is supplied with cooling water from a common system, one standby pump for salt water and fresh water is sufficient.

If a common cooling line is fitted for the main and auxiliary engines, standby pumps for cooling the auxiliary engines are not required.

For the diesel-generators kept ready for immediate use (hot condition) continuous priming with hot water shall be possible, where necessary.

15.1.4 The ballast, bilge or other general service pumps operated only for clean water may be used as standby cooling pumps.

The use of fire pumps for this purpose is permitted if the requirements contained in **3.2.3.2**, Part VI "Fire Protection", are complied with.

15.1.5 An independent cooling system for pistons shall include a standby pump with a capacity not less than that of the main pump.

15.1.6 An independent cooling system of the fuel valves shall include a standby pump with a capacity not less than that of the main pump.

15.1.7 The oil coolers of the main turbine sets shall generally be served by the circulating pumps of the main condensers.

Where for servicing the oil coolers an independent circulating pump is fitted, provision shall be made also for a standby pump having a capacity of at least 0,66 of the consumption of water for the oil cooler, with the turbine running at rated output.

Any one general service pump may be used as a standby pump.

15.1.8 A reserve pump with a capacity not less than that of the main pump shall be provided in an independent sea water cooling and lubricating system for stern bearings.

Any sea water general purpose pump referred to in **15.1.4** may be used as a reserve pump.

15.2 PIPING LAYING

15.2.1 Sea water cooling system shall be supplied from at least two sea chests or ice boxes (bottom and side) arranged in the engine room and interconnected. In cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN** only one sea inlet shall be used.

15.2.2 It is recommended that the cooling systems servicing the auxiliary engines and condensers of auxiliary turbines shall be supplied with water from separate sea inlets.

Where these sea inlets are located in the engine room, the suctions of the above-mentioned systems shall be connected through isolating valves to the cooling main supplied from sea inlets and/or ice boxes according to **15.2.1**.

15.2.3 The requirements for design of sea chests and ice boxes in ice class ships and icebreakers are given in **4.3.1**.

15.3 COOLING WATER FILTERS

15.3.1 Filters shall be fitted on the suction lines of water cooling system servicing the main and auxiliary engines.

Filters shall be provided with a facility that makes it possible to be sure, before the filters are opened up, that there is no pressure.

Means shall be provided to enable the filters to be cleaned without having to stop the cooling pumps.

In a water cooling system of a turbine installation, filters are recommended to be fitted.

15.4 COOLING OF INTERNAL COMBUSTION ENGINES

15.4.1 In a fresh water cooling system of the engine provision shall be made for an expansion tank where the level of water is higher than the maximum level of water in the engine.

The expansion tank shall be connected to the suction piping of the pumps and may be common for the cooling system of several engines.

The tank shall be provided with a device for monitoring the water level.

In the cooling system of engines, the arrangement of the sea water discharge pipes shall be such that the highest cooled spaces of the engines, air coolers and oil coolers are always filled with water and formation of trapped zones is excluded.

15.4.2 The cooling system shall be fitted with thermometers and temperature control devices. It is recommended that suitable alarms shall be provided to warn on the limit value of the cooling water temperature (refer to **2.12**, Part IX "Machinery").

15.4.3 The cooling system of an engine to be used as emergency engine shall comply with the requirements of **2.2.5**, Part IX "Machinery".

15.4.4 Where fuel oil or lubricating oil is used in the cooling systems of nozzles or pistons, such systems shall comply with Section **13** or Section **14**, accordingly.

15.5 COOLING OF GAS TURBINE INSTALLATIONS

15.5.1 The cooling system of turbine casings shall comply with the requirements indicated in **15.4**.

15.5.2 Only fresh water cooling shall be used for turbine casings. Sea water cooling may be admitted in the event of failure of the main cooling water pump.

15.5.3 The cooling system of the air cooler shall comply with the requirements of **19.2.1**, **19.2.3** and 19.3.1.

The standby pump may not be provided, if in the event of failure in water supply to the air coolers, 30 % of turbine rating is maintained.

15.6 SEA-WATER COOLING SYSTEMS

15.6.1 Cooling systems fitted with keel sea coolers shall not be used in icebreakers and, polar and Baltic ice class ships **IA Super** and **IA**, and **Ice4** – **Ice6** ice class ships.

Application of such cooling systems on **Ice4** and Baltic ice class **IA** ships may be allowed if thickness of the used cooling ducts is not less than the side hull plating and the ship's speed is maintained in case of damage of any cooling duct.

15.6.2 For ships equipped with one main engine not less than two sea-water coolers, one of which is stand-by, shall be provided.

15.6.3 For ships equipped with two or more main engines one stand-by cooler shall be provided to keep each engine running. The stand-by cooler may not be fitted if the system allows two engines operate using one cooler.

15.6.4 For ships of restricted area of navigation equipped with two or more main engines the stand-by sea-water cooler may not be fitted.

15.6.5 On the pipelines for supply and rejection of cooled medium to coolers the check valves shall be provided.

15.6.6 Provision shall be made for drainage or purging of cooler.

15.6.7 Each cooler shall be provided with air discharge arrangement.

16. COMPRESSED AIR SYSTEM

16.1 NUMBER AND CAPACITY OF STARTING AIR RECEIVERS

16.1.1 The compressed air system of the main engines shall ensure simultaneous starting and reversing of all the main engines and starting arrangements shall comply with the requirements of **2.9**, Part IX "Machinery".

The requirements for the compressed air system of gas turbines are given in **8.1.5**, Part IX "Machinery".

16.1.2 The total amount of starting air for the main engines starting and the associated pneumatic control systems shall be stored in not less than two air receivers or two groups of them so arranged that they may be used independently; the capacity of each air receiver, or each group of air receivers shall be at least 50 % of that required in **16.1.3** and **16.1.4** (refer also to 16.1.6).

Where an electric tyfon is used in ships of restricted areas of navigation **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN**, it is permitted to fit one air receiver of a capacity sufficient to meet the requirements of **16.1.3** and **16.1.4**.

16.1.3 The total capacity of air receivers for starting and reversing of the main engines shall be sufficient to provide not less than 12 starts alternating between "ahead" and "astern" of each engine in ready to start condition, as well as the function of engine control systems.

16.1.4 The total capacity of air receivers for starting of the main engines connected to a controllable pitch propeller or some other device, enabling to start without opposite torque, shall be sufficient to provide not less than 6 starts of each engine being in ready to start condition, and where there are more than two engines, at least 3 starts of each engine.

At the same time, the function of engine control systems shall be provided.

16.1.5 For starting of the auxiliary engines provision shall be made for one air receiver with a capacity sufficient to provide 6 starts of the largest engine in ready to start condition. Such an air receiver may be dispensed with, when the provisions is made to start the auxiliary engines from the air receivers of the main engines.

In this case, the compressed air storage in each air receiver of the main engines shall be increased for a capacity sufficient to provide six starts of one auxiliary engine of the maximum output, and the air receivers shall be filled automatically and the requirements of **4.5**, Part XV "Automation" shall be complied with.

16.1.6 It is permitted that the starting air stored in one air receiver, or in a group of air receivers of the main engines according to **16.1.2**, be used to feed the tyfon whistle, as well as for domestic needs, provided the capacity of the air receiver is increased by an amount of air specified below for a special air receiver of the tyfon, or where the air receiver is fitted with automatic replenishing means or with alarms warning on a drop of pressure of not more than 0,49 MPa below the working pressure.

Where an air receiver is fitted especially for the tyfon, its capacity shall be determined so that the tyfon will be able to work continuously for 2 min, with hourly performance of compressor being not less than required to provide continuous operation of tyfon during 8 min.

If air from the air receiver of the tyfon is consumed also for other purposes, the capacity of the air receiver shall be increased as compared with that designed for tyfon only, with provision for automatic replenishing or signalling means which shall operate as soon as the amount of air in the air receiver is such as required for tyfon only. In ships having a mark of automation the repleni-shing of air receivers shall proceed according to **4.5**, Part XV "Automation".

16.1.7 The air receivers of auxiliary engines indicated in **16.1.5** may be replenished from the main air receivers stated in **16.1.6**, with any possibility of back flow being excluded.

16.1.8 The starting devices of the emergency diesel generator shall comply with the requirements of **9.5**, Part XI "Electrical Equipment".

Where a compressed air system is used as one of the means of starting the emergency diesel generator, the air receiver may be maintained from main or auxiliary starting air compressors through a non-return valve fitted in the emergency generator room, or from an electric compressor supplied from the emergency switchboard.

16.1.9 Air receivers shall comply with the requirements of **6.4.1**, **6.4** “Special requirements for heat exchangers and pressure vessels” part X “Boilers, heat exchangers and pressure vessels”

16.2 COMPRESSORS

16.2.1 The number of the main air compressors shall be at least two.

The total capacity of the main compressors shall be sufficient for the filling of the main air receivers during one hour for starting the main engines, beginning from the atmospheric pressure to the pressure required to carry out the number of starts and reverses referred to in **16.1.3** and **16.1.4**.

For ships, the main engines of which are started without a load, one of the main compressors may be attached on the engine.

The capacity of individual main compressors shall be approximately the same.

The capacity of the independently driven compressors shall not be less than 50 % of that required of all the main compressors, but not less than the air consumption for the whistle according to **16.1.6**.

16.2.2 In cargo ships of less than 500 gross tonnage navigating in restricted areas **R3-S**, **R3-RS**, **R3** and **R3-IN** with reversible main engines, one independently driven compressor is permitted, whereas with main engines of a non-reversible type, one attached compressor is permitted.

For the above ships having combined starting systems, one attached compressor may be installed.

The capacity of the compressors shall be in accordance with the requirements of **16.2.1**.

16.2.3 In ships with the main and auxiliary engines arranged for compressed air starting, provision shall be made, in case of the ship blackout, for starting the main compressors during not more than one hour.

For this purpose it is allowed to use a hand compressor or a hand operated diesel compressor to fill a separate air receiver, which capacity is sufficient for three starts of one of the diesel generators or one of the main compressors, where it is driven by an internal combustion engine.

A separate air receiver need not be installed where the diesel compressor or hand compressor is capable of filling the smallest of the air receivers specified in **16.1.5** during the aforesaid time period.

Where the motor of the compressor supplying one of the air receivers considered in this para can be energized by the emergency diesel generator, the above-mentioned provisions are not necessary.

Where the above compressor is cooled with the motor pump, the motor of the pump shall be energized by emergency diesel generator.

This requirement is not applicable to cargo ships of less than 500 gross tonnage navigating in restricted areas **R2**, **R2-S**, **R2-RS**, **R3-S**, **R3-RS**, **R3**, **R3-IN**.

16.3 PIPING LAYING

16.3.1 All pressure pipes from starting air compressors shall be laid directly to the starting air receivers, and all starting pipes from the air receivers to main or auxiliary engines shall be entirely separated from the compressor pressure pipe system.

16.3.2 Each of the starting air receivers specified in 16.1 shall be capable of being filled from each main compressor specified in **16.2**.

Possibility of back flow shall be precluded refer to **16.1.7**.

16.3.3 Non-return shut-off valves shall be installed on the discharge pipe of each compressor.

The manifold supplying starting air to each engine shall have a non-return valve placed before the cylinder starting valve.

The non-return valve may be omitted, if provision is made in the engine design for suitable devices protecting the manifold from the effects of an internal explosion (refer to **2.9.1**, Part IX "Machinery").

16.3.4 The temperature of air entering the receiver shall not exceed 90°C.

Where required, provision shall be made for coolers.

16.3.5 The pipes shall be laid as straight as practicable with a slight slope in the direction of the master starting valve of the engine for water drainage.

16.3.6 Suitable arrangements for draining the accumulations of oil and water shall be fitted on the pipes between compressors and air receivers, unless drain arrangements are fitted on the compressors.

16.3.7 If the pressure relief valves or fuse plugs fitted on air receivers are arranged to discharge a compressed air outside engine rooms, the cross-sectional area of discharge pipes shall not be less than a two-fold cross-sectional area of the pressure relief valves or fuse plugs; appropriate arrangements for draining water from the pipes shall be provided.

17. FEED WATER SYSTEM

17.1 PUMPS

17.1.1 Each main boiler and an essential auxiliary boiler or a group of boilers shall be provided with at least two independent feed pumps.

For auxiliary boilers, which are not intended for essential services, as well as for exhaust gas boilers so constructed that they can be left without water when heated by exhaust gas, one feed pump is sufficient.

For boilers with manual feed regulation the capacity of each pump shall not be less than 1,50 times the rated capacity of the boilers, and for boilers with automatic control systems, not less than 1,15 times their rated capacity.

Where several pumps are installed, their adopted capacity shall be such that in the event of damage to any of the pumps the total capacity of the rest of the pumps is not less than the capacity required in the foregoing for each pump.

The capacity of each feed pump of a straight-through boiler shall not be less than the rated capacity of the boiler.

17.1.2 In the case of steam driven feed pumps, live steam shall be supplied to the line having connections from all the boilers fed by these pumps.

17.1.3 The main and essential auxiliary boilers with forced circulation as well as waste heat boilers connected to exhaust gas systems of two-stroke diesels with inlet gas temperature of 270°C and lower, shall be serviced by not less than two circulating pumps, one of which is a standby pump.

17.2 PIPING LAYING

17.2.1 In case of open circuit feed system, the feed pumps and injectors shall be provided with suctions from the hot well and from the feed water storage tanks.

17.2.2 The feed system of each main boiler and each auxiliary boiler for essential services shall be so constructed as to enable a boiler or a group of boilers to be fed by each pump through two separate feeding systems, i.e. the main and the auxiliary lines.

For non-essential auxiliary boilers, one feeding pipeline is sufficient. Where a steam generation system consists of two or more adequately sized boilers, and the feed water for each of these boilers is supplied by a single feed water pipe, the level of redundancy for the piping of the feedwater system is considered sufficient.

17.2.3 All structural measures shall be taken to prevent feed water being contaminated by oil and oily products.

17.2.4 The main boilers and essential auxiliary boilers shall be provided with automatic devices for monitoring of feed water salinity.

17.2.5 For the waste heat boilers with forced circulation, mentioned in 17.1.3, provision shall be made for the circulating water consumption, corresponding to at least 5-times design steam capacity to eliminate excessive heat emission in case of ignition of sediments.

For this purpose a standby circulating pump of a waste heat boiler or another suitable pump may be used.

17.2.6 Each exhaust gas heated economizer shall be provided with arrangements for water treatment, pre-heating and deaeration to ensure the quality of feed water compliance with the manufacturer's requirements.

17.3 TANKS

17.3.1 Feed water tanks shall be separated from tanks containing oil fuel, lubricating oil and vegetable oil by cofferdams, the structural members of which shall comply with the requirements of Part II "Hull".

18. STEAM AND BLOW-OFF SYSTEMS

18.1 PIPING LAYING

18.1.1 Where two or more boilers are connected to a common steam line, a non-return valve shall be fitted on the steam pipe of each boiler before connection to the common line. These valves need not be fitted if the stop valves of the boilers are of non-return shut-off type.

18.1.2 The blow-down and the scum valves of two or more boilers may be connected to a common discharge, provided a not-return stop-check valve is fitted on the blow-off pipe of each boiler before the connection to the discharge line.

18.1.3 The machinery connected with the steam lines shall be relieved of the stresses caused by thermal expansion of pipes. It may be achieved by means of self-compensation (pipe bends) or by installation of thermal compensators in appropriate positions.

18.1.4 In the steam lines supplying the machinery and arrangements designed for a lesser pressure than the boiler pressure, there shall be fitted reducing valves, and requirements of **1.4.4** shall be complied with.

18.1.5 If provision is made for a steaming system for fuel and cargo oil tanks, each tank shall be fitted with non-return shut-off valves.

18.1.6 The steam pipelines in the engine and boiler rooms shall be laid in the upper parts of these spaces, where practicable, in a position accessible for observation and servicing.

Laying of steam lines under the floor plates of engine and boiler rooms, with the exception of heating coils and boiler blow-off pipes, is not permitted. Steam lines shall not be laid near the fuel oil tanks.

Steam lines shall not be laid in spaces used for carriage of flammable substances and in paint rooms.

Steam lines with working temperatures above 220°C are not permitted to be laid in cargo pump rooms of tankers.

18.1.7 While laying steam lines, the minimum distance from pipeline insulation shall be observed:

to hull structures - 50 mm;

to cable routing - 150 mm.

18.1.8 Steam radiators shall be located at a distance of at least 50 mm from hull structures. If the hull structures are lined with a combustible material, the portions located against the heating elements shall be protected with heat insulation of non-combustible material.

In the absence of heat insulation the heating elements shall be located at a distance of not less than 150 mm from the combustible lining.

18.1.9 Steam for the ship's whistle shall be supplied by a separate pipeline directly from the main boiler. This requirement does not apply to vessels having, in addition to a steam whistle, air or electric audible signal means.

18.2 BLOW-OFF ARRANGEMENTS OF STEAM LINES

18.2.1 Pipelines conveying live steam shall have condensate drain arrangements to protect the machinery against water hammer.

18.2.2 The open ends of the pipes for steam line blow-off shall be laid below the floor plates of the engine and boiler rooms (refer also to **5.3.7**).

18.3 CALCULATION OF STEAM PIPES FOR THERMAL EXPANSION

18.3.1 The calculation of steam pipes for thermal expansion shall be based on the methods generally adopted in structural mechanical for computing beam elements.

The calculation may be prepared on a computer or by means of a model method.

18.3.2 The calculation of steam pipes for thermal expansion shall include a summary table of stresses and safety factors for all the pipe ranges dealt with in the calculation.

The steam pipes working under temperatures, which do not cause stress relaxation, shall, as a rule, be calculated for thermal expansion taking into account the initial prestressing, as well as prestressing in cold condition.

The steam pipes working under conditions of stress relaxation shall be calculated in cold condition for a 100 % prestressing considered as great as the displacements due to full thermal expansion (displacements of supports included), but with an opposite sign.

Where a steam pipe in hot condition undergoes displacements, it shall be calculated in view of these displacements and, after that, for a 100 % prestressing in cold condition (displacements of supports included).

18.3.3 In the calculation of thermal expansion the valves and fittings (elbows, T-joints, etc.) may be assumed rigid and need not be calculated for flexibility.

18.3.4 The design stress in pipes shall be calculated depending on the pipe cross-sectional area, including the positive manufacturing tolerance for pipe wall thickness.

The same sizes shall be used for determining the stresses from displacements.

As for the stresses caused by internal pressure, they shall be determined depending on pipe cross-sectional area, including the negative manufacturing tolerance for pipe wall thickness.

18.3.5 For all types of butt joints of steam pipes welded with a back sealing run at the root, butt joints welded from both sides and made by automatic submerged arc welding, including joints welded on a removable backing ring, with surface dressing, the efficiency factor in the formula for stress calculation of piping may be assumed equal to a unity (φ=1).

18.3.6 In a calculation, the three components of reaction for a plane frame in general and the six components for a space frame shall be determined by force method, well known in structural mechanics beam system.

In determining the components of reactions, the space frame of the pipe is reduced to three plane frames.

To minimize the error due to reduction of the space frame to three plan frames, the axes of coordinates plotted for the pipe length under consideration shall be arranged parallel (or perpendicular) to the longest straight portion of the pipe and in a way that the curved portions be projected on the coordinate plane without distortion as far as is possible, or in form of straight lines.

18.3.7 The flexibility coefficient *k* of the curved portion shall be determined by the formulae:

$$k = \frac{10 + 12\lambda^2}{1 + 12\lambda^2} \quad \text{for } \lambda \geq 0{,}4 \qquad (18.3.7\text{-}1)$$

and

$$k = 1{,}65/\lambda \quad \text{for } 0{,}2 \leq \lambda \leq 0{,}4, \qquad (18.3.7\text{-}2)$$

where:

λ – geometrical coefficient of bent pipe equal to sR/r^2;

s – wall thickness of straight pipe, mm;

R – bending radius of the curved portion, mm;

r – average radius of cross-sectional area of a straight pipe, mm.

18.3.8 In calculating the steam pipes for thermal expansion, the maximum stresses to be determined are as follows:

resultant stress for a straight pipe conveying hot steam under working pressure, as well as for cold pipe not subjected to internal pressure;

total local stress acting on the inside of a bent pipe conveying hot steam under working pressure, as well as in bent pipe when cold and not subjected to internal pressure.

Bent pipes with $\lambda \geq 1{,}44$ may be regarder as straight, when determining the resultant stress, and need not be calculated for total local stress.

When the assembled steam pipeline is subjected to a hydraulic test on board ship, the resultant stresses shall be shown also for a cold pipeline at they hydraulic test pressure.

18.3.9 The resultant stress σ_c in a straight pipe when exposed to internal pressure and to the bending and twisting moments shall be determined by the formula

$$\sigma_c = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_1\sigma_3 - \sigma_2\sigma_3 + 3\tau^2}\,, \qquad (18.3.9)$$

where:
σ_1 – total normal stress from bending and internal pressure, MPa;
σ_2 – circumferential stress due to internal pressure, MPa;
σ_3 – radial stress due to internal pressure, MPa;
τ – shearing stress, MPa.

18.3.10 The total stress acting on the inside of a bent pipe shall be determined in all cases of bending (plane, perpendicular to curvature plane of a bent pipe, and tangential) as a sum of bending stresses and circumfe-rential stress from internal pressure.

18.3.11 Safety factors, relating to the yield point and average stress producing rupture, which shall be used in the calculation of the resultant stress and the total local stress, are as follows:

1,2 – for plane frame;
1,5– for space frame.

19. CONDENSER INSTALLATIONS

19.1 GENERAL

19.1.1 Each main turbine set shall be fitted with an independent condenser installation ensuring a stable vacuum under all rated operating conditions.

The auxiliary turbines may have a common condenser installation.

In running conditions, waste steam from the auxiliary turbo-generators may be discharged into the main condenser or into the stages of the main turbine set.

19.2 PUMPS

19.2.1 The main condenser shall be serviced by two circulating cooling pumps, one of which is a standby pump. The capacity of the standby pump shall not be less than 30 %t of rated quantity of circulating water for all consumers.

Any pump of sufficient capacity may be used as a standby pump (refer to **15.1.4**).

In twin-screw ships it is allowed to use one standby circulating pump for both turbine sets.

Where, for servicing the main condenser, provision is made for simultaneous operation of both pumps, the capacity of each pump shall make not less than 50 % of the rated quantity of circulating water for all the consumers.

No standby circulating pump is required in this case.

19.2.2 Where the auxiliary condenser is common for all the turbo-generators, it shall be serviced by two circulating cooling pumps, one of which is a standby pump.

Any pump of sufficient capacity may be used as a standby pump.

19.2.3 A sea inlet scoop arrangement of water cooling may be permitted if a circulating pump is fitted, which has a capacity sufficient to ensure the full astern speed condition.

The standby circulating pump shall meet the requirements of **19.2.1**.

19.2.4 The condensate system of a steam turbine installation shall be serviced by two condensate pumps.

The capacity of each pump shall exceed by not less than 25 % the maximum design amount of steam and condensate entering the condenser. In the installations with two main condensers arranged in the same engine room, the standby condensate pump may be common for both condensers.

19.3 PIPING LAYING

19.3.1 The laying of pipes and their connections shall comply with the requirements of **15.2**.

19.3.2 The condensate collector, discharge pipe and condensate pump shall be so arranged as to preclude flooding of the lower rows of pipes and to ensure the required positive pressure and smooth delivery of condensate to the pump.

Provision shall be made for a handhole for cleaning the condensate collector.

19.3.3 The nozzles of the ejectors of the condenser installations shall be protected against damage and clogging, for which purpose a metal screen shall be fitted in the steam pipe.

19.4 INSTRUMENTATION

19.4.1 The condenser installation shall be fitted with gauges and alarms, including:
.1 a condensate level indicator for the condenser;
.2 vacuum and pressure gauges for the condenser and ejector coolers;
.3 a pressure gauge in the steam line to ejector;
.4 thermometers for the cooling water discharge pipes of the condenser and ejector coolers;
.5 salinometers with visual and audible alarms indicating condensate salinity.

20. THERMAL LIQUID SYSTEMS

20.1 DEFINITIONS

20.1. 1 The following definitions have been adopted for the purpose of this section:

Thermal liquid boiler is the heat-exchange apparatus for heating a thermal liquid up to the required temperature using the energy of fuel oil burnt in it, of an engine exhaust gases or electric power.

Thermal liquid heater is the heat-exchange apparatus for heating a thermal liquid with steam, water electric power or thermal liquid of another circuit.

Working pressure i n the thermal liquid system is the highest pressure that may arise in any part of the system in operation.

Thermal liquid system is the system, in which a thermal liquid circulates in a liquid phase.

Thermal liquid temperature is the temperature measured in the centre of a pipeline cross section.

20.2 REQUIREMENTS FOR THERMAL LIQUID

20.2.1 A thermal liquid may be used within the range of working temperatures specified by a manufacturer. In this case, the maximum working temperature of the thermal liquid shall not be less than 50°C below the temperature of boiling beginning at an atmospheric pressure.

20.2.2 In thermal liquid heaters, the heating medium temperature shall be below the temperature of boiling beginning of the thermal liquid being heated.

20.3 THERMAL LIQUID CIRCULATION SYSTEM

20.3.1 In order to ensure the thermal liquid circulation in the circuits of all boilers as well as the heaters for essential services, the system shall be provided with two circulating pumps.

For the systems for non-essential services, in which heaters are used for heating the thermal liquid, one pump may be provided.

20.3.2 Manometers shall be fitted on the side of the thermal liquid outlet from pumps.

20.3.3 Engines of thermal liquid circulating pumps shall be fitted with disconnectors meeting the requirements of **5.7.1**, Part XI "Electrical Equipment".

20.3.4 The circulating pumps shall be locally and remotely controlled.

20.3.5 In case of disconnection of all services, circulation of the thermal liquid through the boilers and heaters shall automatically continue for a time necessary for eliminating the residual heat release.

If the temperature of the exit gas or thermal liquid cannot exceed the boiling temperature of the thermal liquid at atmospheric pressure, this requirement may be dispensed with.

20.4 EXPANSION TANK

20.4.1 A thermal liquid system shall be provided with an expansion tank placed, as a rule, at the highest point of the system.

20.4.2 An expansion tank shall be fitted with a liquid level indicator meeting the requirements of **10.4**. The lowest permissible liquid level shall be marked on the level indicator.

20.4.3 The expansion tank of an open system shall be equipped with an air pipe, and also with an overflow pipe laid to a drain tank or storage tank if the former is lacking.

20.4.4 Provision shall be made for the alarm, which indicates when the lowest and highest thermal liquid levels are reached in the tank.

When the thermal liquid level is lower than the lowest permissible level, heating in boilers shall be automatically discontinued and circulating pumps shall be stopped.

20.4.5 The expansion tank of a closed system shall be equipped with a manometer and safety valve.

The safety valve outlet pipe shall be connected to a drain or storage tank.

The opportunity of the closed system operation in the mode of the open system shall be provided.

20.4.6 The expansion tanks having thermal insulation shall be fitted with thermometers to monitor the thermal liquid temperature.

20.4.7 The expansion tank capacity within the level indicator range measured form the lowest permissible level mark up to the overflow pipe top shall not less than by 30 % exceed the design increased volume of the thermal liquid in the system during operation.

The total quantity of the thermal liquid in the equipment and piping when filled up to the minimum working level in the expansion tank shall be taken as the initial volume.

20.4.8 The expansion tank shall be fitted with a valve locally and remotely controlled outside the space, in which the tank is located for an emergency discharge of the thermal liquid.

20.5 STORAGE AND DRAIN TANKS

20.5.1 The system shall be provided with a storage and a drain tanks. The storage tank capacity shall be at least 40 % of the system capacity.

Depending on the system purpose and the ship navigation area, the storage tank capacity may be reduced.

20.5.2 The drain tank capacity shall be sufficient for draining the thermal liquid from the largest disconnectible section.

For emergency draining of the thermal liquid from boilers (refer to **3.5**, Part X "Boilers, Heat Exchangers and Pressure Vessels") the tank shall be provided with capacity sufficient for draining into it of the thermal liquid from the whole system.

20.5.3 The common tank for storage of the thermal liquid supply and of its drain from a system may be used. In this case, the capacity of that tank shall be adequate for the simultaneous storage of the thermal liquid supply and drain.

The tank location shall provide an opportunity to drain into it the complete thermal liquid.

20.6 PIPING AND VALVES

20.6.1 Thermal liquid piping laying shall meet the requirements of **13.2** and Section **5**.

20.6.2 Bellows-type valves shall be used in piping containing the pressure thermal liquid.

20.6.3 The use of copper and its alloys is not permitted for the system components contacting the thermal liquid.

20.6.4 Seals and gaskets shall be of materials resistant to thermal liquids.

20.6.5 Threaded connections shall not be used for thermal liquid pipelines.

20.6.6 Steel pipe wall thickness shall meet the requirements of **2.3.1**. In this case, the design pressure shall be assumed not less than 1,4 MPa.

20.6.7 The thermal liquid arrangement design shall provide for filling the system, filling up the expansion tank, and also the thermal liquid pumping.

20.6.8 An opportunity of thermal liquid sampling shall be provided in each independent circulation circuit.

20.6.9 The system shall be designed so as to prevent deterioration of the thermal liquid quality due to local overheating or air contact.

20.6.10 The system shall be provided with an effective arrangement for trapping and removal of emitting vapours and gases.

The operation of this arrangement shall not result in circulation and heating of the thermal liquid in an expansion tank above 50°C.

20.6.11 An opportunity of controlling of at least thermal liquid flow rate and temperature by means of a manual control from a local station shall be provided in the system.

20.6.12 The company nameplate in the conspicuous place in the immediate vicinity of circulating pumps shall be provided.

It shall contain the following main information on the system:

manufacturer; year of mounting;

maximum design working temperature of the thermal liquid;

system capacity;

maximum permissible working pressure.

20.6.13 The tanks containing the thermal liquid in which water may accumulate shall be fitted with drain cocks to remove sediment.

20.7 AIR PIPES AND SOUNDING ARRANGEMENTS

20.7.1 Air pipes of thermal liquid tanks shall meet the requirements of **10.1**, applicable to the fuel oil and lubricating oil tanks.

20.7.2 Air pipes of thermal liquid tanks shall be carried to open decks.

20.7.3 If there are ignition hazards inthe premise, the sounding arrangements of thermal liquid tank shall complay with requirements of **10.4.2** and **10.4.4**.

20.8 ARRANGEMENTS FOR COLLECTING OF THERMAL LIQUID LEAKAGES

20.8.1 Arrangements for collecting of thermal liquid leakages shall meet the requirements of **13.5**.

20.8.2 Provision shall be made for the arrangements on the gas side in waste-heat boilers and on exhaust gas piping, which prevent an ingress of the leaking thermal liquid into an engine, and also of the water used for fire extinguishing or boiler washing.

20.9 THERMAL LIQUID BOILERS

20.9.1 The requirements of **3.5**, Part X "Boilers, Heat Exchangers and Pressure Vessels" apply to thermal liquid boilers and heaters.

20.10 INSULATION

20.10.1 The insulation of the system piping and equipment shall meet the requirements in **4.6**, Part VII "Machinery Installations".

20.11 HEATING OF LIQUID CARGOES

20.11.1 Where a thermal liquid is used for liquid cargoes or other liquid products heating, it shall be compatible with heated products when in contact due to leakages of heater coils or pipes.

The use of a thermal liquid, which may enter into a hazardous reaction with a heated product, is not permitted.

20.11.2 The use of thermal liquid systems for heating liquid cargoes with a flash point below 60°C is permitted only if an independent intermediate system located within a cargo area is fitted. However, such a system may be unnecessary if the following conditions are observed:

.1 the system is designed so that with a circulating pump switched off the excessive pressure in coils is at least 0,03 MPa above the static cargo head;

.2 means for detection of flammable cargo vapours in the thermal liquid system expansion tank are provided;

.3 valves of separate heating coils are provided with locking arrangements, which ensure that the coils are permanently under the above static pressure.

20.12 THERMAL LIQUID SYSTEM PIPING TESTING

20.12.1 Thermal liquid systems piping and their components shall be tested according to the requirements of **21.2** like fuel oil pipelines with a design pressure over 0,35 MPa.

21. TESTS

21.1 HYDRAULIC TESTS OF VALVES

21.1.1 The valves intended for Class I and Class II piping shall be subjected to a hydraulic test by the pressure indicated in **1.3.1**, Part IX "Machinery".

21.1.2 The valves intended to work under a design pressure of 0,098 MPa and less, as well as in vacuum conditions shall be tested by a pressure not less than 0,196 MPa.

21.1.3 Valves, cocks and other fittings intended to be fitted on the ship side below the loadline shall be tested by hydraulic pressure not less than 0,5 MPa.

21.1.4 After assembly, the valves shall be checked for leakage by a hydraulic pressure equal to the design pressure.

21.2 HYDRAULIC TESTS OF PIPING

21.2.1 All Class I and Class II pipes, as well as steam, feed, compressed air and fuel oil pipes with design pressure over 0,35 MPa irrespective of their class, shall be tested by hydraulic pressure in the presence of a surveyor to the Register after completion of manufacture and before insulating and coating, by a test pressure, in MPa

$$P_{test} = 1,5p, \qquad (20.2.1\text{-}1)$$

where: p – design pressure (refer to **2.3.1**), MPa.

The test pressure for steel pipes, MPa, intended for design temperatures over 300°C, shall be determined from the following formula, but it need not exceed 2*p*,

$$p_{\text{test}} = 1,5\frac{\sigma_{100}}{\sigma_t}p, \qquad (20.2.1\text{-}2)$$

where:
σ_{100} – permissible stress at 100 100°C;
σ_t – permissible stress at design temperature.

In case where during the test excessive stress arises the value of test pressure, as obtained from Formula (21.2.1-2), may be reduced to 1,5p on agreement with the Register.

In no case shall be stresses arising during the test exceed 0,9 of the yield point at the temperature of testing.

21.2.2 Pressure testing of small bore pipes (less than 15 mm) of any class may be omitted at discretion of the Register, depending on the application of these pipes.

When assembled piping is exposed to hydraulic strength tests at 1,5*p*, it is allowed not to perform preliminary strength test of pipes listed in **21.2.1**.

21.2.3 All the piping systems shall be checked for tightness in operating conditions in the presence of a surveyor to the Register, except that particular testing is required for the following piping:

.1 heating coils in tanks and liquid or gas fuel lines shall be tested by 1,5*p*, but not less than 0,4 MPa;

.2 liquefied gas pipelines shall be leak tested in comfliance with **13.14.17**.

21.2.4 Where, for technical reasons, the hydraulic test of the entire pipeline cannot be carried out, proposals shall be submitted to the Register for testing of separate pipe lengths, in particular, the end joints.

21.2.5 In the case where hydraulic tests of an assembled piping system are carried out on board, testing of piping for tightness and strength may be combined.

21.2.6 Liquefied gas pipe lines from containers to reducing valves shall be tested in accordance with з **13.14.17**.

21.2.7 The pipes tested by hydraulic pressure after completion of manufacture in compliance with **21.2.1**, all the piping systems (with the exception of steam, feed, boiler blow-off pipes, freon and ammonia, as well as pipelines with welded joints) intended to work under pressure up to 5 MPa are allowed to be tested with compressed air instead of testing for tightness (refer to **21.2.3**).

The value of test pressure with compressed air shall be $P_{\text{test}} = 0,1P$, but not less than 0,2 MPa.

For pipes intended to work in vacuum conditions the test pressure with compressed air shall be 0,2 MPa.

Pipes of fuel oil that work at pressure of up to 0,6 MPa and that have welded joints shall be checked by test pressure with compressed air accepted in compliance with **21.2.1** during the time necessary to check the air leakage but not less than 10 min.

21.3 TESTING OF DEVICES TO PREVENT THE PASSAGE OF FLAME INTO CARGO TANKS IN OIL TANKERS

21.3.1 Prior to assembly on board, flame arresters, flame screens, high velocity vents and pressure/vacuum valves along with protective devices against atmospheric precipitation shall be tested in accordance with the IMO procedure to be found in in IMO circular MSC/Circ. 677 as amended by MSC/Circ.1009 and MSC.1/Circ.1324 taking into account MSC.1/Circ.1325.

21.4 TESTING OF AIR AND VENTILATOR PIPE CLOSING DEVICES

21.4.1 Each type and size of air pipe automatic closing devices shall be surveyed and type tested according to the requirements of **8.10**, Part IV "Technical Supervision during Manufacture of Products", the Rules for Technical Supervision During Construction of Ships and Manufacture of Materials and Products for Ships.

21.5 TESTING OF PLASTIC PIPES

21.5.1 Plastic pipes shall be tested taking into consideration the requirements of **6.8**, Part XIII "Materials", and where necessary, their fire resistance shall be confirmed and flame spread tested in accordance with **3.3.1** and **3.3.2.1** of the present Part.

21.5.2 The quality of joints shall be tested taking into consideration the requirements of **3.5.2**, and piping as assembled on board shall be tested in accordance with the requirements of **3.8**.

PART IX. MACHINERY

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to the following engines and machinery:

.1 main internal combustion engines;

.2 main steam turbines;

.3 main gas turbines;

.4 gears and couplings;

.5 engines driving electric generators or auxiliary and deck machinery, units in assembly;

.6 pumps included into the systems covered by Part VI "Fire Protection", Part VIII "Systems and Piping" and Part XII "Refrigerating Plants";

.7 air compressors;

.8 fans of main boilers, turboblowers (turbochargers) and fans of internal combustion engines;

.9 fans included into the system covered by Part VIII "Systems and Piping";

.10 steering gear;

.11 anchor machinery;

.12 towing winches;

.13 mooring machinery;

.14 hydraulic drives;

.15 centrifugal separators for fuel oil and lubricating oil.

1.2 SCOPE OF SURVEYS

1.2.1 The provisions specifying the procedure of classification and technical survey of the ship construction are contained in General Regulations for the Classification and Other Activity and Part I «Classification» of the Rules for the Classification and Construction of Ships[1].

1.2.2 The Register carries out the survey during the manufacture of engines and machinery listed in **1.1**, except for auxiliary manually driven machinery.

1.2.3 Prior to manufacturing of the machinery, the following technical documentation shall be submitted to the Register for review:

.1 on internal combustion engines:

for information – in compliance with 1.2.3.1-1;

for approval - in compliance with Table1.2.3.1-2;

for gas engines the documents in compliance with Table 1.2.3.1-3 shall be submitted additionally 1.2.3.1-3.

Procedure for submission and review of technical documentation on internal combustion engines (refer to Appendix **2** "Procedure Documentation Flow" to Section **5** "Machinery", Part **IV** "Technical Supervision During Manufacture of Products" of the Rules for Technical Supervision During Construction of Ships and Manufacture of materials and Products for Ships)[2];

.2 machinery particulars as per data sheet or specification;

.2.2 general view plans with machinery longitudinal and transverse sections;

.2.3 drawings of bedplates, crankcases, engine beds, casings, covers and other parts, cast or welded, with welding details and instructions;

.2.4 drawings of crankshafts, thrust shafts, output and other shafts as well as their drives (gears);

.2.5 drawings of connecting rods, piston rods and pistons;

.2.6 drawings of cylinder covers and cylinder liners;

.2.7 drawings of pinions, gear wheels and their shafts;

.2.8 drawings of driving and driven parts of hydraulic gears, disengaging and flexible couplings;

.2.9 drawing of thrust block built in the machinery;

.2.10 drawings of rotors of steam and gas turbines and compressors as well as discs and impellers;

.2.11 drawings of high pressure fuel oil piping and their protection in case of damage;

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[1] Hereinafter refered to as Part I «Classification».

[2] Technical Supervision During Construction of Ships and Manufacture of materials and Products for Ships: hereinafter refered to as RTSC.

.2.12 drawings of insulation and lining of gas exhaust piping associated with machinery;

.2.13 drawings of main pipings and fuel oil, lubricating oil, cooling, gas exhaust, scavenging, air control, governing, alarm, protection and other systems, associated with machinery;

Table 1.2.3-1 **Technical documentation to be submitted for information, as applicable**

1	2
1	Internal combustion engine particulars (refer to Appendix 3 " Internal Combustion Engine Type Approval Application Form and Basic Data Sheet" to Section 5 "Machinery", Part IV "Technical Supervision during Manufacture of Products" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships in compliance with Annex 3 to IACS UR M44 (Rev.9, Corr.2, Nov. 2016)) or Technical Specification
2	Engine cross section
3	Engine longitudinal section
4	Bedplate and crankcase of cast design
5	Thrust bearing assembly[1]
6	Frame/framebox/gearbox of cast design [2]
7	Tie rod
8	Connecting rod
9	Connecting rod, assembly[3]
10	Crosshead, assembly [3]
11	Piston rod, assembly [3]
12	Piston, assembly [3]
13	Cylinder jacket/block of cast design[2]
14	Cylinder cover, assembly[3]
15	Cylinder line
16	Counterweights (if not integral with crankshaft), including fastening
17	Camshaft drive, assembly[3]
18	Flywheel
19	Fuel oil injection pump
20	Shielding and insulation of exhaust pipes and other parts of high temperature which may be impinged as a result of a fuel system failure, assembly
21	For electronically controlled engines, construction and arrangement of:
21.1	Control valves
21.2	High-pressure pumps
21.3	Drive for high pressure pumps
22	Operation and service manuals [4]
23	FMEA (for engine control system)[5]
24	Production specifications for castings and welding (sequence)
25	Evidence of quality control system for engine design and in service maintenance
26	Quality requirements for engine production
27	Type approval certification for environmental tests, control components [6]

[1] If integral with engine and not integrated in the bedplate.

[2] Only for one cylinder or one cylinder configuration.

[3] Including identification (e.g. drawing number) of components.

[4] Operation and service manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance.

[5] Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, a failure mode and effects analysis (FMEA) shall be submitted to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine.

[6] Tests shall demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions.

.2.14 drawings of machinery hydraulic piping systems with hydraulic drives;

.2.15 drawings of securing machinery structure to bedplate and arrangement of foundation bolts (only for main machinery, electric generator drives, steering gears; anchor, mooring and towing machinery);

.2.16 strength calculations of machinery parts, regulated by the Rules;

.2.17 list of main parts of machinery with material specification and all details for test pressure values (if required);

.2.18 operation and service manuals;

.2.19 test programs for prototype and production models of machinery.

Note. Additional requirements for the scope of documentation for ICE turbochargers – refer to **2.5.7.6**.

***Table 1.2.3.1-2* Technical documentation to be submitted for approval, as applicable**

1	2
1	Bedplate and crankcase of welded design, with welding details and welding instructions [1,2]
2	Thrust bearing bedplate of welded design, with welding details and welding instructions [1]
3	Bedplate/oil sump welding drawings [1]
4	Frame/framebox/gearbox of welded design, with welding details and instructions [1,2]
5	Engine frames, welding drawings [1,2]
6	Crankshaft, details, each cylinder No.
7	Crankshaft, assembly, each cylinder No.
8	Crankshaft calculations (for each cylinder configuration) according to the attached data sheet and requirements of Chapter **2.4**
9	Thrust shaft or intermediate shaft (if integral with engine)
10	Shaft coupling bolts
11	Material specifications of main parts with information on non-destructive material tests and pressure tests [3]
12	Schematic layout or other equivalent documents on the engine of:
12.1	Starting air system
12.2	Fuel oil system
12.3	Lubricating oil system
12.4	Cooling water system
12.5	Hydraulic system
12.6	Hydraulic system (for valve lift)
12.7	Engine control and safety system
13	Shielding of high pressure fuel pipes, assembl[4]
14	Construction of accumulators (for electronically controlled engine)
15	Construction of common accumulators for electronically controlled engine
16	Arrangement and details of the crankcase explosion relief valve[5] in compliance with requirements of **2.3.5**
17	Calculation results for crankcase explosion relief valves in compliance with requirements of **2.3.5**
18	Details of the type test program and the type test report)[7]
19	High pressure parts for fuel oil injection system[6]
20	Oil mist detection and/or alternative alarm arrangements in compliance with requirements of **2.3.4.8** – **2.3.4.22**
21	Details of mechanical joints of piping systems (refer to **2.4.5**, Part VIII "Systems and Piping")
22	Documentation verifying compliance with inclination limits (refer to **2.3**, Part VII "Machinery Installations")
23	Documents as required in Chapter **7.10**, Part XV "Automation", as applicable

[1] For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre and post weld heat treatment, weld consumables and fit-up conditions.

[2] For each cylinder for which dimensions and details differ.

[3] For comparison with the Register requirements for material, NDT and pressure testing as applicable.

[4] All engines.

[5] Only for engines of a cylinder diameter of 200 mm or more or a crankcase volume of 0,6 m^3 or more.

[6] The documentation to contain specifications for pressures, pipe dimensions and materials.

[7] The type test report may be submitted shortly after the conclusion of the type test.

Table 1.2.3.1-3 **The following documents shall be submitted for the approval of Dual Fuel (DF) and Gas Fuel (GF) engines[1]**

1	2
1	Schematic layout or other equivalent documents of gas system on the engine
2	Gas piping system (including double-walled arrangement where applicable)
3	Parts for gas admission system (the documentation to contain specification of pressures, pipe dimensions and materials)
4	Arrangement of explosion relief valves (crankcase1, charge air manifold, exhaust gas manifold) as applicable
5	List of certified safe equipment and evidence of relevant certification provided by the competent organization.
6	Safety concept[2]
7	Report of the risk analysis[2]
8	Gas specification[2]
9	Schematic layout or other equivalent documents of fuel oil system (main and pilot fuel systems) on the engine[3]
10	Shielding of high pressure fuel pipes for pilot fuel system, assembly[3]
11	High pressure parts for pilot fuel oil injection system (the documentation to contain specification of pressures, pipe dimensions and materials)[3]
12	Ignition system[4]

[1] taking into account the design features of the engine, the Register may request the provision of additional documentation;
[2] for information;
[3] required for DF engine;
[3] required for GF engine.

1.2.4 Drawings of machinery parts listed in Table 1.2.4, but not mentioned in **1.2.3** are subject to agreement with the Register.

In the process of manufacture all these parts are subject to survey by the Register regarding their compliance with the approved technical documentation and the requirements of Part XIII "Materials" and Part XIV "Welding".

Table 1.2.4

Nos	Item	Material	Chapter of Part XIII "Materials"
1	**2**	**3**	**4**
1	**Internal combustion engines**		
1.1	Bedplate, crankcase, frames, thrust bearing casing, main bearing caps of suspended crankshafts	Cast iron Cast steel Forged steel Rolled steel Aluminium alloy	3.9, 3.10 3.8 3.7 3.2 5.2
1.2	Cylinder block, cylinder covers, valve housings	Cast iron Cast steel Forged steel	3.9, 3.10 3.8 3.7
1.3	Cylinder liners and their parts	Cast iron Cast steel Forged steel	3.9, 3.10 3.8 3.7
1.4	Piston	Cast iron Cast steel Forged steel Aluminium alloy	3.9, 3.10 3.8 3.7 5.2
1.5	Piston rod, crossheads, gudgeon pins	Forged steel	3.7
1.6	Connecting rod with crank bearing covers	Forged steel Cast steel	3.8 3.7
1.7	Crankshaft, thrust shaft of the built-in thrust bearing	Forged steel Cast steel Cast iron	3.7 3.8 3.9
1.8	Crankshaft detachable couplings	Forged steel Cast steel	3.7 3.8

1.9	Bolts and studs of the crossheads, main and connecting rod bearings, cylinder covers	Forged steel	3.7
1.10	Tie rods	Forged steel	3.7
1.11	Inlet and outlet valves	Forged steel	3.7
1.12	Connecting bolts of crankshaft sections	Forged steel	3.7
1.13	Supercharger, i.e. shaft and rotor including blades (turbochargers and starting compressors (inclusive of Roots blowers) except auxiliary blowers)	Forged steel	3.7
1.14	Camshaft, camshaft drive gears	Forged steel	3.7
1.15	Speed governors and overspeed devices	–	–
1.16	Safety valves of the crankcase (for engines having a bore exceeding 200 mm)	–	–
1.17	Counterweights if they are not integral with the crankshaft	Forged steel Cast steel Cast iron	3.7 3.8 3.9
1.18	Main, connecting-rod, crank bearings	–	–
1.19	High pressure fuel oil pumps	–	–
1.20	Nozzles	–	–
1.21	High-pressure oil fuel injection pipes	Rolled steel	3.4
2	**Steam turbines**		
2.1	Casings of turbines	Cast iron Cast steel Rolled steel	3.9, 3.10 3.8 3.3
2.2	Manoeuvring gear casings, nozzle boxes	Cast steel	3.8
2.3	Solid-forged rotors, shafts and disks	Forged steel	3.7
2.4	Blades	Forged steel Cast steel	3.7 3.8
2.5	Shrouds and lashing wire	–	–
2.6	Nozzles and diaphragms	Cast iron Forged steel Cast steel	3.9, 3.10 3.7 3.8
2.7	Gland seals	–	–
2.8	Couplings	Forged steel Cast steel	3.7 3.8
2.9	Bolts for joints of rotor parts, split casings and couplings	Forged steel	3.7
3	**Gears, elastic and disengaging couplings**		
3.1	Casing	Rolled steel Forged steel Cast steel Cast iron Aluminium alloy	3.7 3.2 3.8 3.9, 3.10 5.2
3.2	Shafts	Forged steel	3.7
3.3	Pinions, wheels, wheel rims	Forged steel Cast steel	3.7 3.8
3.4	Coupling components transmitting the torque:		
	.1 rigid components	Rolled steel Forged steel Cast steel Cast iron Aluminium alloy	3.2 3.7 3.8 3.9 5.1, 5.2
3.4	**.2** elastic components	Rubber, synthetic material Spring steel	
3.5	Coupling bolts	Forged steel	3.7
4	**Compressors and piston-type pumps**		
4.1	Crankshaft	Forged steel Cast steel Cast iron	3.7 3.8 3.9
4.2	Piston rod	Forged steel	3.7

4.3	Connecting rod	Forged steel Cast iron Aluminium alloy	3.7 3.9, 3.10 5.2
4.4	Piston	Forged steel Cast steel Cast iron Cooper alloy Aluminium alloy	3.9, 3.10 3.8 3.7 4.1 5.2
4.5	Cylinder block, cylinder covers	Cast steel Cast iron	3.9, 3.10 3.8
4.6	Cylinder liner	Cast iron	3.9, 3.10
5	**Centrifugal pumps, fans and air blowers**		
5.1	Shaft	Rolled steel Forged steel	3.2 3.7
5.2	Impeller	Cast steel Copper alloy Aluminium alloy	3.8 4.1 5.2
5.3	Casing	Rolled steel Cast steel Cast iron Copper alloy Aluminium alloy	3.9, 3.10 3.8 3.2 4.1 5.2
6	**Steering gear**		
6.1	Tiller of main and emergency gear	Forged steel Cast steel	3.7 3.8
6.2	Rudder quadrant	Cast steel	3.8
6.3	Rudder stock yoke	Forged steel	3.7
6.4	Pistons with rods	Forged steel Cast steel	3.7 3.8
6.5	Cylinders	Steel tube Cast steel Cast iron	3.9, 3.10 3.4 3.8
6.6	Drive shaft	Forged steel	3.7
6.7	Pinions, gear wheels, tooth rims	Forged steel Cast steel Cast iron	3.7 3.8 3.9
7	**Windlasses, capstans, mooring and towing winches**		
7.1	Drive, intermediate and output shafts	Forged steel	3.7
7.2	Pinions, gear wheels and tooth rims	Forged steel Cast steel Cast iron	3.7 3.8 3.9
7.3	Sprockets	Cast steel Cast iron	3.8 3.9, 3.10
7.4	Claw clutches	Forged steel Cast steel	3.7 3.8
7.5	Band brakes	Rolled steel	3.2
8	**Hydraulic drives, screw, gear and rotary pumps**		
8.1	Shaft, screw, rotor	Forged steel Cast steel Copper alloy	3.7 3.8 4.1
8.2	Piston rod	Forged steel Copper alloy	3.7 4.1
8.3	Piston	Forged steel Cast steel	3.7 3.8
8.4	Casing, cylinder and housing of screw pump	Cast steel Cast iron Copper alloy	3.8 3.9, 3.10 4.1
8.5	Pinions	Forged steel Cast steel Cast iron Copper alloy	3.7 3.8 3.9, 3.10 4.1

9	**Centrifugal fuel and lubricating oil separators**		
9.1	Bowl shaft	Forged steel	3.7
9.2	Bowl body, bowl discs	Forged steel	3.7
9.3	Drive pinions	Forged steel Copper alloy	3.7 4.1
10	**Gas turbines**		
10.1	Casings of turbines and compressors, diaphragms and combustion chamber casings	Rolled steel Cast stee	3.3 3.8
10.2	Rotors and discs of turbines	Forged steel	3.7
10.3	Rotors and discs of compressors	Forged steel	3.7
10.4	Turbine blades	Rolled steel Forged steel Cast steel	3.3 3.7 3.8
10.5	Compressor blades	Forged steel Cast steel	3.7 3.8
10.6	Shrouds and lashing wire	–	–
10.7	Flame tubes of combustion chambers	Forged steel	3.3
10.8	Heat-exchanging surfaces of regenerators	Forged steel	3.3
10.9	Sealings	–	–
10.10	Flanges of couplings	Forged steel Cast steel	3.7 3.8
10.11	Bolts for joints of rotor parts, turbine and compressor split casings	Forged steel	3.7
Note. The materials shall be selected in accordance with the requirements of 1.6 considering 1.6.7.			

1.2.5 Rotors, shafts and disks of steam turbines and gas turbines engines, as well as the bolts for joints of casings of high pressure turbines are subject to ultrasonic testing during manufacture.

Shafts of main gears more than 100 kg in mass, pinions, tooth rims more than 250 kg in mass are subject to ultrasonic testing during manufacture.

Details of internal combustion engines made of steel are also subject to ultrasonic control in accordance with the requirements of Table 1.2.5.

Ultrasonic testing shall be carried out in accordance with the requirements of **2.2.9.2**, Part XIII "Materials".

Table 1.2.5

Nos	Cylinder bore, mm	Part No. acc. to Table 1.2.4
1	Up to 400 inclusive	1.1, 1.2, 1.4, 1.6 i 1.7
2	Over 400	1.1, 1.2, 1.4 – 1.7

1.2.6 For the internal combustion engines the steel case and forged parts listed in Table 1.2.6, their welded joints included, shall be tested during the manufacture for the absence of the surface defects by the magnetic particle or dye penetrant method and they are also subject to ultrasonic testing.

The runner blades of main and auxiliary steam turbines, guide blades of main turbines and turbine blades of gas turbine engines shall also be subjected to the above testing.

1.2.7 If there are doubts about the absence of defects in the part material, the Register may require to carry out non-destructive testing of other machinery parts and their welded joints.

Table 1.2.6

Nos	Cylinder bore, mm	Part No. acc. to Table 1.2.4
1	Up to 400 inclusive	1.1, 1.5, 1.6
2	Over 400	All parts

1.3 HYDRAULIC TESTS

1.3.1 The machinery parts, with the exception of the internal combustion engine parts, operating under excessive pressure shall be subjected to a hydraulic test by a pressure p_{test} after final machining and before protective coating is applied. The hydraulic test pressure p_{test}, in MPa, is found by the formula

$$P_{test} = (1{,}5 + 0{,}1k)p, \qquad (1.3.1)$$

where:
p – maximum working pressure, MPa;
k – factor taken from Table 1.3.1.

In all cases, the value of test pressure shall not be lower than the pressure setting with the safety valve fully open, but not less than 0,4 MPa for cooled spaces of parts and various seals and not less than 0,2 MPa in all other cases.

Table 1.3.1

Material	Characteristic	Working temperature, °C, up to									
		120	200	250	300	350	400	430	450	475	500
Carbon steel	p, MPa	–	20	20	20	20	10	10	10	–	–
	k	0	0	1	3	5	8	11	17	–	–
Molybdenum and molybdenumchrome steel with a t least 0,4 % molybdenum content	p, MPa	–	–	–	–	20	20	20	20	20	20
	k	0	0	0	0	0	1	2	3,5	6	11
Cast iron	p, MPa	6	6	6	6	–	–	–	–	–	–
	k	0	2	3	4	–	–	–	–	–	–
Bronze, brass and copper	p, MPa	20	3	3	–	–	–	–	–	–	
	k	0	3,5	7	–	–	–	–	–	–	–

If temperatures or working pressures exceed the ratings indicated in Table 1.3.1, the value of test pressure shall be approved by the Register in each case.

1.3.2 The machinery parts and assemblies may be tested separately along the spaces by test pressures prescribed in compliance with the working pressures and temperatures inside each space.

1.3.3 Parts of internal combustion engines shall be tested according to the requirements specified in Table 2.2.2 of Appendix 8 to Section 5, Part IV "Technical Supervision during Manufacture of Products" of RTSC.

1.3.4 The machinery parts and assemblies filled with petroleum products or their vapours (viz., reduction gear casings, sumps, etc.) under hydrostatic or atmospheric pressure shall be tested for oiltightness by the method approved by the Register. Oil-tightness tests of welded structures may be confined to welds only.

1.4 OPERATION TESTS

1.4.1 On completion of assembly, adjustment and running-in, each piece of machinery shall be bench tested under the load conditions prior to installation aboard the ship. The test program shall be approved by the Register. In particular cases, bench tests may be substituted by tests aboard the ship on agreement with the Register.

1.4.2 The pilot models of the machinery shall be tested under a program providing for checking reliability and long-term operational capacity of certain unit components and of the machinery as a whole.

1.5 GENERAL TECHNICAL REQUIREMENTS

1.5.1 Machinery indicated in 1.1 shall remain operative under environmental conditions specified in 2.3, Part VII "Machinery Installations".

1.5.2 The design of the main engines intended for installation aboard single-shaft ships shall provide, as a rule, for a possibility of emergency operation at reduced power in case of a failure of parts, the replacement of which cannot be carried out aboard the ship or demands much time.

1.5.3 The forged, cast and welded steel parts, as well as cast iron parts of the machinery shall be heat treated during manufacture in compliance with the requirements of **3.7.4**, **3.8.4**, **3.9.4**, **3.10.4**, Part XIII "Materials" and **2.1.16**, Part XIV "Welding".

1.5.4 The fasteners used in moving parts of machinery and gears, as well as fasteners difficult for access shall be properly designed or shall have special arrangements aimed at preventing their selfloosening and self-releasing.

1.5.5 The heated surfaces of machinery and equipment shall be insulated according to the requirements of **4.6**, Part VII "Machinery Installations".

1.5.6 The machinery parts that are in contact with a corrosive medium shall be made of an anticorrosive material or shall have corrosion-resistant coatings. Sea water cooling spaces of engines and coolers shall be provided with protectors.

1.5.7 The remote and automatic control and protection systems, the warning alarms included, shall comply with the requirements specified in Part XV "Automation".

1.5.8 Pumping and piping of machinery shall comply with the relevant requirements of Part VIII "Systems and Piping".

1.5.9 Electrical equipment of engines and auxi-liaries shall comply with the relevant requirements of Part XI "Electrical Equipment".

1.6 MATERIALS AND WELDING

1.6.1 Materials intended for manufacture of the machinery parts stated in column 4 of Table 1.2.4 shall comply with the requirements of the appropriate chapters of Part XIII "Materials".

Materials of parts stated in Table 1.2.4 may be also selected according to the standards. In this case, the application of materials is subject to agreement with the Register during consideration of the technical documentation.

1.6.2 Materials of parts listed in **2.1** to **2.4**, **2.6**, **3.2**, **3.3**, **3.4.1**, **4.1**, **6.1**, **6.6**, **7.1**, **10.1** to **10.5** of Table 1.2.4 are subject to survey by the Register during manufacture.

able 1.2.4 are subject to survey by the Register during manufacture. Materials of the parts of internal combustion engines are subject to survey by the Register in accordance with Appendix 8 to Section 5, Part IV "Technical Supervision During Manufacture of Materials" of RTSC.

At the discretion of the Register the survey may also be required during manufacture of pipes and valves of the pressure systems associated with the engine.

1.6.3 When the alloy steels, including heat resistant, high temperature oxidation resistant and high strength steels, or alloy cast iron is used for the machinery parts, the information on chemical composition, mechanical and special properties confirming suitability of the material for intended application shall be submitted to the Register.

1.6.4 The parts of steam turbines and gas turbine engines operating under the conditions of high temperatures (400°C and above) shall be subjected to tensile tests at the design temperature and, if necessary, the Register may require to submit the information on the average stress at the design temperature.

1.6.5 Spheroidal or nodular graphite cast iron is allowed for use up to the temperature of 300°C, and grey cast iron - up to 250°C.

1.6.6 Manufacture of the machinery parts with application of welding shall comply with the requirements of Part XIV "Welding".

1.6.7 In internal combustion engine installations with turbines and gears, the application of materials other than steel may be assessed in relation to the risk of fire associated with component and its installation. The use of materials other than steel is considered acceptable for the following applications:

.1 internal pipes which cannot cause any release of flammable fluid onto the machinery or into the machinery space in case of failure;

.2 components that are only subject to liquid spray on the inside when the machinery is running, such as machinery covers, camshaft end covers, rocker box covers, inspection plates and sump tanks. Refer also to **2.1.10**, Part VIII "Systems and Piping";

.3 components attached to machinery which satisfy fire test criteria according to the applicable national or international standards thus maintaining mechanical properties sufficient for their intended application (also refer to **2.1.10**, Part VIII "Systems and Piping").».

2. INTERNAL COMBUSTION ENGINES

2.1 GENERAL PROVISIONS

2.1.1 The requirements of the present Section are applicable to all internal combustion engines of power output 55 kW and above.

The scope of requirements to the engines of power output less than 55 kW may be reduced regarding to their structural features and purpose.

The requirements for dual-fuel internal combustion engines are specified in Section **9**.

The Register may impose additional requirements upon the design, scope of surveys and tests of internal combustion engines with electronic control systems, based on the regulating documents developed by the Register.

2.2 GENERAL REQUIREMENTS

2.2.1 The engines shall be capable of working with an overload exceeding the rated power by at least 10% for not less than one hour.

2.2.2 The engines intended to be used as main engines shall also comply with the requirements of **2.1**, Part VII “Machinery Installations”.

2.2.3 Irregularity of speed of a.c. diesel generating sets intended for parallel operation shall be such that the amplitude of angle oscillations of the generator shaft does not exceed 3,5°/*P*, where *P* is the number of pairs of generator poles.

2.2.4 The crosshead-type engines, which scavenge spaces are in open connection with the cylinders, shall be provided with the fire extinguishing system approved by the Register, which is entirely separate from the fire extinguishing system of the engine room (refer to **19** Table 3.1.2.1, Part VI "Fire Protection").

The scavenge spaces of the main engines in ships with unattended machinery spaces of category A shall be equipped with a timely fire alarm and fire detection system (refer to **4.2.3.1**, Part VI "Fire Protection").

2.2.5 The diesel generating sets intended as emergency units shall be provided with self-contained fuel supply, cooling and lubricating systems.

Cooling systems are considered to be self-contained if they are independent of the equipment specified in **4.3**, Part VIII "Systems and piping"..

2.2.6 6 Engines intended to drive emergency ge-nerators, which may be also used as sources of electrical power for non-emergency consumers (refer to **9.4.2**, Part XI "Electrical Equipment") shall be equipped with oil fuel and lubricating oil filters, as well as with monitoring equipment, alarm and protective devices as required for prime movers of the main sources of electrical power when in unattended operation.

Along with that, their oil fuel supply tanks shall be fitted with a low level alarm arranged at a level ensuring sufficient oil fuel capacity for the emergency services (refer to **13.8.5**, Part VIII "Systems and Piping").

Besides, such engines shall be designed for continuous operation and shall 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.

2.2.7 The rated power of the engines shall be determined under the following conditions: atmospheric pressure, kPa -100;

air temperature, °C – +45;

relative humidity, % – 60;

sea water temperature, °C– 32.

Other conditions may be specified in compliance with **2.3.1**, Part VII "Machinery Installations".

2.2.8 In the crankshaft speed range (071,2) n_r, where n_r is the rated speed, no restricted speed areas shall be permitted. Along with that, the requirements of **8.8.3** to **8.8.5**, Part VII "Machinery Installations" shall be met.

2.2.9 Fuel oil and lubricating oil pipes, valves, flanged connections, filters shall be screened or otherwise protected so that in case of their failure petroleum products falling onto hot surfaces (refer to **4.6**, Part VII "Machinery Installations") is prevented.

2.2.10 Where special tools and gauges are required for maintenance purposes in compliance with item **22** of Table 1.2.3.1-1 (refer to footnote «4»), these shall be supplied by the manufacturer. Engine servicing shall be performed in compliance with the manufacturer’s recommendations.

2.2.11 For engines with electronic control system where the basic operation processes (fuel supply, gas exchange, starting and reversing, cylinder lubrication) are performed by means of hydraulic (pneumatic) systems controlled by programmable electronic devices upon a signal from the crankshaft-position sensor, a single failure of any component of the electronic control system shall not result in the loss of manoeuvrability or in spontaneous stoppage of the engine (refer to footnote «5» of Table 1.2.3.1-1).

2.3 ENGINE FRAME

2.3.1 The mating surfaces of the frame parts forming the engine crankcase shall be close-fitting and oil- and gastight as well as be fixed together by means of calibrating pieces.

2.3.2 The engine frame and conjugated parts shall be provided with draining arrangements (drain grooves, pipes, etc.) and other facilities preventing penetration of fuel and water into the circulating oil.

The cooling spaces of the cylinder blocks shall be fitted with drain arrangements providing complete drainage.

2.3.3 Engines with a cylinder bore in excess of 230 mm shall be fitted with alarm devices to give a signal indicating that the specified excess of the maximum combustion pressure in a cylinder has been reached.

2.3.4 Protection of internal combustion engines against crankcase explosions.

2.3.4.1 Crankcase construction and crankcase doors shall be of sufficient strength to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by **2.3.5**.

Crankcase doors are to be fastened sufficiently securely for them not to be readily displaced by a crankcase explosion.

2.3.4.2 Additional relief valves shall be fitted on separate spaces of crankcase such as gear or chain cases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3 (considering **2.3.5.2** and **2.3.5.3**).

2.3.4.3 Scavenge spaces in open connection to the cylinders shall be fitted with explosion relief valves.

2.3.4.4 Design, arrangement and location of explosion relief valves shall comply with the requirements of **2.3.5**.

2.3.4.5 Ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines where crankcase ventilation shall be provided in accordance with **9.5.2**.

2.3.4.5.1 Crankcase ventilation pipes, where provided, shall be as small as practicable to minimize the inrush of air after a crankcase explosion. The ends of the ventilation pipes shall be fitted with lamearresting devices and arranged so as to prevent water from getting into engine.

Ventilation pipes shall be laid to the weather deck to locations preventing the suction of vapors into accommodation and service spaces.

For engines with power output up to 750 kW suction of gas from the crankcase by turbochargers or blowers may be admitted, provided reliable oil separators are fitted to prevent the oil from being carried into the engine with suction gas.

2.3.4.5.2 If a forced extraction of the oil mist atmosphere from the crankcase is provided (for mist detection purposes, for instance), the vacuum in the crankcase shall not exceed 250 Pa.

2.3.4.5.3 To avoid interconnection between crankcases and the possible spread of fire following an explosion, crankcase ventilation pipes and oil drain pipes for each engine shall be independent of any other engine.

2.3.4.6 Lubricating oil drain pipes from the engine sump to the drain tank shall be submerged at their outlet ends.

Crankcase drain outlets shall be fitted with grates and grids preventing foreign objects from getting into the drain piping.

The above requirement is also applied to engines with dry crankcase.

2.3.4.7 A warning notice shall be fitted either on the control stand or, preferably, on a crankcase door on each side of the engine. This warning notice shall specify that, whenever overheating is suspected within the crankcase, the crankcase doors or sight holes shall not be opened before a reasonable time, sufficient to permit adequate cooling after stopping the engine.

2.3.4.8 Oil mist detection arrangements (or engine bearing temperature monitors or equivalent devices) are required:

.1 for alarm and slow down purposes for low speed diesel engines of 2250 kW and above or having cylinders of more than 300 mm bore (refer also to Table 4.2.10-1, Part XV "Automation");

.2 for alarm and automatic shutoff purposes for medium and high speed diesel engine of 2250 kW and above or having cylinders of more than 300 mm bore (refer also to Tables 4.2.10-2, 4.4.6-2, Part XV "Automation");

Oil mist detection arrangements shall be of a type approved by the Register and comply with the requirements of **2.3.4.9** and **2.3.4.20**.

Engine bearing temperature monitors or equivalent devices used as safety devices shall be of a type approved by the Register for such purposes.

*Note.*1. For the purpose of the requirements given in **2.3.4.8.1** and **2.3.4.8.2**, the following definitions apply:

Low-speed engines mean diesel engines having a rated speed less than 300 rpm.

Medium-speed engines mean diesel engines having a rated speed of 300 rpm and above, but less than 1400 rpm.

High-speed engines mean diesel engines having a rated speed of 1400 rpm and above.

2. An equivalent device could be interpreted as measures applied to high-speed engines where specific design features to preclude the risk of crankcase explosions are incorporated.

2.3.4.9 The oil mist detection system and arrangements shall be installed in accordance with the engine designer's and oil mist detection arrangements manufacturer's instructions/recommendations.

The following particulars shall be included in the instructions:

.1 schematic layout of engine oil mist detection and alarm system showing location of engine crankcase sample points and piping or cable arrangements together with pipe dimensions to detector;

.2 evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate;

.3 the manufacturer's maintenance and test manual;

.4 information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

2.3.4.10 An engine installed on board ship shall be provided with a manufacturer's maintenance and test manual of oil mist detection arrangements according to **2.3.4.9**.

2.3.4.11 Oil mist detection and alarm information shall be capable of being read from a safe location away from the engine.

2.3.4.12 Each engine shall be provided with its own independent oil mist detection arrangement and a dedicated alarm.

2.3.4.13 Oil mist detection and alarm systems shall be capable of being tested on the test bed and board under engine at standstill and engine running at normal operating conditions in accordance with test procedures approved by the Register.

2.3.4.14 Alarms and shutdowns for the oil mist detection system shall be in accordance with the requirements of Part XV "Automation".

2.3.4.15 The oil mist detection arrangements shall provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangement.

2.3.4.16 The oil mist detection system shall provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

2.3.4.17 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements shall comply with **7.10** "Programmable electronic systems", Part XV "Automation" of the Rules for the Classification and Construction of Sea-Going Ships.

2.3.4.18 Plans showing details and arrangements of oil mist detection and alarm arrangements shall be approved by the Register.

2.3.4.19 The equipment together with detectors shall be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functionally operates.

The testing arrangements shall be approved by the Register.

2.3.4.20 Where sequential oil mist detection arrangements are provided the sampling frequency and time shall be as short as reasonably practicable.

2.3.4.21 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase details, they shall be agreed upon with the Register and provided with the technical substantiation submitted to the Register.

In addition to the requirements of **1.2.3.1.19** the following information shall be included in the details to be submitted for consideration:

.1 engine particulars – type, power, speed, stroke, bore and crankcase volume;

.2 details of arrangements preventing the build up of potentially explosive conditions within the crankcase, e. g., bearing temperature monitoring, oil splash temperature, crankcase pressure monitoring and recirculation arrangements;

.3 evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience;

.4 operating instructions and the maintenance and test instructions.

2.3.4.22 Where it is proposed to use the introduction of inert gas into crankcase to minimize a potential crankcase explosion, details of the arrangements shall be submitted to the Register for consideration.

2.3.5 Engine crankcase explosion relief valves.

2.3.5.1 Engines having a cylinder bore of 200 mm and above or a crankcase volume of 0,6 m3 and above shall be provided with crankcase explosion relief valves in accordance with **2.3.4.2**, **2.3.5.2**, andi **2.3.5.13** as follows:

.1 engines having a cylinder bore not exceeding 250 mm shall have at least one valve near each end, but, if the crankshaft of these engines has over 8 crankthrows, an additional valve shall be fitted near the middle of the engine;

.2 engines having a cylinder bore exceeding 250 mm but not exceeding 300 mm shall have at least one valve in way of each alternate crankthrow, with at least two valves per the crankcase in all cases;

.3 engines having a cylinder bore exceeding 300 mm shall have at least one valve in way of each main crankthrow.

2.3.5.2 The free area of each relief valve shall be not less than 45 cm^2.

2.3.5.3 The combined free area of the valves fitted on an engine shall be not less than 115 cm^2 per 1 m^3 of the crankcase gross volume.

In estimating the crankcase gross volume the stationary parts may be discounted (however, the rotary and reciprocating components shall be included into the gross volume).

2.3.5.4 Crankcase explosion relief valves shall 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 the inrush of air thereafter.

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

2.3.5.6 Crankcase explosion relief valves shall be designed to open quickly and be fully open at an over-pressure in the crankcase of not greater than 0,02 MPa.

2.3.5.7 Crankcase explosion relief valves shall be provided with flame arresters that permits flow for crankcase pressure relief and prevents passage of flame following a crankcase explosion.

2.3.5.8 Crankcase explosion relief valves shall be of type approved by the Register and be tested in a configuration that represents the installation arrangements that will be used on an engine.

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

2.3.5.10 In a delivery set of crankcase explosion relief valves a copy of the manufacturer's installation and maintenance manual shall be provided that is pertinent to the size and type of valve being supplied for installation on a particular engine.

The manual shall contain the following information:

.1 description of the valve with details of functional and design limits;

.2 copy of Type Approval/Test Certificate;

.3 installation instruction;

.4 maintenance and in-service instructions including testing and replacement of any sealing arrangements;

.5 actions required after a crankcase explosion.

2.3.5.11 A copy of the manual specified in **2.3.5.10**, 0 shall be kept on board ship together with the valve after its installation (refer also to **5.2.3.3.2** Part IV "Technical Supervision during Manufacture of Products" of RTSC).

2.3.5.12 Details of crankcase explosion relief valves design and arrangement shall be submitted for the Register approval in addition to the requirements of **1.2.3.1.19**.

2.3.5.13 Valves shall be provided with suitable marking including the following information:

name and address of the manufacturer;

designation and size;
date of manufacture;
approved installation orientation.

2.4 CRANKSHAFTS

2.4.1 The check calculation method as described below is applicable to solid-forged and semibuilt crankshafts of forged or cast steel intended for marine diesel engines having the cylinders either in line or in V-arrangement, with one crankthrow between main bearings.

Cast iron crankshafts may be approved on agreement with the Register, provided calculations considering the applicable requirements of Appendices III, V and VI to Section **2** and experimental data obtained in compliance with the requirements of Appendix IV to Section **2** are submitted. Thus, the assumed safety factors shall be justified.

2.4.2 The outlets of oil bores into crankpins and journals shall 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, if requested by the Register, shall submit documentation supporting his oil bore design.

2.4.3 For the calculation of crankshafts, the documents and particulars listed in the following shall be submitted:

crankshaft drawing, which shall contain all scantlings required by the Chapter;

type designation and kind of engine (in-line engine or V-type engine with adjacent connecting rods, forked connecting rod or articulated-type connecting rod);

operating and combustion method (direct injection, precombustion chamber, etc.);

number of cylinders;

rated power, kW;

rated engine speed, min^{-1} ;

sense of rotation (Fig.2.4.3-1);

firing order with the respective ignition intervals and, where necessary, V-angle av, deg. (refer to Fig. 2.4.3-1),

cylinder diameter, mm;

stroke, mm;

maximum cylinder pressure P_{max}, MPa;

charge air pressure, in MPa, before inlet valves or scavenge ports, whichever applies;

nominal compression ratio;

connecting rod length L_H, mm;

oscillating weight of one crank gear, in kg (in case of V-type engines, where necessary, also for the cylinder unit with master and articulated-type connecting rod or forked and inner connecting rod);

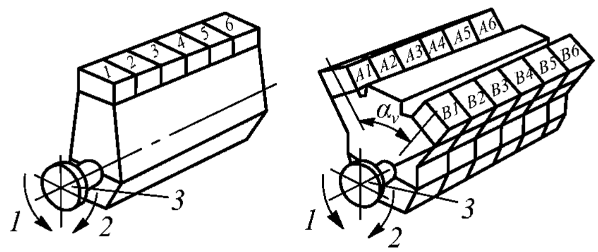

Fig.2.4.3-1. Sense of crankshaft rotation:
1 – counter-clockwise; *2* – clockwise; *3* – driving shaft flange

digitalized gas-pressure-versus-crank-angle curve presented at equidistant intervals and integrally divisible by the V-angle, but not more than 5°;

For bending moments, shearing forces and torques, refer to **2.4.4.2**, **2.4.5.1**;

Details of crankshaft material:

material designation (according to standards, etc.);

chemical composition;

tensile strength R_m, MPa;

yield stress R_{eH}, MПa;

reduction in area at break Z, %;

elongation A_5, %;

impact energy, *KV*, J;

method of material melting process (basic oxygen furnace, open-hearth furnace, electric furnace, etc.);

type of forging (free form forged, continuous grain flow forged, drop forged, etc.;

with description of the forging process);

heat treatment;

surface treatment of journal and crankpin fillets and oil bore outlets (induction hardening, flame hardening, nitriding, rolling, shot peening and so on with description of hardening process) refer to Appendix V to Section **2**;

hardness at surface, *HV*;

hardness as a function of depth, mm;

extension of surface hardening.

For engines with articulated-type connecting rod (refer to Fig. 2.4.3-2), the following details shall be submitted additionally:

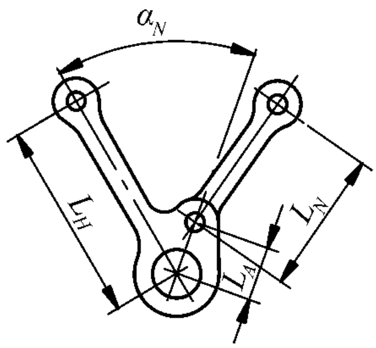

Fig.2.4.3-2. Articulated-type connecting rod

distance to link point L_A, mm;

link angle α_N, deg.;

connecting rod length L_H, mm;

articulated-type connecting rod length L_N, mm.

2.4.4 Calculation of alternating stresses due to bending moments and shearing forces.

2.4.4.1 Assumptions..

The calculation is based on a statically determined system, so that only one single crankthrow is considered of which the journals are supported in the centre of adjacent bearings and which is subject to gas and inertia forces (refer to Figs. 2.4.4.1-1 and 2.4.4.1-2).

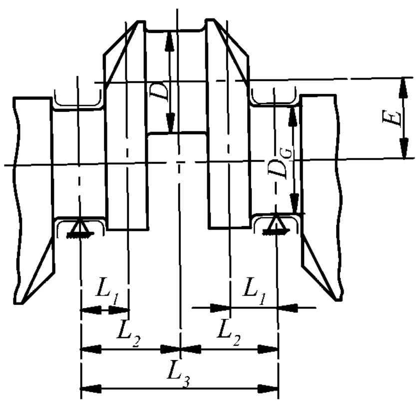

Fig.2.4.4.1-1. Crank throw for in-line engine

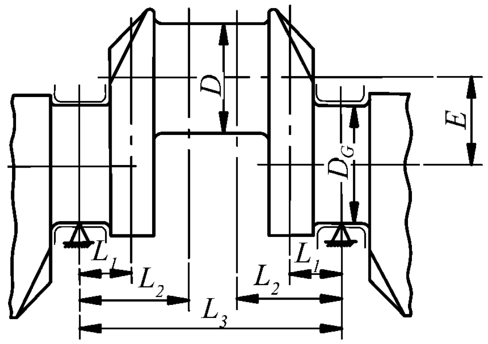

Fig.2.4.4.1-2. Crank throw for engine with 2 adjacent connecting rods

The nominal bending moment is taken as a moment with the bending lever (distance L_1 for fillets and L_2 for oil bore, for semi-built crankshafts with recess of crankpin exceeding the value of the radius of that crankpin fillet, the distance L_1 is specified as shown on Fig. 2.4.6.1-2), due to the radial components of the connecting rod force.

For crankthrows with two connecting rods acting upon one crankpin the nominal bending moment is taken as a bending moment obtained by superposition of two bending moment loads according to phase.

The nominal alternating stresses due to bending moments and shearing forces shall be related to the cross-sectional area of the crank web in the centre of the overlap of the pins (refer to Fig 2.4.6.1-1) or passing though the centre of the fillet radius of the crankpin for pins which do not overlap (refer to Fig. 2.4.6.1-2).

2.4.4.2 Calculation of nominal alternating bending and shearing stresses.

The maximum and minimum bending moment values $M_{B\,\max}$, $M_{BO\,\max}$, $M_{B\,\min}$ and $M_{BO\,\min}$, as well as the maximum and minimum shearing force values $Q_{\max}$ and $Q_{\min}$ shall be submitted to the Register, determined by calculating the radial forces acting upon the crankpin owing to gas and inertia forces.

On agreement with the Register, a simplified calculation of the radial forces may be submitted. The nominal alternating bending moment M_{BN}, in N·m, shall be determined as

$$M_{BN} = \pm\tfrac{1}{2}(M_{B\max} - M_{B\min}). \qquad (2.4.4.2\text{-}1)$$

The nominal alternating bending stress in fillets σ_{BN}, in MPa, shall be determined by the formula

$$\sigma_{BN} = \pm\frac{M_{BN}}{W_{eq}}K_e\cdot 10^3, \qquad (2.4.4.2\text{-}2)$$

where:
W_{eq} – equatorial moment of resistance related to cross-sectional area of web, mm³, $W_{eq} = BW^2/6$;
K_e – factor equal to 0,8 for 2-stroke engines and 1,0 for 4-stroke engines.
B and M - refeer to 2.4.6.

The nominal alternating shearing stress in fillets σ_{QN}, MPa, shall be determined by the formula

$$\sigma_{QN} = \pm\frac{Q_N}{F}K_e, \qquad (2.4.4.2\text{-}3)$$

where:
Q_N – nominal alternating shearing force, N, $Q_N = \pm\, 0{,}5(Q_{\max} - Q_{\min})$;
F - area related to cross-section of web, mm², $F = BW$.

Nominal alternating bending stress in outlet of crankpin oil bore σ_{BON}, MPa, shall be determined by the formula

$$\sigma_{BON} = \pm\frac{M_{BON}}{W_e}10^3, \qquad (2.4.4.2\text{-}4)$$

where:
M_{BON} – nominal alternating bending moment at the outlet of crankpin of oil bore, N·m;
$M_{BON} = \pm\, 0{,}5(M_{BO\max} - M_{BO\min})$;
M_{BO} – vector sum of alternating bending moments MBTO and MBRO due to tangential and radial force, respectively, N·m,
$M_{BO} = (M_{BTO}\cos\psi + M_{BRO}\sin\psi)$;

Ψ – angle between oil bore and horizontal measured in the sense of rotation of the crankshaft (refer to Fig. 2.4.4.2), deg;

W_e – section modulus related to cross-section of axially bored crankpin, mm^3,

$W_e = (\pi/32)[(D^4 - D^4_{BH})/D]$

D and D_{BH} – refer to **2.4.6**;

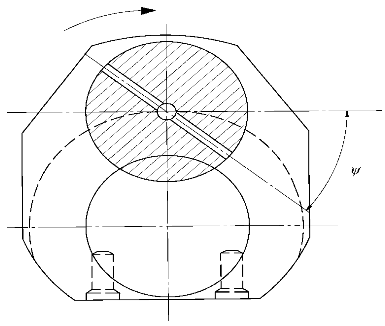

Fig. 2.4.4.2. Sectional view of the crankpin in way of oil bore

2.4.4.3 Calculation of alternating bending stresses in fillets.

The alternating bending stress in a crankpin fillet σ_{BH}, in MPa, shall be determined by the formula

$$\sigma_{BH} = \pm (\alpha_B \sigma_{BN}), \qquad (2.4.4.3\text{-}1)$$

where: α_B – stress concentration factor for bending in crankpin fillet (for determination, refer to **2.4.6**).

The alternating bending stress in a journal fillet σ_{BG}, in MPa, shall be determined by the formula

$$\sigma_{BG} = \pm (\beta_B \sigma_{BN} + \beta_Q \sigma_{QN}), \qquad (2.4.4.3\text{-}2)$$

where:

β_B – stress concentration factor for bending in journal fillet (for determination, refer to **2.4.6**);

β_Q – stress concentration factor for shearing (for determination, refer to **2.4.6**).

2.4.4.4 Calculation of alternating bending stresses in outlet of crankpin oil bore.

The alternating bending stress σ_{BO}, MPa, in outlet of crankpin oil bore shall be determined by the formula

$$\sigma_{BO} = \pm (\gamma_B \sigma_{BON}) \qquad (2.4.4.4)$$

where: γ_B – bending stress concentration factor in outlet of crankpin oil bore (for determination of value - refer to **2.4.6**).

2.4.5 Calculation of alternating torsional stresses.

2.4.5.1 Calculation of nominal alternating torsional stresses.

The calculation for nominal alternating torsional stresses shall be undertaken by the engine manufacturer according to the information below. The maximum values obtained from such calculations shall be submitted to the Register.

The maximum and minimum alternating torques shall be ascertained for each crankthrow and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 16th order for 2-stroke cycle engines and from 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance shall be made for the dampings that exist in the system and for unfavourable conditions (misfiring in one of the cylinders).

The speed ranges shall be selected in such a way that the transient response can be recorded with sufficient accuracy.

The nominal alternating torsional stress τ_N, in MPa, referred to crankpin or journal shall be determined by the formula

$$\tau_N = \pm \frac{M_T}{W_p} \cdot 10^3, \qquad (2.4.5.1)$$

where: M_T – nominal alternating torque, N·m, to be determined by the formula

$$M_T = \pm \frac{1}{2}\left(M_{T\max} - M_{T\min}\right);$$

where:

$M_{T\max}$, $M_{T\min}$ – = extreme values of the torque with consideration of the mean torque, N·m;

W_p – = polar moment of resistance related to cross-sectional area of bored crankpin or bored journal, in mm3 , and determined by the formulae:

$$W_p = \frac{\pi}{16}\left(\frac{D^4 - D_{BH}^4}{D}\right), \qquad W_p = \frac{\pi}{16}\left(\frac{D_G^4 - D_{BG}^4}{D_G}\right),$$

D, D_{BH} and D_{BG} – refer to **2.4.6**.

2.4.5.2 Calculation of alternating torsional stresses in fillets.

In the crankpin fillet, the alternating torsional stress, τ_H, MПa, shall be determined by the formula

$$\tau_H = \pm(\alpha_T \tau_N), \qquad (2.4.5.2\text{-}1)$$

where: α_T – stress concentration factor for torsion in crankpin fillet (for determination, refer to **2.4.6**).

In the journal fillet, the alternating torsional stress τ_G, in MPa, shall be determined by the formula

$$\tau_G = \pm(\beta_T \tau_N), \qquad (2.4.5.2\text{-}2)$$

where: β_T – stress concentration factor for torsion in journal fillet (for determination, refer to **2.4.6**).

2.4.5.3 Calculation of alternating torsional stresses in outlet of crankpin oil bore.

The alternating torsional stress σ_{BO}, MPa, in outlet of crankpin oil bore shall be determined by the formula

$$\sigma_{TO} = \pm(\gamma_T \tau_N) \qquad (2.4.5.3)$$

where: γ_T – torsional stress concentration factor in outlet of crankpin oil bore (for determination of value _ refer to **2.4.6**).

2.4.6 Calculation of stress concentration factors.

2.4.6.1 Where the stress concentration factor cannot be furnished by reliable measurements the values may be evaluated by means of the formulae according to **2.4.6.2**, **2.4.6.3** and **2.4.6.4**, 4 applicable to the fillets and outlets of crankpin oil bores of solid-forged web-type crankshafts and to the crankpin fillets of semi-built crankshafts only.

All crank dimensions necessary for the calculation of stress concentration factors are shown in Fig. 2.4.6.1-1 and Fig. 2.4.6.1-2.

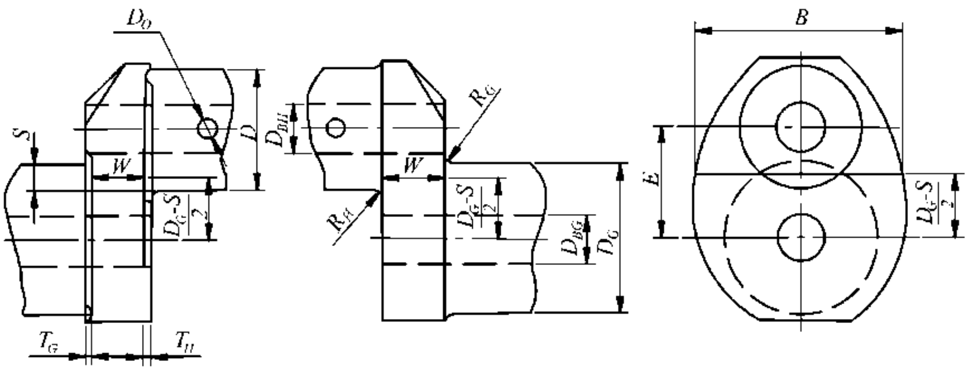

Fig.2.4.6.1-1 Crank dimensions necessary for the calculation of stress concentration factors:

D – crankpin diameter, mm; D_{BH} – diameter of bore in crankpin, mm; R_H – fillet radius of crankpin, mm; T_H – recess of crankpin, mm; D_G – journal diameter, mm; D_{BG} –diameter of bore in journal, mm; D_O – diameter of oil bore in crankpin, mm; R_G – fillet radius of journal, mm; T_G – recess of journal, mm; E – pin eccentricity, mm;
S – pin overlap, mm; $S = (D - D_G)/2 - E$; W, B – web thickness and width, mm.

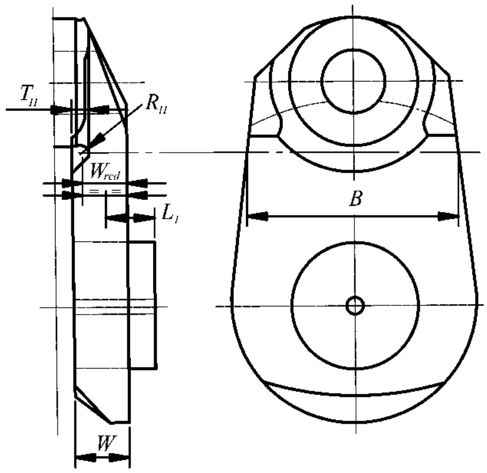

Fig.2.4.6.1-2 Crank dimensions without web overlap necessary for calculation of stress concentration factors at $T_H > R_H$:

W_{red} – design thickness of web, mm; $W_{red} = W_{red} - T_H + R_H$.

For the calculation of stress concentration factors in crankpin and journal fillets and for outlet of the crankpin oil bore, the following related dimensions will be applied:

$$s = S/D \text{ with } s \le 0{,}5;$$
$$w = W/D \text{ with } 0{,}2 \le w \le 0{,}8 \text{ i } T_H \le R_H;$$
$$w = W_{red}/D \text{ with } 0{,}2 \le w \le 0{,}8 \text{ i } T_H > R_H;$$
$$b = B/D \text{ with } 1{,}1 \le b \le 2{,}2;$$
$$d_G = D_{BG}/D \text{ with } 0 \le d_G \le 0{,}8;$$
$$d_H = D_{BH}/D \text{ with } 0 \le d_H \le 0{,}8;$$
$$d_O = D_O/D \text{ with } 0 \le d_O \le 0{,}2;$$
$$t_H = T_H/D; \quad t_G = T_G/D;$$

for crankpin fillets

$$r = R_H/D \text{ with } 0{,}03 \le r \le 0{,}13;$$

for journal fillets

$$r = R_G/D \text{ with } 0{,}03 \le r \le 0{,}13.$$

The factor f_t, which accounts for the influence of a recess in the fillets is not considered if the values of (f_t=1).

The factors $f(s,w)$ and $f(r,s)$ at the relative overlap of pins s < -0,5 shall be evaluated replacing actual value of s by - 0,5.

The alternative calculation procedure for the stress concentration factor with the use of the finiteelement method shall be agreed upon with the Register (refer to Appendices III and IV to Section **2**).

2.4.6.2 Crankpin fillet (refer to Appendix I to Section 2).

The stress concentration factor for bending α_B is

$$\alpha_B = 2{,}6914 f(s,w) f(w) f(b) f(r) f(d_G) f(d_H) f_t, \qquad (2.4.6.2\text{-}1)$$

where:

$f(s,w) = -4{,}1883 + 29{,}2004w - 77{,}5925w^2 + 91{,}9454w^3 - 40{,}0416w^4 + (1 - s)(9{,}5440 - 58{,}3480w + 159{,}3415w^2 - 192{,}5846w^3 + + 85{,}2916w^4) + (1 - s)^2(-3{,}8399 + 25{,}0444w - 70{,}5571w^2 + 87{,}0328w^3 - 39{,}1832w^4)$;

$f(w) = 2{,}1790w^{0{,}7171}$;

$f(b) = 0{,}6840 - 0{,}0077b + 0{,}1473b^2$;

$f(r) = 0{,}2081r^{(-0{,}5231)}$;

$f(d_G) = 0{,}9993 + 0{,}27d_G - 1{,}0211\,d_G^2 + 0{,}5306\,d_G^3$;

$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

$f(d_H) = 0{,}9978 + 0{,}3145d_H - 1{,}5241\,d_H^2 + 2{,}4147\,d_H^3$;

The stress concentration factor for torsion is

$$\alpha_T = 0{,}8f(r,s)\,f(b)\,f(w), \qquad (2.4.6.2\text{-}2)$$

where:
$f(r,s) = r^{\,(-0{,}332\,+\,0{,}1015(1-s))}$,
$f(b) = 7{,}8955 - 10{,}654b + 5{,}3482b^2 - 0{,}857b^3$,
$f(w) = w^{\,(-0{,}145)}$.

2.4.6.3 Journal fillet (refer to Appendix I Section **2**).
The stress concentration factor for bending β_B is

$$\beta_B = 2{,}7146\, f_B(s,w) f_B(w) f_B(b) f_B(r) \times f_B(d_G) f_B(d_H) f_t\,, \qquad (2.4.6.3\text{-}1)$$

where:
$f_B(s,w) = -1{,}7625 + 2{,}9821w - 1{,}5276w^2 + (1-s)(5{,}1169 - 5{,}8089w + 3{,}1391w^2) + (1-s)^2 \times (-2{,}1567 + 2{,}3297w - 1{,}2952w^2)$,
$f_B(w) = 2{,}2422w^{0{,}7548}$,
$f_B(b) = 0{,}5616 + 0{,}1197b + 0{,}1176b^2$,
$f_B(r) = 0{,}1908r^{(-0{,}5568)}$,
$f_B(d_G) = 1{,}0012 - 0{,}6441d_G + 1{,}2265\, d_G^2$,
$f_B(d_H) = 1{,}0012 - 0{,}1903d_H + 0{,}0073\, d_H^2$,
$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

The stress concentration factor for shearing β_Q is

$$\beta_Q = 3{,}0128 f_Q(s)\, f_Q(w)\, f_Q(b)\, f_Q(r)\, f_Q(d_H)\, f_t, \qquad (2.4.6.3\text{-}2)$$

where:
$f_Q(s) = 0{,}4368 + 2{,}1630(1-s) - 1{,}5212 \times (1-s)^2$,
$f_Q(w) = w/(0{,}0637 + 0{,}9369w)$,
$f_Q(b) = -0{,}5 + b$,
$f_Q(r) = 0{,}5331r^{(-0{,}2038)}$,
$f_Q(d_H) = 0{,}9937 - 1{,}1949d_H + 1{,}7373\, d_H^2$,
$f_t = 1 + (t_H + t_G)(1{,}8 + 3{,}2s)$.

The stress concentration factor for torsion β_T is:

$$\beta_T = \alpha_T, \qquad (2.4.6.3\text{-}3)$$

if the diameters and fillet radii or crankpin and journal are the same, and

$$\beta_T = 0{,}8f(r,s)\,f(b)\,f(w), \qquad (2.4.6.3\text{-}4)$$

if crankpin and journal diameters and/or radii are of different sizes,
where:
$f(r,s)$; $f(b)$; $f(w)$ shall be determined by Formula (2.4.6.2-2);
in this case, r is the ratio of the journal fillet radius to the journal diameter, $r = R_G/D_G$.

2.4.6.4 Outlet of oil bore (refer to Appendix II to Section 2).
The stress concentration factor for bending γ_B shall be determined by the formula

$$\gamma_B = 3 - 5{,}88d_O + 34{,}6d_O^2. \qquad (2.4.6.4\text{-}1)$$

The stress concentration factor for torsion γ_T shall be determined by the formula

$$\gamma_T = 4 - 6d_O + 30\, d_O^2\,. \qquad (2.4.6.4\text{-}2)$$

2.4.7 Additional bending stresses.
In addition to the alternating bending stresses in fillets (refer to **2.4.4.3**) further bending stresses due to misalignment and bedplate deformation as well as due to axial and bending vibrations shall be considered by applying σ_{add}, as given in Table 2.4.7.

For crosshead type engines the additional stress (30 MPa) includes stress due to axial vibrations (20 MPa) and stress due to misalignment and bedplate deformation (10 MPa).

It is recommended that a value of 20 MPa be used where axial vibration calculation results of the complete dynamic system engine/shafting/gearing/propeller) are not available.

Where axial vibration calculation results of the complete dynamic system are available, the calculated figures may be used instead.

Table 2.4.7

Type of engine	σ_{add}, MPa
Crosshead	± 30
Trunk piston	± 10

2.4.8 Calculation of equivalent alternating stresses.

For the crankpin fillet, the equivalent alternating stress σ_{VH}, in MPa, shall be determined by the formula

$$\sigma_{VH} = \pm\sqrt{(\sigma_{BH}+\sigma_{add})^2+3\tau_H^2}, \qquad (2.4.8\text{-}1)$$

For the journal fillet, the equivalent alternating stress σ_{VG}, in MPa, shall be determined by the formula

$$\sigma_{VG} = \pm\sqrt{(\sigma_{BG}+\sigma_{add})^2+3\tau_G^2}. , \qquad (2.4.8\text{-}2)$$

For the outlet of crankpin oil bore, the equivalent alternating stress σ_{VO}, in MPa, shall be determined by the formula

$$\sigma_{VO} = +\frac{1}{3}\sigma_{BO}[1+2\sqrt{1+2{,}25(\sigma_{TO}/\sigma_{BO})^2}], \qquad (2.4.8\text{-}3)$$

For other parameters, refer to **2.4.4.3**, **2.4.5.2** and **2.4.7**.

2.4.9 Calculation of fatigue strength.

Where the fatigue strength for a crankshaft cannot be furnished by reliable measurements, the fatigue strength σ_{DWH} , σ_{DWG}, i σ_{DWO}, МПа, O in MPa, may be evaluated by means of the following formulae:

related to the crankpin diameter

$$\sigma_{DWH} = K(0{,}42R_m+39{,}3)(0{,}264+1{,}073D^{-0{,}2}+\frac{785 - R_m}{4900}+\frac{196}{R_m}\sqrt{\frac{1}{R_H}}), \qquad (2.4.9\text{-}1)$$

related to the journal diameter

$$\sigma_{DWG} = K(0{,}42R_m+39{,}3)(0{,}264+1{,}073D^{-0{,}2}+\frac{785 - R_m}{4900}+\frac{196}{R_m}\sqrt{\frac{1}{R_G}}), \qquad (2.4.9\text{-}2)$$

related to the crankpin in outlet of crankpin oil bore

$$\sigma_{DWO} = K(0{,}42R_m+39{,}3)(0{,}264+1{,}073D^{-0{,}2}+\frac{785 - R_m}{4900}+\frac{196}{R_m}\sqrt{\frac{2}{D_O}}), \qquad (2.4.9\text{-}3)$$

where:

K – = factor for different types of forged and cast crankshafts without surface treatment equal to:

1,05 for continuous grain flow forged or drop-forged crankshafts, applied only to fatigue strength in a fillet;

1,0 for free form forged crankshafts;

0,93 for cast steel crankshafts;

R_m – minimum tensile strength of crankshaft material, MPa.

K = 1,3 for crankshafts subject for surface treatment.

For other parameters refer to **2.4.6.1**. However, it shall be considered that for calculation purposes R_H, R_G and $D_O/2$ shall not be taken less than 2 mm.

Where the results of the fatigue tests conducted on full size crankthrows or crankshafts, which have been subjected to surface treatment are available, the K factors shall be used based on the tests (refer to Appendices IV and V to Section **2**).

The experimental values of fatigue strength testing obtained during the fatigue tests shall be agreed upon with the Register. The survival probability for fatigue strength values derived from testing shall not be less than 80 % of the average value.

2.4.10 Calculation of shrink-fits of semi-built crankshafts.

2.4.10.1 All crank dimensions necessary for the calculation of the shrink-fit are shown in Fig. 2.4.10.1.

The radius of the transition from the journal to the shrink diameter shall not be less than the greater of the two values:

$$R_G \geq 0{,}015 D_G \quad \text{i} \quad R_G \geq 0{,}5\,(D_S - D_G).$$

The actual oversize Z of the shrink-fit shall be within the limits $Z_{\min}$ and $Z_{\max}$ calculated in accordance with **2.4.10.2 – 2.4.10.4**.

The necessary minimum oversize is determined by the greater value calculated in accordance with **2.4.10.2** and **2.4.10.3**.

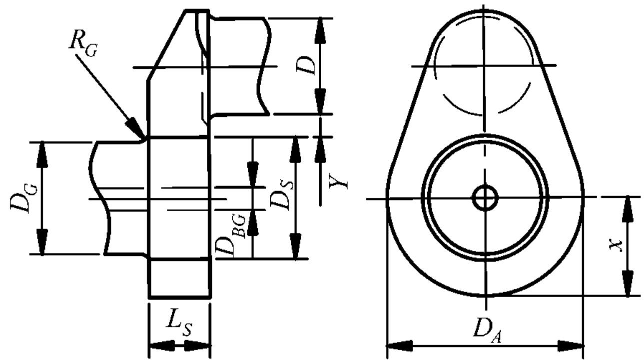

Fig.2.4.10.1. Crank throw of semi-built crankshaft:

D_S – shrink diameter, mm; L_S – length of shrink-fit, mm; D_A – outside diameter of web or twice the minimum distance x between centre-lines of journals and outer contours of web, whichever is less (mm); y – distance between the adjacent generating lines of journal and pin (mm), $y \geq 0{,}05 D_S$.

Where y is less than $0{,}1 D_S$, special consideration shall be given to the effect of stress due to the shrink on the fatigue strength at the crankpin fillet (For other parameters, refer to **2.4.6.1**).

2.4.10.2 The calculation of the minimum oversize $Z_{\min}$ shall be carried out for the crankthrow with the maximum torque $M_{T\max}$ (refer to **2.4.5.2**) using the formula

$$Z_{\min} \geqslant \frac{4 \cdot 10^3\, S_R M_{T\max}}{\pi \mu E_M D_S L_S} \cdot \frac{1 - Q_A^2 Q_S^2}{(1 - Q_A^2)(1 - Q_S^2)}, \qquad (2.4.10.2)$$

where:

$Z_{\min}$ – minimum oversize, mm;

S_R – safety factor against slipping to be taken not less than 2;

μ – coefficient for static friction equal to 0,20 where $L_S/D_S \geq 0{,}40$;

E_M – Young's modulus, MPa;

$Q_A = D_S/D_A$; $Q_S = D_{BG}/D_S$.

where $D_{BG} \leqslant D_S \sqrt{\dfrac{1 - 4000 S_R M_{T\max}}{\mu \pi D_S^2 L_S R_{eH}}}$.

2.4.10.3 In addition to **2.4.10.2** the minimum oversize $Z_{\min}$, in mm, shall also be calculated according to the following formula

$$Z_{\min} \geq R_{eH} D_S / E_M, \qquad (2.4.10.3)$$

where: R_{eH} – minimum yield strength of material for journal pin, MPa.

2.4.10.4 The maximum permissible oversize Z_{max}, in mm, is calculated in accordance with the following formula

$$Z_{\max} \leq \frac{R_{eH} D_S}{E_M} + \frac{0{,}8 D_S}{1000}. \qquad (2.4.10.4)$$

2.4.11 Acceptability factor.

Adequate dimensioning of a crankshaft is ensured if the acceptability factors (the ratio of the fatigue strength to the equivalent alternating stress) for both the crankpin and journal fillets as well as for outlet of crankpin oil bore satisfy the criteria:

$$Q_H = \sigma_{DWH}/\sigma_{VH} \geq 1{,}15,$$

$$Q_G = \sigma_{DWG}/\sigma_{VG} \geq 1{,}15,$$

$$Q_O = \sigma_{DWO}/\sigma_{VO} \geq 1{,}15.$$

2.4.12 At the junction of the web with the journal or pin, the radius of the fillet shall not be less than 0,05*D*.

Where crankshafts have flanges, the radius of the fillet at the junction of the flange with the journal shall not be less than 0,08*D*.

2.4.13 The edges of the oil holes shall be rounded to a radius of not less than 0,25 of the diameter of the hole with a smooth finish.

2.4.14 In built and semi-built crankshafts, no keys or pins are permitted for joining a crankpin or journal to the web. On the outer sides of junction of webs to pins or journals, reference marks shall be provided.

2.4.15 Where the thrust bearing is built in the engine frame, the diameter of the thrust shaft in way of the bearing shall not be less either than that of the crankshaft journal or the shaft diameter determined in accordance with **5.2.2**, Part VII "Machinery Installations".

2.5 SCAVENGING AND SUPERCHARGING

2.5.1 The operation and manoeuvrability of main engine shall be guaranteed in the case of failure of one or all turbochargers under running conditions permitted by the engine manufacturer (refer to **2.1.7**, Part VII "Machinery Installations").

2.5.2 For main engines, which turbochargers do not provide a sufficient air supply when started and within low-load range, provision shall be made for an auxiliary supercharging system generally comprising two air blowers, which would make it possible for the engine to reach running conditions, under which the necessary degree of supercharging would be ensured.

If one of the blowers of the auxiliary supercharging system fails, the other one that remains intact shall ensure the operation of the system.

2.5.3 Where supercharging air is cooled, the scavenge manifolds shall be fitted with thermometers and condensate drain arrangements after each air cooler.

2.5.4 Scavenge manifolds shall be provided with relief valves set for a pressure exceeding that of scavenging air by not more than 50 %.

The free area of the relief valves shall not be less than 30 cm^2 per cubic metre of the manifold volume including the volume of the underpiston spaces in crosshead engines fitted with diaphragms if these spaces are not used as scavenging pumps.

2.5.5 Scavenge manifolds and underpiston spaces shall be provided with draining arrangements for removing accumulations of sludge and water.

2.5.6 The air intake pipes of engines and scavenging-and-supercharging units shall be fitted with safety gauzes.

2.5.7 The requirements of the para are applicable to the turbochargers of internal combustion engines. The requirements for type testing and survey of the turbochargers are specified in Appendix *9* "Procedure for Survey, Testing, Approval of Turbochargers and their Matching on ICE", Section **5** "Machinery", Part IV "Technical Supervision during Manufacture of Products" of RTSC.

2.5.7.1 Turbochargers shall be type approved, either separately or as a part of an engine considering.

The requirements of **2.5.7** are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

2.5.7.2 Turbochargers shall be designed to operate under service conditions given in 2.3, Part VII "Machinery Installations" and **2.2.7**, Part IX "Machinery".

The component lifetime and the alarm level for speed shall be based on 45°C air inlet temperature.

2.5.7.3 The air inlet of turbochargers shall be fitted with a filter.

2.5.7.4 The requirements escalate with the size of the turbochargers. The parameter for size is the engine power (at MCR) supplied by a group of cylinders served by the actual turbocharger, (e.g. for a Vengine with one turbocharger for each bank the size is half of the total engine power).

2.5.7.5 Turbochargers are categorised in three groups depending on served power by cylinder groups with:

Category A: ≤ 1000 kW;

Category B: > 1000 kW and ≤ 2500 kW;

Category C: > 2500 kW.

2.5.7.6 Documentation to be submitted:

.1 Category A:

On the Register request:

containment test report;

cross sectional drawing with principal dimensions and names of components;

test program.

2. Category B and C:

cross sectional drawing with principal dimensions and materials of housing components for containment evaluation;

documentation of containment in the event of disc fracture (refer to **3.2**);

operational data and limitations as:

maximum permissible operating speed (rpm);

alarm level for over-speed;

maximum permissible exhaust gas temperature before turbine;

alarm level for exhaust gas temperature before turbine;

minimum lubrication oil inlet pressure;

lubrication oil inlet pressure low alarm set point;

maximum lubrication oil outlet temperature;

Lubrication oil outlet temperature high alarm set point;

Maximum permissible vibration levels, i.e. self- and externally generated vibration (Alarm levels may be equal to permissible limits but shall not be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110 %.);

arrangement of lubrication system, all variants within a range;

type test reports;

test program.

.3 Category C:

drawings of the housing and rotating parts including details of blade fixing;

material specifications (chemical composition and mechanical properties) of all parts mentioned above;

welding details and welding procedure of above mentioned parts, if applicable;

documentation of safe torque transmission when the disc is connected to the shaft by an interference fit (refer to **3.3**)[3];

information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;

Operation and maintenance manuals.

2.5.7.7 Applicable to Category C in cases where the disc is connected to the shaft with interference fit, calculations shall substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

2.5.7.8 Turbochargers shall meet the following criteria of strength (taking into account the requirements of **5.3.2**):

.1 turbochargers shall fulfil containment in the event of a rotor burst.

This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake.

For documentation purposes (test/calculation), it shall be assumed that the discs disintegrate in the worst possible way;

.2 for category B and C, containment shall be documented by testing.

Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit.

Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range.

In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.

2.5.7.9 In addition to the requirements of **2.12.1** for all turbochargers of Categories B and C, indications and alarms as listed in Table 2.5.7.9 are required. Indications may be provided at either local or remote locations.

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[3] Applicable to two sizes in a generic range of turbochargers.

Table 2.5.7.9.

№	Monitored parameters	Category of Turbochargers B: Alarm	B: Indication	C: Alarm	C: Indication	Notes
1	Speed	High [1]	×[1]	High [2]	×[2]	
2	Exhaust gas at each turbocharger inlet, temperature	High [2]	×[2]	High	×	High temp. alarms for each cylinder at engine is acceptable[3]
3	Lub. oil at turbocharger outlet, temperature			High	×	If not forced system, oil temperature near bearings
4	Lub. oil at turbocharger inlet, pressure	Low	×	Low	×	Only for forced lubrication systems[4]

[1] On turbocharging systems where turbochargers are activated sequentially, speed monitoring is not required for the turbocharger(s) being activated last in the sequence, provided all turbochargers share the same intake air filter and they are not fitted with waste gates.

[2] For Category B turbochargers, the exhaust gas temperature may be alternatively monitored at the turbocharger outlet, provided that the alarm level is set to a safe level for the turbine and that correlation between inlet and outlet temperatures is substantiated.

[3] Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value safe for the turbocharger.

[4] Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the diesel engine or if it is separated by a throttle or pressure reduction valve from the diesel engine lubrication oil.

2.6 FUEL SYSTEM

2.6.1 The fuel injection pumps or their prime movers shall ensure quick shutting off the fuel supply to any cylinder of the engine. Exemption from this requirement is allowed for engines with cylinders not over 180 mm in bore having grouped fuel pumps.

2.6.2 The high-pressure fuel oil injection pipes shall be made from thick-walled seamless steel pipes without welded or soldered intermediate joints (refer to item **1.21** of Table 1.2.4).

2.6.3 External high-pressure fuel delivery lines between the high-pressure fuel pumps and fuel injectors shall be protected with a jacketed piping system capable of containing fuel from a highpressure line failure. A jacketed pipe incorporates an outer pipe, into which the high-pressure fuel pipe is placed, forming a permanent assembly.

The jacketed piping system shall include a means for collection of leakages and arrangements and shall be provided with an alarm in case of a fuel line failure.

When in return piping the propulsion of pressure with peak to peak values exceeds 1,6 MPa, shielding of this piping is also required.

2.6.4 The fuel injection pumps and fuel delivery piping shall be so designed that they can withstand the pressure fluctuation or special means shall be provided to reduce it even to the point of disappearance.

2.6.5 For the main engine provision shall be made for an arrangement to limit the fuel supply by the rated power mode.

2.7 LUBRICATION

2.7.1 The lubricators supplying oil for lubricating the cylinders shall be fitted with an arrangement enabling to control the amount of oil delivered to each point.

To supervise the oil supply to all points to be lubricated, flow indicators shall be provided in position convenient for observation.

2.7.2 Every union supplying lubricating oil to the two-stroke engine cylinders, as well as the unions arranged in the upper part of the cylinder liner shall be provided with a non-return valve.

2.7.3 The turbochargers and governors with ball or roller bearings shall have independent lubricating oil systems. If other constructions are used, a technical justification confirming the reliability excellence must be submitted to the Register for review.

2.7.4 Provision shall be made to prevent penetration of water and fuel oil into the circulating oil and the entry of oil into the cooling water.

2.8 COOLING

2.8.1 Where telescopic devices are employed for cooling pistons or for supplying lubricating oil to moving parts, protection from hydraulic shocks shall be provided.

2.9 STARTING ARRANGEMENTS

2.9.1 The manifold supplying starting air from the master starting air valve to the cylinder starting valves shall be fitted with one or more relief valves and with a device relieving the manifold of pressure after the engine has been started.

The relief valve shall be loaded to a pressure not more than 1,2 times that in the starting air manifold.

The relieving device and the relief valve may be fitted directly on the master starting air valve.

Alternative device designed to protect the starting air manifold from the effects of inner explosions is also admitted (refer to **16.3.3**, Part VIII "Systems and Piping").

2.9.2 Flame arresters or bursting discs shall be fitted on each branch pipe for air supply to the starting valves of the reversing engine cylinder covers.

In case of non-reversing engines at least one flame arrester or bursting disc shall be fitted on the manifold supplying starting air from the main starting air valve to the manifold.

Flame arresters or bursting discs may be omitted for the engines having a bore not exceeding 230 mm.

2.9.3 The starting arrangements of electrically-started engines shall meet the requirements of **13.7**, Part XI "Electrical Equipment". Furthermore, it is recommended to equip electrically-started engines with engine-driven generators for automatic charging of the starting storage batteries.

2.9.4 In emergency diesel generators, the starting system and drive motor characteristics shall comply with the requirements of **16.1.8** Part VIII "Systems and Piping", and **9.3.4.2**, **9.5** and **19.1.2.4.2**, Part XI "Electrical Equipment".

Emergency diesel generators shall be capable of being readily started in their cold condition at the ambient temperature of 0°C.

Where such starting is impractical or at lower temperatures at the space, provision shall be made for heating devices to ensure safe starting and taking up the load by the diesel generators.

If necessary, provision shall be made for heating devices to ensure safe starting and taking up the load according to the requirements stated above.

Spaces for emergency diesel generators shall comply with the requirements of **9.2.6**, Part XI "Electrical Equipment".

2.10 EXHAUST ARRANGEMENTS

2.10.1 In two-stroke engines fitted with the exhaust gas turboblowers, which operate on the impulse systems, provision shall be made to prevent broken piston rings and valves from entering the turbine casing.

2.11 CONTROL, PROTECTION AND REGULATION

2.11.1 The starting and reversing arrangements shall eliminate the possibility of:

.1 running the engine in the direction opposite to the required one;

.2 reversing the engine when the fuel supply is cut in;

.3 starting the engine before reversal is completed;

.4 starting the engine with the power-driven turning gear engaged.

2.11.2 Each main engine shall have a speed gover-nor so adjusted that the engine speed cannot exceed the rated (nominal) speed by more than 15 %.

In addition to the governor, each main engine of power output 220 kW and upwards, which may be disengaged from the shafting or which is driving a con-trollable-pitch propeller, shall be provided with a sepa-rate overspeed device so adjusted that the engine speed cannot exceed the rated speed by more than 20 %.

The overspeed device shall be activated after the speed governor.

2.11.3 Each prime mover for driving a generator shall be fitted with a speed governor, which shall meet the following requirements:

.1 when the maximum electrical load step of a generator is thrown off or on (refer to Fig. 2.11.3.2 for maximum possible sudden power increase of four-stroke diesel engines), the transient speed variations in the electrical network shall not exceed 10 % of the rated speed. Refer also to **2.1.3.1**, Part XI "Electrical Equipment;

.2 when a prime mover running at no-load is suddenly loaded to 50 % of the rated power of the generator followed by the remaining 50 % after the interval sufficient to restore the speed to steady state, the transient speed variations shall not exceed 10 % of the rated speed.

Application of electrical load in more than two load steps can only be permitted, if the conditions within the ship's mains permit the use of such prime movers, which can only be loaded in more than two load steps (refer to Fig. 2.11.3.2 for maximum possible sudden power increase of four stroke diesel engines) and provided that this is already allowed for in the designing stage.

This shall be verified in the form of system specifications to be approved and to be demonstrated at ship's trials. In this case the power required for the electrical equipment to be automatically switched on after blackout as well as the sequence in which it is connected shall fit the load steps. This applies analogously also to generators to be operated in parallel and where the power has to be transferred from one generator to another in the event of any one generator has to be switched off;

.3 where a.c. generators operate in parallel within 20 - 100 % of the total load, the load distribution between the generators shall be in proportion to their power and shall not differ by more than 15 % from the design load for the greater generator or by more than 25 % from the design load for the generator considered, whichever is less;

.4 at all loads between no-load and rated power the permanent speed variation shall not exceed the rated speed by more than 5 % of the rated speed

.5 when the generator rated power is thrown off or on, as specified in **2.11.3.1** and **2.11.3.2**, steady state conditions shall be achieved in not more than 5 seconds;

.6 ions shall be achieved in not more than 5 seconds; .6 steady state conditions are those, at which the envelope of speed variation does not exceed ±1 % of the declared speed at the new power;

.7 for main engines driving shaft-generators, the values of load-relief and load-on stated in **2.11.3.1**, **2.11.3.2**, **2.11.3.4**, **2.11.3.5**, shall comply with the load of the engines.

Speed governor of the driving engine shall have the parameters to meet the requirements of **2.11.3**.

.8 when 100 % of the generator rated power is thrown off, a transient speed variation in excess of 10 % of the rated speed may be acceptable, provided this does not cause the intervention of the overspeed device as required by **2.11.2**.

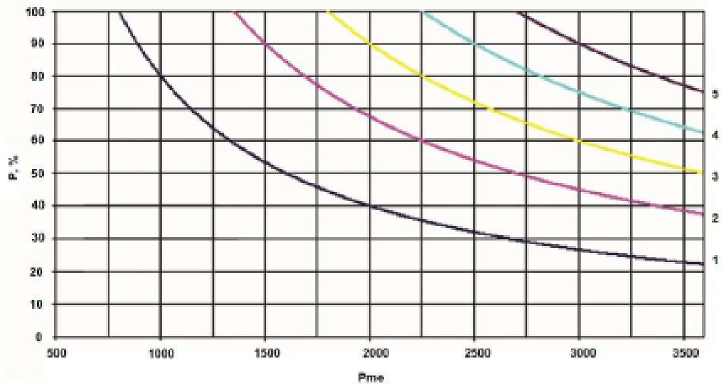


Fig. 2.11.3.2. Maximum possible sudden power increases as a function of brake mean effective pressure, Pme, at declared power (four-stroke diesel engines: Pme – declared power mean effective pressure (in кPa); P – power increase referred to declared power at site conditions; 1 – first power stage; 2 – second power stage; 3 – third power stage; 4 – fourth power stage; 5 – fifth power stage.

2.11.4 The characteristics of the speed governor for the emergency generator driving engine shall meet the requirements of **2.11.3** (except for **2.11.3.2**) when a 100 % load is taken off and put on.

At stepwise loading the full (100 %) load shall be provided in 45 s after power loss on the main switchboard busbars.

The time delay and successive stepwise loading shall be demonstrated during sea trials of the ship.

2.11.5 Provision shall be made for local and remote control of speed variation within -20 ÷ +10 % of the nominal value.

Remote control of speed variation for generators to be operated in parallel shall be arranged so to provide with possibility of controlling them by one operator.

2.11.6 In addition to the speed governor each driving engine stated in 2.11.3 having a power 220 kW and above shall be fitted with a separate overspeed protective device so adjusted that the speed cannot exceed the rated speed by more than 15%.

2.11.7 The overspeed protective device stated in **2.11.2** and **2.11.6** including its driving mechanism and emergency stop effector shall be independent of the speed governor.

2.11.8 In addition to the requirements of the Chapter, electric (electronic) speed governors shall also comply with **2.1**, Part XV "Automation".

If the electric (electronic) speed governors comprise a part of the remote automatic control system they shall meet the requirements of **3.1.8** and **3.1.10**, Part VII "Machinery Installations" and also of **2.3**, Part XV "Automation", in order to carry out this requirement, a separate speed governor shall be additionally provided for the local control station.

The electric (electronic) speed governors shall be of an approved type.

2.11.9 Protection system of main and auxiliary engines (refer to **1.1.1.5**), apart from the overspeed protective device, shall provide complete cut-off the fuel when the pressure of lubricating oil in the system drops below the allowable value.

2.12 INSTRUMENTS AND ALARM DEVICES

2.12.1 Main and auxiliary engines shall be equipped with instruments for measuring:

.1 lubricating oil pressure at engine inlet and in way of camshaft (where lubricating oil system is independent);

.2 freshwater pressure (or flow) in the engine cooling system;

.3 starting air pressure at main starting valve or starting device inlet;

.4 fuel pressure at fuel injection pumps inlets (where an oil-fuel priming pump is installed);

.5 exhaust gas temperature at each cylinder (for engines with a cylinder bore of 180 mm and less, exhaust piping temperature);

.6 lubricating oil temperature at engine inlet;

.7 pressure (or flow) in the fuel injector cooling system (where the system is independent);

.8 fuel temperature at fuel injection pump inlets (where the fuel requires heating);

.9 pressure (or flow) in the independent piston cooling system;

.10 oil pressure in way of main bearings where lubricating oil is supplied independently and in way of thrust bearing (for thrust bearings built in the engine);

.11 lubricating oil pressure at crosshead bearings (where lubricating oil is supplied independently);

.12 lubricating oil temperature in way of camshaft (where lubricating oil is supplied independently);

.13 lubricating oil pressure at turbocharger inlet where circulating oil of the engine is used;

.14 lubricating oil temperature and flow at the outlet of each turbocharger bearing (where gravity lubrication systems are applied);

.15 cooling liquid temperature and flow at each piston outlet (for engines with controlled piston cooling);

.16 fuel injector cooling medium temperature at outlet (where an independent system is used);

.17 freshwater temperature at each cylinder outlet or at engine outlet (where the engine has one cooling space);

.18 freshwater temperature at engine inlet;

.19 freshwater temperature at turbocharger outlet;

.20 supercharging receiver pressure;

.21 supercharging air temperature behind air coolers;

.22 exhaust gas temperature in front of turbochargers and behind them.

Note. Proceeding from the structural features of the internal combustion engines, changes may be introduced to the list of measuring instruments provided the technical substantiation is submitted to the Register.

Additional requirements for engine turbochargers are given in 2.5.7.9.

2.12.2 Each driving above 37 kW shall be fitted with an alarm device with audible and visual signals for the failure of lubricating oil system as well as an alarm to indicate leaks from the highpressure oil fuel injection pipes of diesel engines (refer to **2.6.3**).

The following warning alarms are recommended:

.1 pressure drop in freshwater cooling system or water temperature rise at engine outlet;

.2 drop of lubricating oil level in the gravity tank of turbochargers;

.3 rise of temperature of thrust bearing built in the engine.

2.12.3 The local control stations of main engines shall be equipped with instruments in accordance with **2.12.1.1** − **2.12.1.3**, **2.12.1.7**, **2.12.1.9** (where media other than circulation oil are used), **4.2.5.3** and with an instrument for measuring crankshaft speed, and where disengaging couplings are fitted, with an instrument for measuring propeller shaft speed as well.

The local control stations of main reversible engines and engines with reverse-reduction gear shall be provided with indicators of the direction of propeller shaft rotation.

2.12.4 Local control stations of auxiliary engines (refer to **1.1.1.5**) shall be equipped with instruments in compliance with **2.12.1.1** to **2.12.1.3** and with an instrument for measuring the crankshaft speed.

2.13 TORSIONAL VIBRATION DAMPER. ANTIVIBRATOR

2.13.1 The damper design shall make air removal possible when filling the damper with oil or silicone liquid, and the silicone damper design shall also enable a sampling of the liquid.

2.13.2 Lubrication of a spring damper shall, as a rule, be effected from the lubricating oil circulation system of the engine.

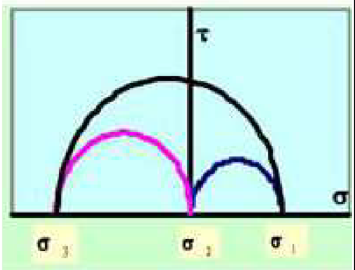
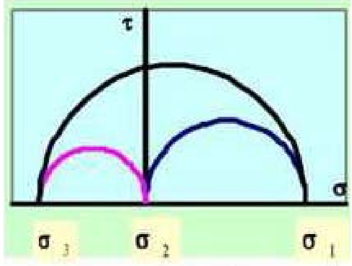
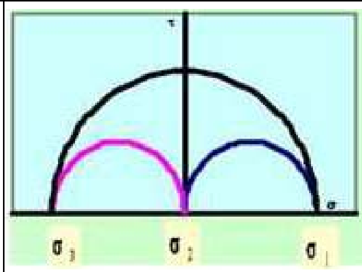
2.13.3 The design of the damper fitted at the free end of the crankshaft shall make it possible to connect devices for measuring torsional vibration to the crankshaft.

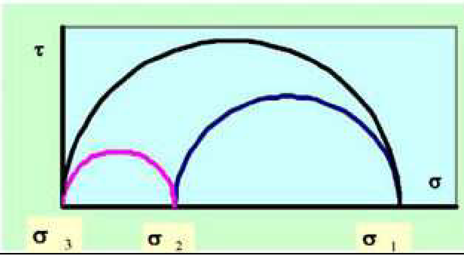
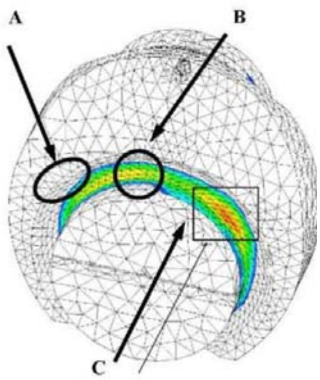
2.13.4 The damper shall be used with regard to the requirements of **8.8.3** to **8.8.5**, Part VII "Machinery Installations".

APPENDIX I

DEFINITION OF STRESS CONCENTRATION FACTORS IN CRANKSHAFT FILLETS [4]

<table>
<tr><td></td><td>Stress</td><td>Max $\|\sigma_3\|$</td><td>Max σ_1</td><td></td></tr>
<tr><td rowspan="3">Torsiomnal loading</td><td>Location of maximal stresses</td><td>A</td><td>C</td><td>B</td></tr>
<tr><td>Typical principal stress system

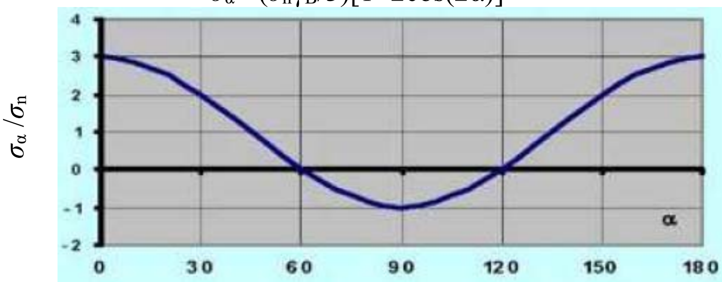
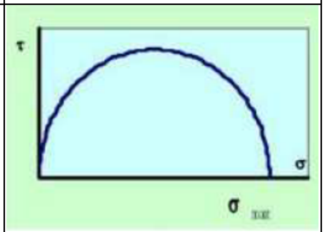
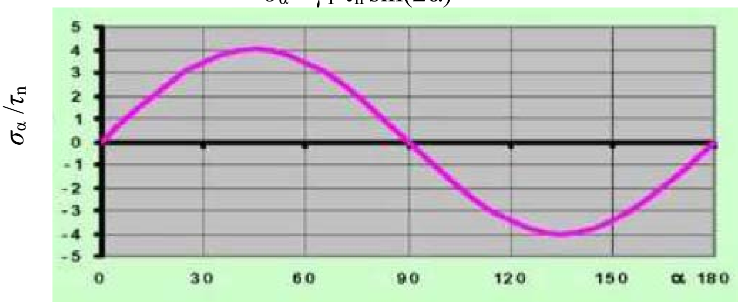
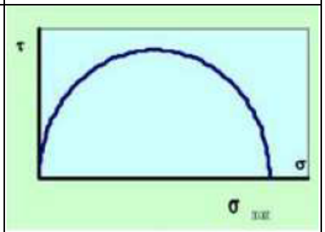
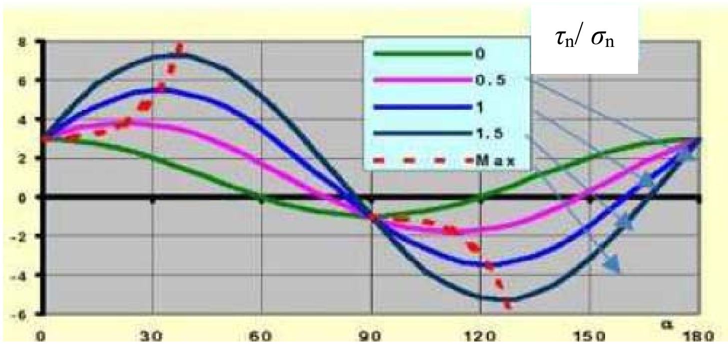
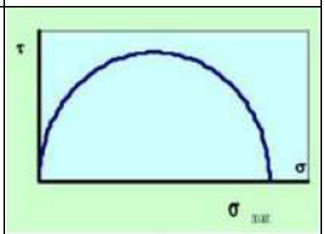
Mohr's circle diagram with $\sigma_2 = 0$</td><td>
$\|\sigma_3\| > \sigma_1$</td><td>
$\sigma_1 > \|\sigma_3\|$</td><td>
$\sigma_1 = \|\sigma_3\|$</td></tr>
<tr><td>Equivalent stress and SCF</td><td colspan="3">$\tau_{equiv} = (\sigma_1 - \sigma_3)/2$
$SCF = \tau_{equiv} / \tau_n$ for α_T, β_T</td></tr>
<tr><td rowspan="3">Bending loading</td><td>Location of maximal stresses</td><td>B</td><td>B</td><td>B</td></tr>
<tr><td>Typical principal stress system

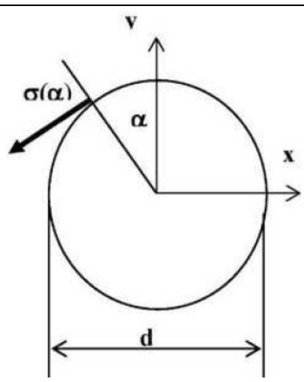
Mohr's circle diagram with $\sigma_3 = 0$</td><td colspan="3"> $\sigma_2 \neq 0$</td></tr>
<tr><td>Equivalent stress and SCF</td><td colspan="3">$\sigma_{equiv} = (\sigma_1^2 + \sigma_2^2 + \sigma_1 \cdot \sigma_2^2)^{0,5}$
$SCF = \sigma_{equiv} / \sigma_n$ for α_B, β_B, β_Q</td></tr>
<tr><td colspan="5"></td></tr>
</table>

[4] Refer to IACS UR M53 (Rev.3 June 2017)

APPENDIX II

STRESS CONCENTRATION FACTORS AND STRESS DISTRIBUTION AT THE EDGE OF OIL DRILLINGS[5]

Stress type	Nominal stress tensor	Uniaxial stress distribution around outlet	Mohr's circle
Shear	$\begin{bmatrix} 0 & \sigma_n \\ \sigma_n & 0 \end{bmatrix}$	$\sigma_\alpha = (\sigma_n\gamma_B/3)[1+2\cos(2\alpha)]$ 	 $\gamma_B=\sigma_{max}/\sigma_n$ for $\alpha=k\pi$
Cut	$\begin{bmatrix} 0 & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha=\gamma_T\,\tau_n\sin(2\alpha)$ 	 $\gamma_T=\sigma_{max}/\tau_n$ for $\alpha=(\pi/4)+(k\pi/2)$
Tension + shear	$\begin{bmatrix} \sigma_n & \tau_n \\ \tau_n & 0 \end{bmatrix}$	$\sigma_\alpha=(\sigma_n\gamma_B/3)\{1+2\,[\cos(2\alpha)+\tfrac{2}{3}(\gamma_T/\gamma_B)\,(\tau_n/\sigma_\alpha)]\}$ 	 $\sigma_{max}=(\sigma_n\gamma_B/3)\{1+2\times$ $\times\,[1+2(1+\Theta)^{0,5}\}$ for $\alpha=½tg^{-1}3[(\gamma_T/\gamma_B)\times\ (\tau_n/\sigma_\alpha)]/2$, where: $\Theta=2{,}25[(\gamma_T/\gamma_B)(\tau_n/\sigma_\alpha)]^2$



where: d-bore diameter

[5] Refer to IACS UR M53 (Rev.3 June 2017)

APPENDIX III

GUIDANCE FOR CALCULATION OF STRESS CONCENTRATION FACTORS IN THE WEB FILLET RADII OF CRANKCHAFTS BY USING FINITE ELEMENT METHOD [6]

Contents

1. GENERAL

The objective of the analysis is to develop Finite Element Method (FEM) calculated figures as an alternative to the analytically calculated Stress Concentration Factors (SCF) at the crankshaft fillets. The analytical method is based on empirical formulae developed from strain gauge measurements of various crank geometries and accordingly the application of these formulae is limited to those geometries.

The SCF's calculated according to the rules of this document are defined as the ratio of stresses calculated by FEM to nominal stresses in both journal and pin fillets. When used in connection with the present method in Chapter **2.4** of this Part or the alternative methods, von Mises stresses shall be calculated for bending and principal stresses for torsion.

This procedure as well as the evaluation guidelines are valid for both solid crankshafts and semibuilt crankshafts (except for journal fillets).

The analysis shall be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude shall be applied for all load cases.

The calculation of SCF at the oil bores is not covered by this Appendix.

It is advised to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the stresses obtained by FEM with the analytical solution for pure bending and torsion.

The Boundary Element Method (BEM) may be used instead of FEM.

2. MODEL REQUIREMENTS

The basic recommendations and assumptions for building the FE-model are presented in **2.1**. It is obligatory for the final FE-model to fulfil the requirement in **2.3**.

2.1 Element mesh recommendations.

In order to fulfil the mesh quality criteria, the FE model for the evaluation of Stress Concentration Factors shall be built according to the following recommendations:

The model shall describe one complete crank, from the main bearing centreline to the adjacent main bearing centreline.

Element types used in the vicinity of the fillets are:

10-node tetrahedral elements;

8-node hexahedral elements;

20-node hexahedral elements. Mesh properties at fillet radii.

The following requirements apply to ± 90-degree area in the circumferential direction from the crank plane:

Maximum element size $a = r/4$ through the entire fillet as well as in the circumferential direction.

When 20-node hexahedral elements are used, the element size in the circumferential direction may be extended up to $5a$. In the case of multi-radii fillet, r is the local fillet radius. (If 8-node hexahedral elements are used, even smaller element size is required to meet the quality criteria.).

[6] Refer to IACS UR M53 (Rev.3 June 2017)

Recommended element sizes in fillet depth direction:

first layer thickness equal to element size of a;

second layer thickness equal to element size of $2a$;

third layer thickness equal to element size of $3a$.

Minimum of 6 elements across web thickness.

The rest of the crank should be suitable for the numeric stability of the solver.

Counterweights have to be modelled only when they significantly affect the total stiffness of the crank.

Modelling of oil bores is not necessary, if they negligibly affect the total stiffness and the proximity to the fillet is more than $2r$ (refer to Fig. 2.1).

Drillings and holes for weight reduction have to be modelled.

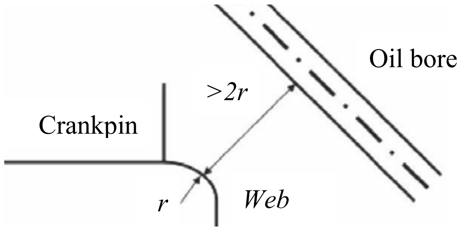


Fig. 2.1. Oil bore proximity to fillet

2.2 Material.

Chapter 2.4 of this Part does not cover material properties such as Young's modulus (E) and Poisson's ratio (v).

These material parameters are required for FE analysis, as strains are primarily calculated and stresses are derived from strains using the Young's modulus and Poisson's ratio.

Reliable values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

The following values are recommended for steel: E = 2,05×105MPa and v = 0,3.

2.3 Element mesh quality criteria.

If the actual element mesh does not fulfil any of the following criteria for the SCF evaluation in the examined area, then a second calculation with a refined mesh shall be performed.

2.3.1 Principal stresses criterion.

The mesh quality shall be assured by checking the stress component normal to the fillet radius surface. Ideally, this stress shall be zero.

With principal stresses σ1, σ2 and σ3, the following requirement shall be met.

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|) < 0{,}03 \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

2.3.2 Averaged / unaveraged stresses criterion.

This criterion is based on observing the discontinuity of stress results over the fillet elements in calculation of SCFs:

unaveraged nodal stress results calculated from each element connected to a node shall differ by less than 5 % from 100 % of averaged nodal stress results at this node in the examined area.

3. LOAD CASES

To substitute the analytically calculated SCFs as described in Chapter **2.4** of this Part, the following load cases have to be calculated;

3.1 Torsion.

As with the testing used for the investigations made by FVV, the structure is loaded with pure torsion.

Model end face warp is suppressed.

Torque is applied to the central node located at the crankshaft axis.

This node acts as the master node with 6 degrees of freedom and is rigidly connected to all nodes of the end face.

Such boundary and load conditions are valid for both in-line and V-type engines.

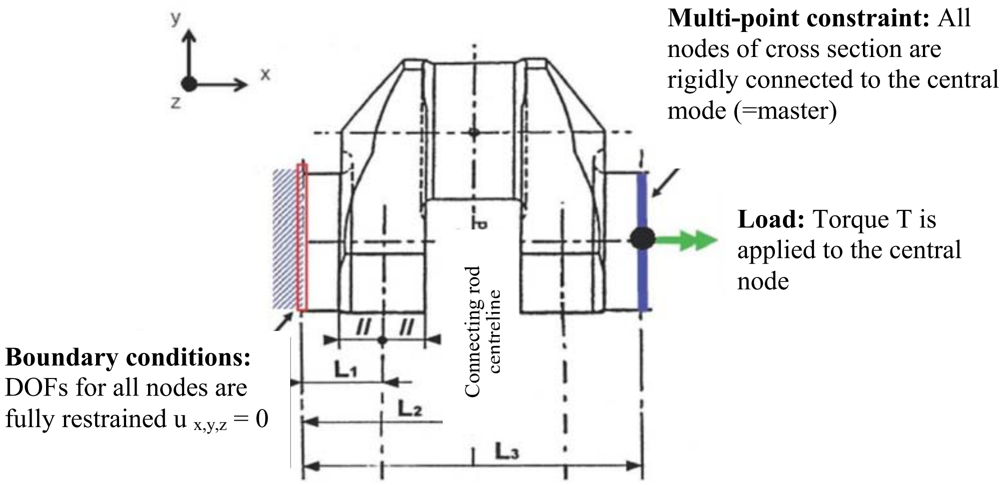


Fig. 3.1. Boundary and load conditions for torsion load case

For all nodes in both journal and crankpin fillets, the principal stresses are determined, and the equivalent torsional stress is calculated according to the following formula:

$$T_{equiv}=\max\left(|\sigma_1-\sigma_2|/2,\ |\sigma_2-\sigma_3|/2,\ |\sigma_1-\sigma_3|/2\right)$$

The maximum value taken for the subsequent calculation of the SCF is:

$$\alpha_T=\tau_{EKB.,\alpha}/\tau_N$$

$$\beta_T=\tau_{EKB.,\beta}/\tau_N$$

where: τ_N - is the nominal torsional stress in the crankpin and journal as per **2.4.5.1** of this Part at torsional torque T:

$$\tau_N = T/W_p.$$

3.2 Pure bending (4 point bending).

As with the testing used for the investigations made by FVV, the structure is loaded with pure bending. In the model, surface warp at the end faces is suppressed.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is rigidly connected to all nodes of the end face.

Such boundary and load conditions are valid for both in-line and V-type engines.

For all nodes in both journal and crankpin fillets, von Mises equivalent stresses σ_{equiv} are determined. The maximum value is used to calculate the SCF according to the following formulae:

$$\alpha_B=\sigma_{equiv.,\alpha}/\sigma_N$$

$$\beta_B=\sigma_{equiv.,\beta}/\sigma_N$$

Nominal stress σ_N is calculated as per **2.4.4.2** of Chapter **2.4** of this Part at the bending moment M as per the following formula:

$$\tau_N = M/W_{equ}.$$

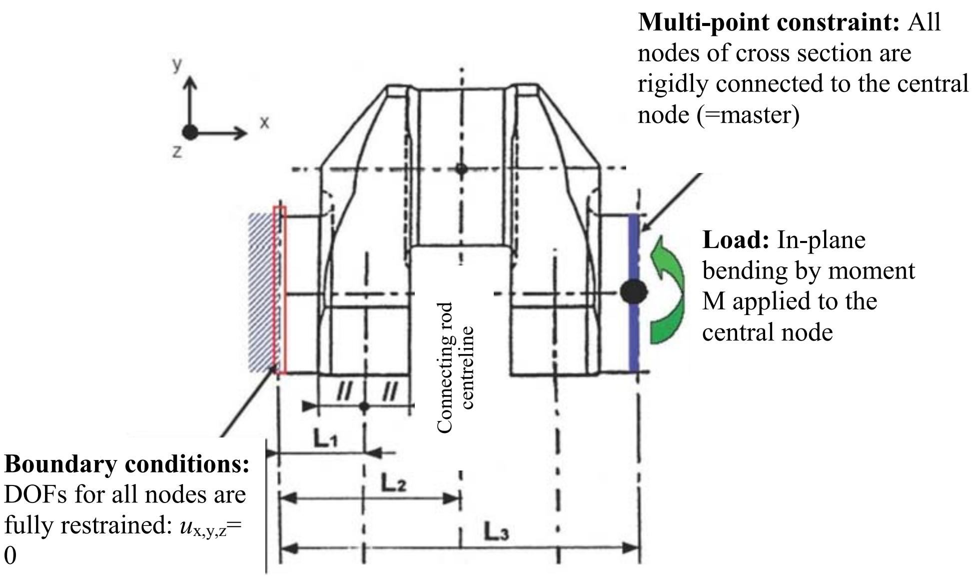


Fig. 3.2. Boundary and load conditions for pure bending load case

3.3 Bending with shear (3-point bending).

This load case is calculated to determine the SCF for pure transverse (radial) force β_Q, applied to the journal fillet.

As with the testing used for the investigations made by FVV, the structure is loaded with 3-point bending. In the model, surface warp at both end faces is suppressed. All nodes are rigidly connected to the central node; boundary conditions are applied to the central nodes.

These nodes act as master nodes with 6 degrees of freedom.

The force is applied to the central node located on the crankpin at the connecting rod centreline. This node is connected to all nodes of the crankpin cross-section area. Cross-sectional warping is not suppressed.

Such boundary and load conditions are valid for both in-line and V-type engines. One connecting rod force only can be modelled for V-type engines. Using two connecting rod forces will make no significant change to SCF values.

The maximum equivalent von Mises stress σ_{3P} P in the journal fillet is calculated.

The SCF for the journal fillet can be determined by two methods as described below.

3.3.1 Method 1.

The 3-point and 4-point bending calculation results are combined as follows:

$$\sigma_{3P} = \sigma_{N3P}\,\beta_B + \sigma_{Q3P}\,\beta_Q$$

where:

σ_{3P} – is as found by the FE calculation;

σ_{N3P} – is the nominal bending stress in the web centre due to the force F_{3P} [H], applied to the centreline of the actual connecting rod (refer to Fig. 3.4);

β_{Q3P} – is as determined in **3.2**;

$\sigma_{Q3P} = Q_{3P}/(BW)$, where Q_{3P} is the radial (shear) force at the web due to the force F_{3P} [H], applied to the centreline of the actual connecting rod(also refer to Fig. 2.4.4.1-1 and 2.4.4.1-2 of this Part).

3.3.2 Method 2.

This method differs from the FVV investigation procedure. In a statically determined system with one crank throw supported by two bearings, the bending moment and radial (shear) force are proportional. Therefore, the journal fillet SCF can be found directly by the 3-point bending FE calculation. The SCF is calculated according to the following formula:

$$\beta_{BQ} = \sigma_{3P}/\sigma_{N3P}$$

For symbols, refer to **3.3.1**.

When this method is used, the radial force and stress determination as per Chapter **2.4** of this Part becomes superfluous. The alternating bending stress in the journal fillet as per **2.4.4.3** of Chapter **2.4** of this Part is then calculated according to the following formula:

$$\sigma_{BG} = \pm\,|\sigma_{BFN}\,\beta_{BQ}|$$

This method does not apply to the crankpin fillet, and this SCF must not be used in the calculation methods other than those assuming a statically determined system as in Chapter **2.4** of this Part.

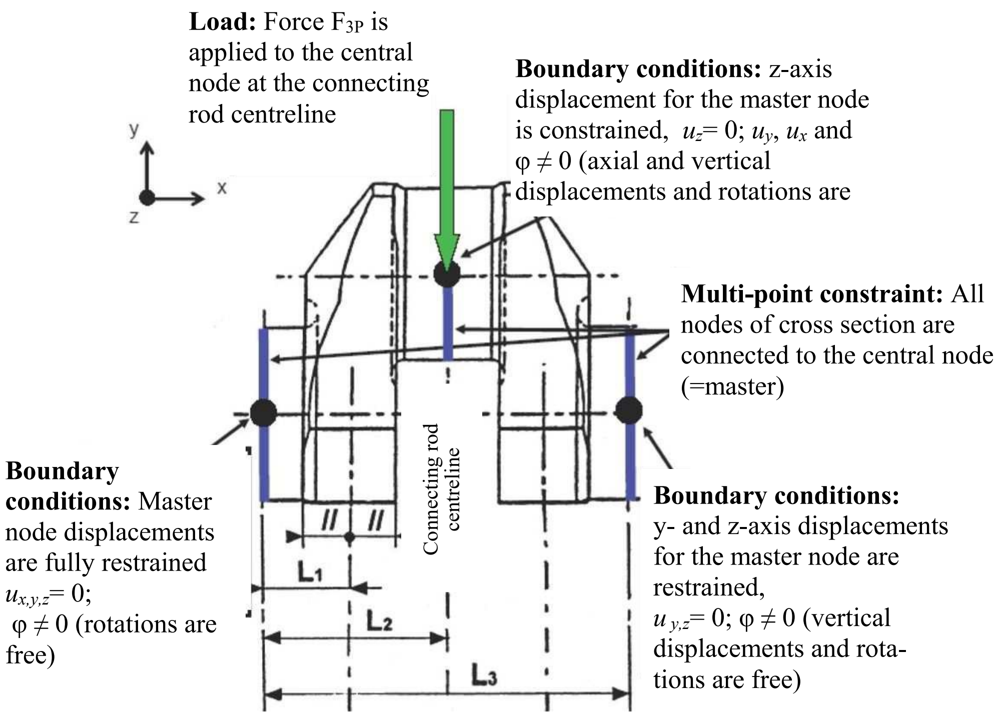


Fig. 3.3. Boundary and load conditions for 3-point bending load case of in-line engine

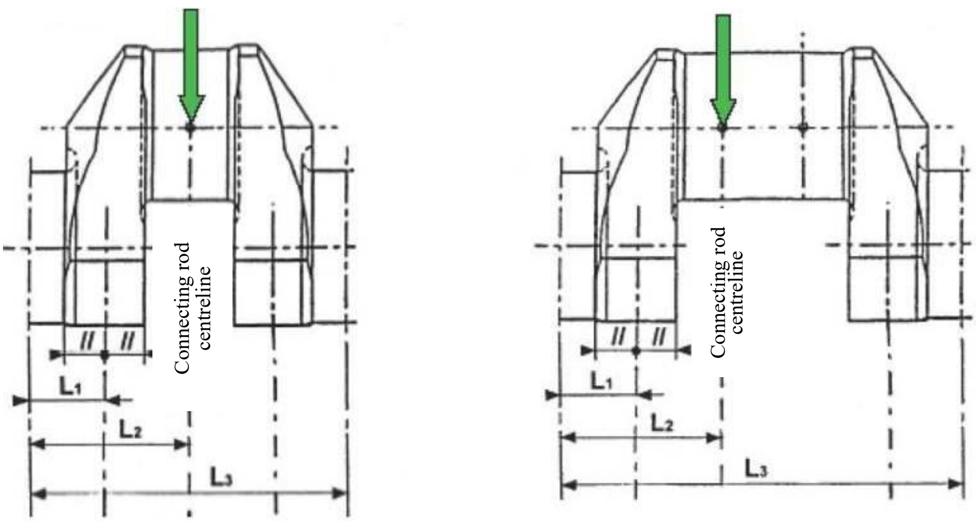


Fig. 3.4 . Load applications for in-line and V-type engines

APPENDIX IV

GUIDANCE FOR EVALUATION OF FATIGUE TESTS[7]

Contents

1. INTRODUCTION

Fatigue testing can be divided into two main groups: small specimen testing and full-scale crank throw testing. Testing can be performed using the staircase method or a modified version thereof. Other statistical evaluation methods may also be applied.

1.1 Випробування малих зразків.

For crankshafts without any fillet surface hardening, the fatigue strength can be determined by testing small specimens taken from a full-size crank throw. However, this method shall not be applied, if the areas adjacent to the fillets are surface-hardened which causes residual stresses in the fillets.

This testing features possibility of manufacturing fairly large number of specimens for testing with various stress ratios R and in various load conditions (axial, bending and torsion), with or without a notch to evaluate characteristics of used materials under multiaxial loading conditions.

1.2 Full-size crank throw testing.

For surface-hardened crankshafts, the fatigue strength can only be determined through testing of fullscale crank throws.

In case of 3- or 4- point bending, the load can be applied using hydraulic actuators or an exciter in a resonance test rig which enables testing with R stress ratio equal to -1.

2. EVALUATION OF TEST RESULTS

2.1 Principles.

Prior to fatigue testing, the crankshaft must be checked as required by the quality control procedures, including check for chemical composition of material, its mechanical properties, surface hardness, hardness depth and extension, crankpin/journal surface finish.

The test specimens shall be prepared so as to represent the "lower end" of the acceptance range; in particular, for induction hardened crankshafts this means the minimum acceptable hardness depth, shortest extension through a fillet, etc. Otherwise the mean test results shall be corrected in view of a confidence interval: a 90 % confidence interval may be used both for the mean and for the standard deviation.

The test results, when applied for Chapter **2.4** of this Part, shall be evaluated for compliance with the mean fatigue strength, with or without taking into account the 90 % confidence interval as mentioned above.

[7] Refer to IACS UR M53 (Rev.3 June 2017)

The standard deviation shall be determined with taking the 90 % confidence interval into account. Subsequently the result to be used as the fatigue strength will be equal to the mean fatigue strength minus one standard deviation.

If the evaluation aims to find relation between mechanical properties of material under static load and fatigue strength, this relation must be based on the actual (i.e. measured) mechanical properties, not on the specified minimum values of these properties.

The calculation procedure presented in **2.4** can be applied both to the staircase method and to the modified staircase method.

2.2 Staircase method.

In the staircase method, the first specimen is subjected to a stress corresponding to the expected average fatigue strength. If the specimen withstands 10^7 cycles, it is removed, and the next specimen is subjected to a stress that is one increment above the previous stress, i.e. a survivor is always followed by the next one which is subjected to a stress with one increment above the previous value. The increment shall be selected to correspond to the expected level of the standard deviation.

When a specimen fails before 10^7 cycles are completed, the actual number of cycles is noted, and the next specimen is subjected to a stress that is one increment below the previous one. With this approach, the sum of failed and successful tests is equal to the number of specimens.

The original staircase method is only applicable when a large number of specimens are available as about 25 specimens shall be used to obtain the sufficient accuracy of test result.

2.3 Modified staircase method.

When the modified staircase method is applied, the first specimen is subjected to a stress level that is most likely well below the average fatigue strength.

When this specimen has withstood 10^7 cycles, this same specimen is subjected to a stress level with one increment above the previous value. The increment shall be selected to correspond to the expected level of the standard deviation. The stepwise load increase process continues until the specimen fails. After the specimen fails, the next specimen is subjected to a stress that is at least 2 increments below the level at which the previous specimen failed.

With this approach, the number of failed and successful tests (in view of the highest level at which 10^7 cycles were reached) is usually equal to the number of specimens.

The acquired result of testing performed by the modified staircase method shall be used with care, since it is probable that stepwise increase of load applied to the specimen, especially at high mean stresses, tends to increase the fatigue limit. However, this "training effect" is less pronounced in testing of high strength steels with UTS > 800 MPa.

If the confidence calculation is required, the minimum number of test specimens is 3.

2.4 Calculation of sample mean and standard deviation.

This section covers an example of testing for 5 crank throws. When the modified staircase method and the Dixon and Mood's evaluation method are applied, the number of specimens is 10, meaning 5 successful results and 5 failures:

Number of specimens n = 10

Furthermore, this method distinguishes between two cases:

Less frequent result is failure C = 1

Less frequent result is success C = 2

This method uses only the less frequent test results, i.e. if there are more failures than successes, the number of successes is used and vice versa.

In the modified staircase method, the numbers of successes and failures are usually equal. However, the testing can be unsuccessful, e.g. the number of successes can be less than the number of failures if a specimen with 2 increments below the previous failure level goes immediately to failure. On the other hand, if this unexpected premature failure occurs after a rather large number of cycles, it is possible to define the stress level below this as a success.

Dixon and Mood's approach derived from the maximum likelihood theory, which also may be applied here, especially in tests with few specimens, presents some simple approximate equations to calculate the sample mean and the standard deviation from the outcome of the staircase test. The sample mean can be calculated as follows:

$$\overline{S_a} = S_{\alpha 0} + d(A/F - ½) \text{ for } C = 1$$

$$\overline{S_a} = S_{a0} + d(A/F + ½) \text{ for } C = 1$$

The standard deviation can be found as follows:

$$s = 1{,}62d\,[(F \cdot B - A^2)/F^2 + 0{,}029]$$

where:
S_{a0} — is the lowest stress level for the less frequent result
d — is the stress increment
$F = \Sigma fi$
$A = \Sigma i \cdot fi$
$B = \Sigma i^2 \cdot fi$
i — is the stress level number
fi — is the number of specimens at stress level i.

The formula for the standard deviation is an approximation and can be used when

$$(F \cdot B - A^2)/F^2 > 0{,}3 \text{ and } \quad 0{,}5s < d < 1{,}5s$$

If any of these two conditions are not fulfilled, a new staircase test shall be considered or the standard deviation shall be taken quite large in order to be on the safe side.

If increment d is much greater than the standard deviation s, this procedure results in a lower standard deviation and a slightly higher sample mean, both compared to values calculated when the difference between the increment and the standard deviation is relatively small.

Thereafter if increment d is much less than the standard deviation s, this procedure results in a higher standard deviation and a slightly lower sample mean.

2.5 Confidence interval for mean fatigue limit.

When the staircase fatigue test is repeated, the sample mean and the standard deviation will most likely be different from the previous test. Therefore, it is necessary to assure with a given confidence that the repeated test values will be above the chosen fatigue limit by using the confidence interval for the sample mean.

The confidence interval for the sample mean value with unknown variance is known to have t-distribution (also called Student's distribution) which is symmetric relative to the mean.

Note: the resulting confidence interval - the range of values obtained that are considered reliable (sufficiently correct) in relation to the applied test procedure.

If S_a is the empirical mean and s is the empirical standard deviation for a series of n specimens, in which the variable values are normally distributed with an unknown sample mean and unknown variance, the (1-α)·100% confidence interval for the mean is:

$$P(S_a - t_{\alpha,n\text{-}1} \cdot s/\sqrt{n} < S_{\alpha X\%}) = 1\text{-}\alpha$$

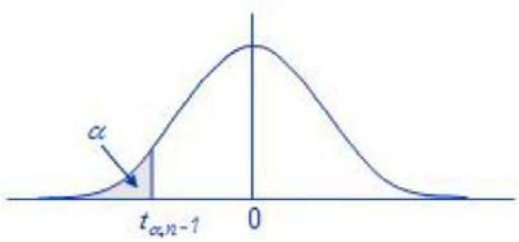


Fig. 2.5. Student's distribution

The confidence level normally used for the sample mean is 90%, meaning that 90% of sample means obtained from repeated tests will be above the value calculated with the chosen confidence level. The figure shows the t-value for (1 - α) 100 % confidence interval for the sample mean.

The resulting confidence interval is symmetric relative to the empirical mean of the sample values, and the lower limit can be found as:

$$S_{\alpha\chi\,\%} = S_\alpha - t_{\alpha,n\text{-}1} \cdot s/\sqrt{n},$$

which is the mean fatigue limit (aggregate value) to be used to obtain the reduced fatigue limit where the failure probability limits are taken into consideration.

2.6 Confidence interval for standard deviation.

The confidence interval for the variance of a normal random variable is known to possess a chi-square distribution with n-1 degrees of freedom.

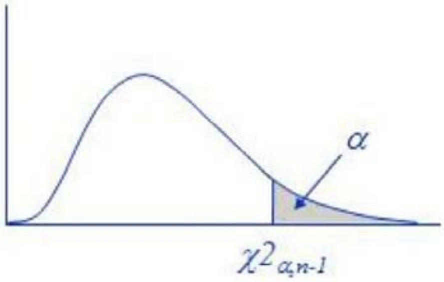


Fig. 2.6. Chi-square distribution

The standard deviation confidence level is used to ensure that the standard deviations for repeated tests are below the upper limit obtained from the fatigue test standard deviation with a given confidence level. The figure shows the chisquare for (1 - α) 100% confidence interval for the variance..

An assumed fatigue test result from n specimens is a normal random variable with a variance of σ^2 and has an empirical variance σ^2. Then the $(1\text{-}\alpha)\cdot 100\%$ confidence interval for this variance is

$$P[(n\text{-}1)s^2/\sigma^2 < \chi^2_{\alpha,n\text{-}1})] = 1\text{-}\alpha$$

The $(1\text{-}\alpha)\cdot 100$ % confidence interval for the standard deviation is equal to the square root of the upper limit of the confidence interval for the variance and can be found as follows:

$$S_{X\%}=[(n\text{-}1) / \chi^2_{\alpha,n\text{-}1}]^{0,5}S$$

This is the standard deviation (aggregate value) to be used to obtain the fatigue limit, where the failure probability limits are taken into consideration.

3. SMALL SPECIMEN TESTING

A small specimen here means one of the specimens taken from a crank throw. Since the specimens shall be representative for the fillet fatigue strength, they shall be taken out close to the fillets, as shown in Figure 3.

It shall be made certain that the principal stress direction in the specimen testing is equivalent to that in the full-size crank throw. The verification is recommended to be done by utilizing the finite element method.

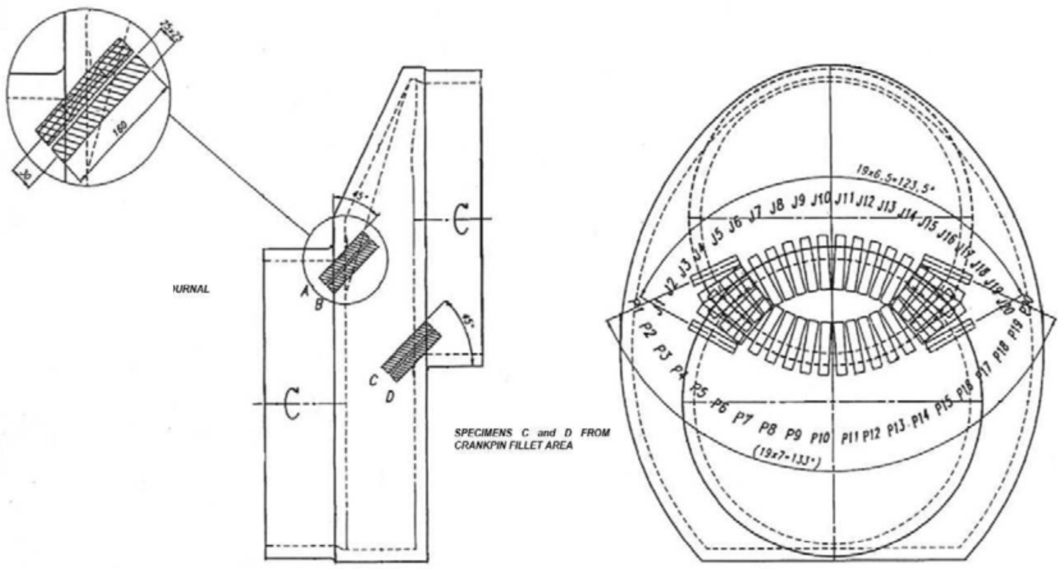


Fig. 3. Specimen locations in a crank throw

The static mechanical properties are to be determined as stipulated by the quality control procedures.

3.1 Determination of bending fatigue strength.

It is advisable to use unnotched specimens in order to avoid uncertainties related to the stress gradient influence.

Alternate stress testing method (stress ratio$R = -1$), is preferred, but in view of testing peculiarities and for multiaxial loading conditions, other methods may be applied.

In order to ensure the principal stress direction in alternate stress testing to represent the principal stress direction at full-size crank throw and when no further information is available, the specimen shall be arranged at 45 degrees as shown in Fig. 3.

A. If the objective of the testing is to determine the influence of surface roughness, the specimens taken from the area of approximately 120 degrees in a circumferential direction may be used (refer to Fig. 3).

B. If the objective of the testing is to determine the influence of continuous grain flow (cgf) forging, the specimens shall be restricted to the vicinity of the crank plane.

3.2 Determination of torsional fatigue strength.

A. If the specimens are subjected to torsional testing, the specimens shall be selected in view of the same criteria as for bending testing. The stress gradient influence has to be considered in the evaluation.

B. If the specimens are tested with alternate stress and no further information is available, the specimens shall be taken out within 45 degrees to the crank plane in order to ensure the principal stress direction collinearity between the specimens and the full-size crank throw. When the specimen is taken out at a distance from the (crank) middle plane of the crankshaft along the fillet, this plane can be rotated around the crankpin centre point making it possible to take several specimens to determine the torsional fracture direction (the results are to be converted into the pertinent torsional values).

3.3 Other sampling locations.

If the test purpose is to find fatigue properties and the crankshaft is made by continuous forging, the specimens may also be taken longitudinally from a longer shaft pieces where mechanical testing specimens are usually taken from. The condition is that this long shaft piece is heat treated as a part of the crankshaft and its size provides a quenching rate similar to that of the crank throw.

When test results for a long shaft piece specimens are used, it shall be considered how well the grain structure in that shaft piece is representative for the crankpin fillets.

3.4 Correlation of test results.

The fatigue strength resulted from specimen testing shall be converted to correspond to the full-size crankshaft fatigue strength.

When bending fatigue properties resulted from tests are used, it shall be kept in mind that successful continuous forging results in higher properties compared to other forging types, but it normally does not result in commensurable torsional fatigue strength improvement.

In such cases, it is advised to either carry out additional torsional testing or make a conservative evaluation of torsional fatigue strength, e.g. without continuous forging taken into account. This approach is applicable when the Gough-Pollard criterion is used. However, this approach is inapplicable when the von Mises criterion or multiaxial criteria such as Findley criterion are used.

If found ratio between bending and torsion fatigue differs significantly from$\sqrt{3}$, the Gough Pollard criterion shall be applied instead of the von Mises criterion.

Besides, when the material properties under multiaxial loading conditions are investigated, it must be kept in mind that continuous forging along grain flow makes the material inhomogeneous in terms of fatigue strength, meaning that the material properties in different planes will differ.

Any addition of influence factors must be justified. Since the factors used for scaling of test results for a material not subjected to surface hardening and a material subjected to surface hardening may be different, it is preferred that specimens taken out of both hardened and unhardened materials are tested.

4. FULL-SCALE TESTING

4.1 Hydraulic pulsation

A hydraulic test rig can be arranged for testing a crankshaft with 3-point or 4-point bending and torsion which enables testing with any values of stress ratio R.

Although the applied load shall be verified with strain gauges on plain shaft sections for the initiation of the test, the use of the same for load control during the test is not necessary. It is also pertinent to check fillet stresses with strain gauge chains.

Furthermore, it is important that the test rig provides boundary conditions as defined in Appendix III (**3.1** – **3.3**).

The static mechanical properties are to be determined as stipulated by the quality control procedures.

4.2 Резонансний стенд.

A resonance test rig with relatively low power consumption is used to determine the torsion fatigue strength usually at stress ratio R = −1. Its operating frequency is usually relatively high, meaning that 107 cycles can be reached within some days. Fig. 4.2-1 shows the test rig setup.

The applied load shall be verified with strain gauges on plain shaft sections.

It is also pertinent to check fillet stresses with strain gauge chains. Clamping around the journals must be arranged in a way that prevents severe fretting which could lead to a failure under the edges of the clamps.

If some distance between the clamps and the journal fillets is provided, the loading will be consistent with 4-point bending and thus representative for the journal fillets too.

The crankpin fillets in an engine normally operate with stress ratio R slightly above –1, and the journal fillets, slightly below –1. If found necessary, it is possible to provide such load by creating a preload.

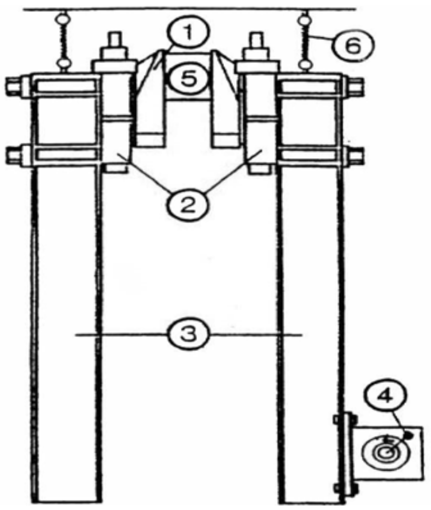


Fig. 4.2-1. An example of resonance test rig setup for bending loading test

1 — Crank throw; 2 — Mounts; *3* — "I" beam; 4 — Eccentric driven by speed-controlled motor; 5 — — Strain gauge to adjust and monitor loading; 6 — Elastic suspension

The torsion fatigue test rig setup is shown in Fig. 4.2-2.

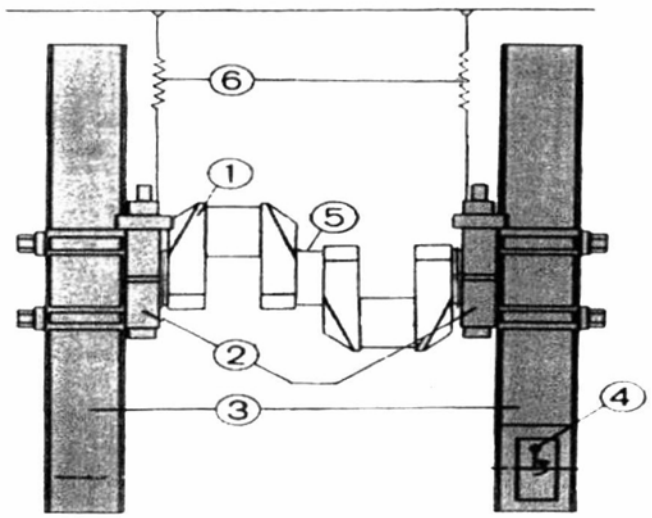


Fig. 4.2-2. An example of testing arrangement of the resonance tester for torsion loading with double crank throw section

1 — Crank throw; 2 — Clamp; 3 — I-beams; 4 — Motor-driven eccentric weight; 5 — Strain gage; 6 — Elastic suspension

When a crank throw is subjected to torsional load, the crankpin twist makes the journals move sideways.

If a single crank throw is tested in a torsional resonance test rig, the journals with their clamped-on weights may vibrate sideways. This sideway movement of the clamped-on weights can be reduced by using two crank throws, especially if the cranks are in the same direction. However, the journal in the middle will move more intensively.

Since sideway movements can cause some bending stresses, the plain portions of the crankpins shall also be provided with strain gauges arranged to measure any possible bending that could have effect on the test results.

As the case is for the bending test, the applied load shall be verified with strain gauges on plain shaft sections. It is also pertinent to check fillet stresses with strain gauge chains.

4.3 Use of results and crankshaft acceptability.

In order to combine the bending and torsion fatigue strength test results in calculation of crankshaft acceptability (refer to **2.4.11** of this Part), the Gough-Pollard approach can be applied for the following cases:

As for the crankpin diameter:

$$Q = \left(\sqrt{(\sigma_{BH}/\sigma_{DWCT})^2 + (\tau_{BH}/\tau_{DWCT})^2}\right)^{-1}$$

where:

σ_{DWCT} is bending test fatigue strength;

τ_{DWCT} is torsion test fatigue strength.

As for the crankpin oil bore:

$$Q = \left(\sqrt{(\sigma_{BO}/\sigma_{DWOT})^2 + (\tau_{TO}/\tau_{DWOT})^2}\right)^{-1}$$

де:

σ_{DWOT} is bending test fatigue strength;

τ_{DWOT} is torsion test fatigue strength.

As for the journal diameter:

$$Q = \left(\sqrt{(\sigma_{BG}/\sigma_{DWJT})^2 + (\tau_{G}/\tau_{DWJT})^2}\right)^{-1}$$

де:

σ_{DWJT} is bending test fatigue strength;

τ_{DWJT} is torsion test fatigue strength.

If increase in fatigue strength due to surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical locations according to the calculation where surface treatment has not been taken into account.

5. USE OF AVAILABLE RESULTS FOR SIMILAR CRANKSHAFTS

For fillets or oil bores without surface treatment, the fatigue properties found by testing may be used for similar crankshaft designs if the following conditions are met:

Material:

similar material type;

roughness of the same level or better;

the same mechanical properties (ratio of dimensions and hardenability) can be given.

Geometry:

difference in effect of stress gradient due to size differences is insignificant or it is considered.

principal stress direction is equivalent. Refer to Chapter **3**.

Manufacturing:

similar manufacturing process.

An induction hardened or gas nitrided crankshaft will suffer fatigue either at the surface or at the transition to the core. The surface fatigue strength as determined by fatigue tests of full-scale cranks may be used for crankshafts of equal or similar design, if the fatigue is initiated at the surface.

The design similarity means the similar material type and surface hardness, as well as the fillet radius and the hardening depth within approximately ±30% of the tested crankshaft values.

Fatigue initiation in the transition zone can be either subsurface, i.e. below the hard layer, or at the surface where the hardening ends.

The fatigue strength at the transition to the core can be determined through the above fatigue tests provided that the fatigue occurred at the transition to the core.

Tests made with the core material only will not be representative since they do not consider the tensile residual stresses in the transition zone. It has to be noted that some recent research has shown that the fatigue limit can decrease in the very high cycle domain with subsurface crack initiation due to trapped hydrogen that accumulates through diffusion around some internal defects functioning as initiation points.

In such cases, it would be appropriate to reduce the fatigue limit by a few percent per decade of cycles over 10^7 . If hydrogen content is high, it is possible to apply reduction of 5 % per decade of cycles.

APPENDIX V

GUIDANCE FOR CALCULATION OF SURFACE TREATED FILLETS AND OIL BORE OUTLETS[8]

Contents

1. INTRODUCTION

This Appendix contains instructions for calculation of oil bore outlets and surface treated fillets. It explains how to consider various treatments and presents some empirical formulae for calculation purposes. The conservative empiricism has been applied intentionally in order increase calculation reliability.

It shall be noted that measurement results or more accurate data shall be used if available. However, in case of a wide scatter (e.g. for residual stresses), the values shall be chosen from the range end which would provide known greater persistence.

2. DEFINITION OF SURFACE TREATMENT.

Surface treatment is a term covering thermal, chemical or mechanical treatments resulting in inhomogeneous material properties (hardness, chemistry or residual stresses) from the surface to the core.

2.1 Surface treatment methods.

The following list covers possible treatment methods and how they influence the properties that are decisive for the fatigue strength.

Table 1.2.4

Treatment method	Affecting
Induction hardening	Hardness and residual stresses
Nitriding	Chemistry, hardness, and residual stresses
Case hardening	Chemistry, hardness, and residual stresses
Die quenching (no temper)	Hardness and residual stresses
Cold rolling	Residual stresses
Surface hardening by peening	Residual stresses
Shot peening	Residual stresses
Laser surface hardening	Residual stresses
Ball peening	Residual stresses
Note: It is important to note that since only induction hardening, nitriding, cold rolling and peening are considered relevant for marine engines, other methods and combination of two or more of the above are not dealt with in this document. In addition, die quenching can be considered in the same way as induction hardening.	

[8] Refer to IACS UR M53 (Rev.3 June 2017)

3. CALCULATION PRINCIPLES

The basic principle is that the alternating working stresses shall be below the local fatigue strength (including the effect of surface treatment) wherein non-propagating cracks may occur, also refer to 6.1 for details.

This is then divided by the given safety factor. This principle applies to the entire fillets and oil bore outlets, as well as to the subsurface layer to a depth below the treatment-affected zone, i.e. to cover the depth all the way to the core.

Consideration of local fatigue strength shall include effect of local hardness, residual stress and mean working stress. Influence of 'giga-cycle effect', especially for initiation of subsurface cracks, shall be covered by the selected safety margin.

It is of vital importance that the extension of treatment in stress concentration zones be duly considered. Any transition, where hardening is ended, is likely to have considerable tensile residual stresses.

This forms 'weak spots' which is important if they are located within the area of high stresses.

Alternating and mean working stresses shall be known for the entire stress concentration zone and for a depth of about 1,2 times the treatment depth.

The following figure 3 shows how this principle is applied for induction hardening. X-axis is directed either to the depth (perpendicular to the surface) or along the fillet contour.

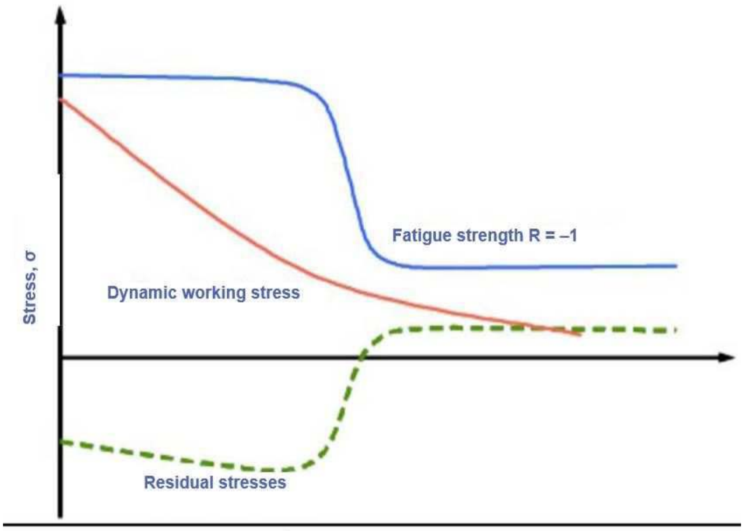


Fig. 3. . Stresses as functions of depth, general principles

The acceptability criterion shall be applied stepwise from the surface to the core and from the point of maximum stress concentration along the fillet surface contour to the web.

3.1 Evaluation of local fillet stresses.

It is necessary to know the stresses along the fillet contour and in the subsurface layer to a depth somewhat beyond the hardened layer. Normally such data can be found via FEM as described in Appendix III. However, the subsurface layer elements shall have the same sizes as the surface ones. For crankpin hardening case, only the small elements shall be spread along the surface to the hard layer.

If no FEM is possible, a simplified approach may be used for crankshafts made of steel. This can be based on the empirically determined SCFs as described in **2.4.6** of this Part, if within this method validity range, and on the relative stress gradient inversely proportional to the fillet radius. Bending and torsional stresses must be addressed separately. The combination of the above parameters shall meet the acceptability criterion.

The subsurface transition-zone stresses, with the minimum hardening depth, can be determined by means of local stress concentration factors along an axis perpendicular to the fillet surface.

Functions $\alpha_{B\text{-}local}$ and $\alpha_{T\text{-}local}$ have different shapes because of different stress gradients.

SCFs α_B and α_T are valid at the surface. Local $\alpha_{B\text{-}local}$ and $\alpha_{T\text{-}local}$ drop with increasing depth. The relative stress gradients at the surface depend on the type of stress concentrator, but for the crankpin fillets they can be simplified to $2/R_H$ for bending and $1/R_H$ for torsion. The journal fillets are handled analogously with using

R_G and D_G. The nominal stresses are assumed to be linear from the surface to the midpoint in the web between the crankpin fillet and the journal fillet for bending and to the crankpin or journal centre for torsion.

The local SCFs are then functions of depth t according to equation (3.1-1) and in Fig. 3.1-1 for bending and in equation (3.1-2) and Fig. 3.1-2 for torsion.

$$\alpha_{B\text{-}local} = (\alpha_B - 1)\cdot e^{\frac{-2\cdot t}{R_H}} + 1 - \left(\frac{2\cdot t}{\sqrt{W^2+S^2}}\right)^{\frac{0.6}{\sqrt{\alpha_B}}} \qquad (3.1\text{-}1)$$

$$\alpha_{T\text{-}local} = (\alpha_T - 1)\cdot e^{\frac{-t}{R_H}} + 1 - \left(\frac{2\cdot t}{D}\right)^{\frac{1}{\sqrt{\alpha_T}}} \qquad (3.1\text{-}2)$$

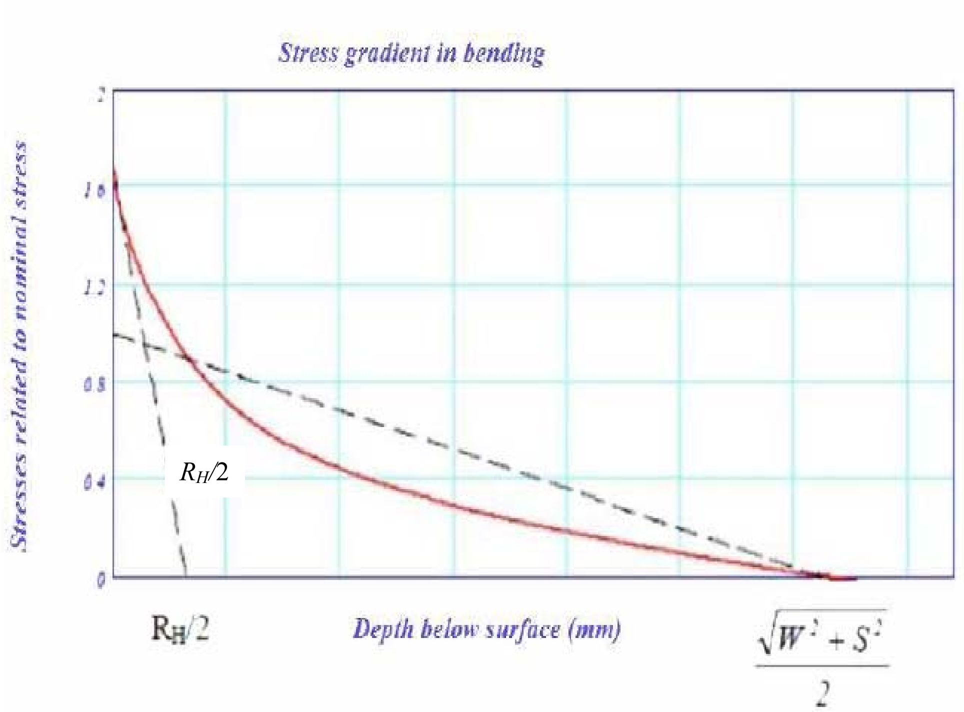


Fig. 3.1-1. Bending SCF in crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G

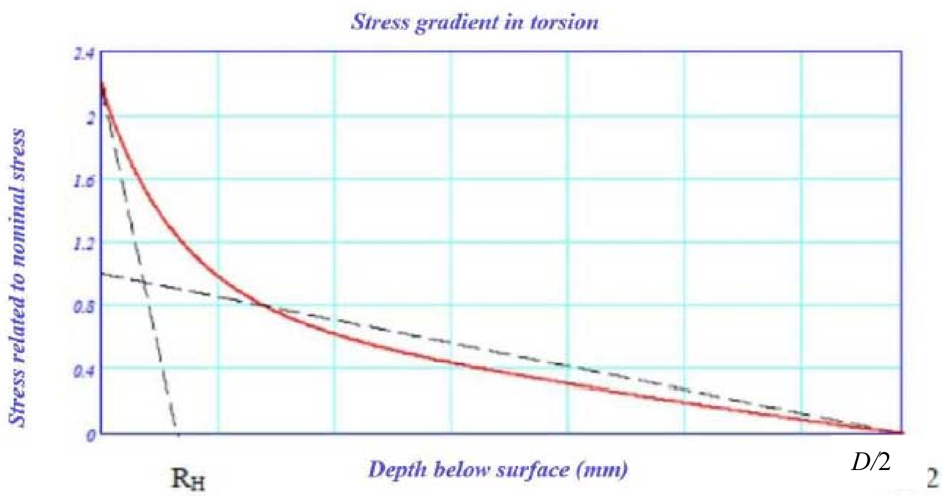


Fig. 3.1-2. Torsional SCF in crankpin fillet as a function of depth. The corresponding SCF for the journal fillet can be found by replacing R_H with R_G and D with D_G

If the crankpin only is hardened and the end of the hardened zone is closer to the fillet than three times the maximum hardening depth, FEM shall be used to determine the actual stresses in the transition zone.

3.2 Evaluation of oil bore outlet stresses.

Stresses in the oil bore outlets can be also determined by FEM. The element size shall not exceed 1/8 of the oil bore diameter D_o and the element mesh quality criteria shall be followed as prescribed in Appendix III.

The finite-element mesh shall continue well beyond the hardening depth in radial direction.

The loads to be applied in the FEM are the torque (refer to **3.1**, Appendix III) and the four-point bending moment (refer to **3.2**, Appendix III).

If no FEM is possible, a simplified approach may be used for crankshafts made of steel. This can be based on the empirically determined SCFs as described in **2.4.6** of this Part, if within this method validity range. Bending and torsional stresses at the peak stress point are combined according to **2.4.8** of this Part.

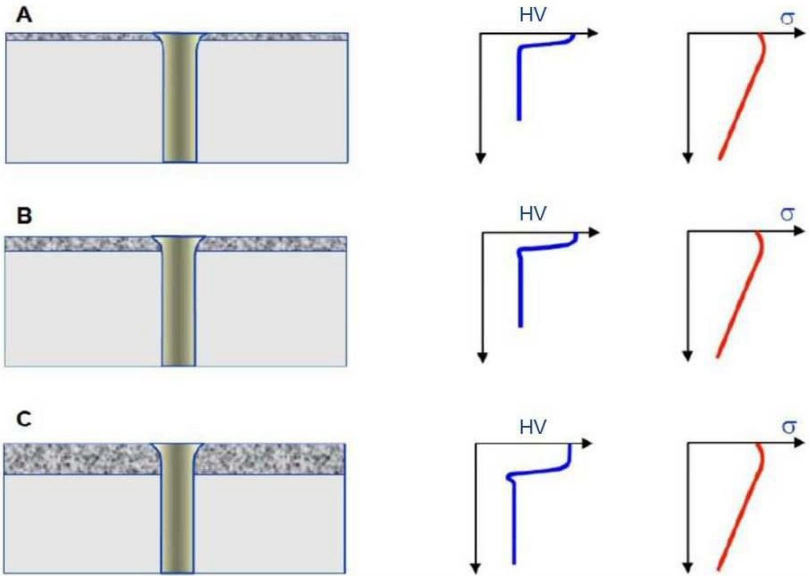


Fig. 3.2. Stresses and hardness in induction hardened oil hole outlets

Fig. 3.2 shows the hardness behaviour in the transition zone between the hard and soft zones of material. The behaviour depends among others on the tempering temperature in the QT process.

The peak stress in the bore outlets occurs at the end of the outlet rounding.

The stress drops within this zone almost linearly over the distance to the crankpin centre. As can be seen in Fig. 3.2, for shallow (A) and intermediate (B) hardening, the transition point practically coincides with the peal stress point. As for deep hardening, the transition point comes outside of the peak stress point, and the local stress can be assessed as a portion equal to $(1 - 2tH/D)$ of the peak stress where tH is the hardening depth.

The subsurface transition-zone stresses (at the minimum hardening depth) can be determined by means of local SCFs along an axis perpendicular to the oil bore outlet surface.

These functions $\gamma_{B\text{-}local}$ and $\gamma_{T\text{-}local}$ have different shapes because of different stress gradients.

The SCFs γ_B and γ_T are valid at the surface.

The local SCFs $\gamma_{B\text{-}local}$ and $\gamma_{T\text{-}local}$ drop with increasing depth. The relative stress gradients at the surface depend on the type of stress concentrator, but for crankpin oil bore outlets, they can be simplified to $4/D_o$ for bending and $2/D_o$ for torsion. The local SCFs are then functions of the depth t:

$$\gamma_{B\text{-}local} = (\gamma_B - 1)e^{-4t/Do} + 1 \qquad (3.2\text{-}1)$$

$$\gamma_{T\text{-}local} = (\gamma_T - 1)e^{-2t/Do} + 1 \qquad (3.2\text{-}2)$$

3.3 Acceptability criterion.

The crankshaft design acceptability criterion is based on fatigue compliance. Chapter **2.4** of this Part compares the ration of equivalent alternating stress to fatigue strength with the acceptability factor of Q>1.15 for oil bore outlets, crankpin fillets and journal fillets of steel crankshafts.

This criterion shall also apply to the surface treated areas irrespective of the fact whether the surface or the transition zone is examined.

4. INDUCTION HARDENING

Generally, the hardness requirements shall specify the surface hardness range, i.e. minimum and maximum values, minimum and maximum extension in or through the fillet, as well as minimum and maximum depth along the fillet contour. Here, Vickers hardness scales within HV0.5 to HV5 shall be used.

The induction hardening depth is defined as the depth where the material hardness is 80% of the minimum specified surface hardness.

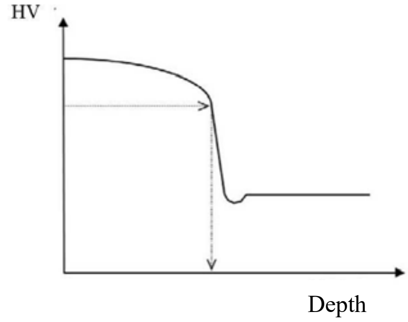


Fig. 4-1. Typical hardness as a function of depth. The arrows indicate the hardening depth

The possible hardness pattern in the transition zone to the core is shown. The shown hardness reduction zone could be a "weak" point: its local hardness could be reduced and residual tensile stress could occur in this point.

In the case of crankpin or journal hardening only, the minimum distance to the fillet shall be specified in view of the tensile stress in the heat-affected zone as shown in Fig. 4.-2.

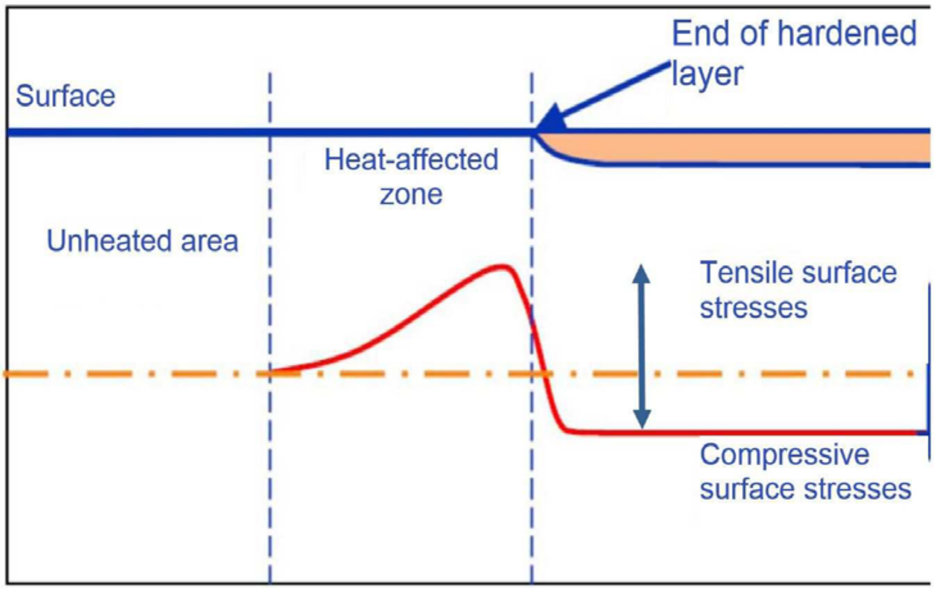


Fig. 4-2. Residual stresses along the surface of a crankpin and fillet

If the hardness-versus-depth profile and the residual stresses are unknown or unspecified, the following may be assumed:

The hardness profile consists of two layers (refer to Fig. 4-1):

constant hardness from the surface to the transition zone;

constant hardness from the transition zone to the core material;

the residual stresses in the hard zone are 200 MPa (compression);

the transition zone hardness is 90 % of the core hardness unless a hardness drop is present in the transition zone to the core shown in Fig. 4-1.

the maximum residual stresses (von Mises) in the transition zone are 300 MPa (tension).

If the crankpin or journal hardening ends are close to the fillet, the influence of tensile residual stresses has to be considered. If the minimum distance between the hardening end and the fillet beginning is more than 3 times the maximum hardening depth, the influence may be disregarded.

4.1 Local fatigue strength.

Induction-hardened crankshafts will suffer fatigue either at the surface or at the transition to the core. The fatigue strength for both the surface and the transition zone can be calculated following the full-scale crankshaft fatigue testing results according to Appendix IV. In the case of a transition zone, the fatigue may occur either in the subsurface (i.e. below the hard layer) or at the surface where the hardening ends.

Tests made with the core material only are not representative since they do not consider the tensile residual stresses in the transition zone.

Alternatively, the surface fatigue strength for the steel crankshafts can be determined empirically as follows where HV is the Vickers surface hardness. Equation (4.1-1) provides a conservative value, with which the fatigue strength is assumed to include the influence of the residual stress. The resulting value is valid for R stress ratio of –1.

$$\sigma_{Fsurface} = 400+0{,}5(HV-400) \qquad (4.1\text{-}1)$$

It has to be noted that the mean stress influence for induction-hardened steels may be significantly higher than that for QT steels.

The fatigue strength in the transition zone, without taking into account any irregular hardness drop in the transition to the core as shown in Figure 4.-1, shall be determined by the equation introduced in 2.4.9 of this Part.

The following formula applies to journal fillets and crankpin fillets, respectively:

$$\sigma_{Ftransition,\ cpin} = +\,K(0{,}42\sigma_B+39{,}3)[0{,}264+1{,}073\,Y^{-0{,}2}+\frac{785-\sigma_B}{4900}+\frac{196}{\sigma_B}\sqrt{1/X}\,], \qquad (4.1\text{-}2)$$

where:
$Y=D_G$ and $X=R_G$ for journal fillet,
$Y=D$ and $X=R_H$ for crankpin fillet,
$Y=D$ and $X=D_o/2$ for oil bore outlet.

The influence of the residual stress is not considered in equation (4.1-2).

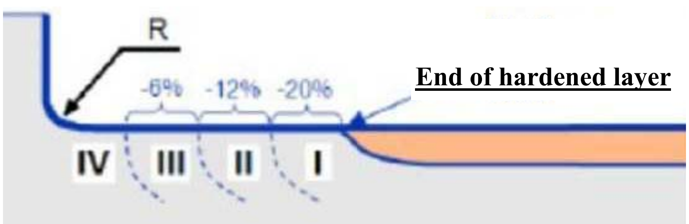
For the purpose of fatigue analysis of subsurface layer (below the hardened layer), the neglect of tensile residual stresses has to be considered by subtracting 20 % from the value determined above. This subtracted 20 % is based on the mean stress influence in the alloyed quenched and tempered steel having a residual tensile stress of 300 MPa.

For low-strength steels, the percentage chosen shall be higher. When the residual stresses are known to be lower, their actual value shall be taken into account.

For the purpose of analysis of surface fatigue near the end of the hardened zone, i.e. in the heataffected zone shown in Fig. 4-2, the influence of the tensile residual stresses can be considered by subtracting a certain percentage in accordance with Table 4.1 from the value determined by the above formula (4.1-2).

Table 4.1. **Influence of tensile residual stresses at a given distance from hardened zone end and fillet**

I	0...1,0 of the max. hardening depth:	20%
II	1,0...2,0 max. hardening depths:	12%
III	2,0...3,0 max. hardening depths:	0%
IV	3.0 max. hardening depths or more:	0%



5. NITRIDING

The hardness requirements shall include the surface hardness range (min and max) and the minimum and maximum depth.

This Section covers gas nitriding only. Here, Vickers hardness scales within HV0,5 shall be used.

For the purpose of this Section, the nitriding depth t_N is defined as the depth where the material hardness is 50 HV above the core hardness.

The hardening profile shall be specified all the way to the core. If this is unknown, it may be determined empirically via the following formulae:

$$HV(t)=HV_{core}+(HV_{surface}-HV_{core})[(50/(HV_{surface}-HV_{core})]^{(t/t_N)^2}$$

where:
t is the local depth,
$HV(t)$ is the hardness at depth t,
HV_{core} is the core hardness (minimum),
$HV_{surface}$ is the surface hardness (minimum),
t_N is the minimum nitriding depth.

5.1 Local fatigue strength.

It is important to note that in nitrided crankshaft cases, fatigue occurs either at the surface or at the transition to the core. This means that the fatigue strength can be determined by testing as described in Appendix IV.

Alternatively, the surface fatigue strength (principal stress) for the steel crankshafts can be determined empirically and conservatively as follows:

$$\sigma_{Fsurface} = 450\text{MPa} \qquad (5.1\text{-}1)$$

The dependence (5.1-1) may be used if the fatigue strength is assumed to include the influence of the surface residual stress, and stress ratio R is –1.

The fatigue strength in the transition zone can be determined by the equation in **2.4.9** of this Chapter. for journal fillet and, accordingly, for crankpin fillet the following equation is introduced:

$$\sigma_{Ftransition,\ cpin} = +\,K(0{,}42\sigma_B+39{,}3)[0{,}264+1{,}073\,Y^{-0{,}2}+\frac{785-\sigma_B}{4900}+\frac{196}{\sigma_B}\sqrt{1/X}\,] \qquad (5.1\text{-}2)$$

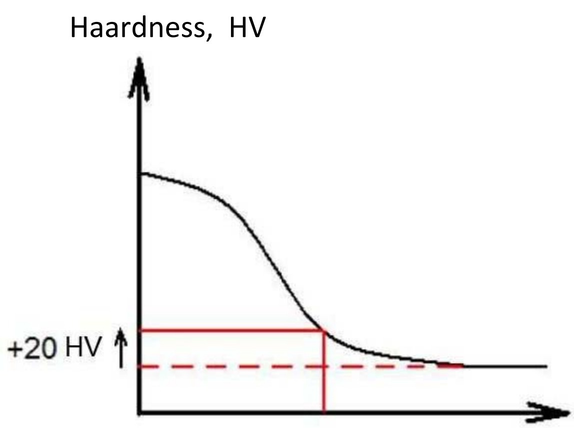
where:
$Y=D_G$ and $X=R_G$ for journal fillet,
$Y=D$ and $X=R_H$ for crankpin fillet,
$Y=D$ and $X=D_o/2$ for oil bore outlet.

The influence of the residual stress is not considered in equation (5.1-2)..

In contrast to induction-hardened items, the nitrited items have no such distinct transition to the core. Although the compressive residual stresses at the surface are high, the balancing tensile stresses in the core are moderate because of the shallow depth.

For the purpose of analysis of subsurface fatigue the neglect of tensile residual stresses in and below the transition zone may be even disregarded due to the smooth contour of the nitriding hardness profile.

Although the calculation generally shall be carried out along the entire hardness profile, it can be limited to a simplified approach of analyzing the surface and determining the conditional transition point which can be taken at the depth where the local hardness is approximately 20 HV above the core hardness. In this case, the core material properties shall be used in calculations, and the stresses at the transition to the core can be found by using the local SCF formulae and t = 1,2 t_N.



t_N t

Fig. 5.1. Sketch of the location for the artificial transition point in the depth direction

6. COLD FORMING

The advantage of surface hardening by peening or cold rolling of fillets is the compressive residual stress introduced in the highly loaded areas. Even though the surface residual stresses can be determined by X-ray diffraction, and the subsurface residual stresses, by neutron diffraction, the local fatigue strength cannot be determined for certain; therefore, it shall be determined by fatigue testing in view of requirements of Appendix IV.

Such testing is normally carried out with four-point bending at stress ratio R of −1.

Based on the test results, the bending fatigue strength (surface or subsurface one depending on the manner of failure) can be determined and taken as the representative fatigue strength for this type of loading in the fillet zone.

The ratio of torsion and bending fatigue strength in the fillet zone may differ considerably from the ratio of √3, which is used in the von Mises criterion. The reason for this is that the forming-affected depth, which is sufficient to prevent the bending subsurface fatigue, may still allow the torsion subsurface fatigue to occur and the extension of the highly loaded area.

The results obtained in a full-scale crankshaft test can be applied to other crankshaft sizes provided that their material as for amount of alloys and heat treatment is of the similar type and that the forming is done so as to obtain the similar level of compressive residual stresses both at the surface and in the depth, i.e. the cold forming extension and depth must be proportional to the fillet radius.

6.1 Surface hardening by ball peening.

The fatigue strength can be determined by means of full-scale crankshaft tests or by empirical methods, if these provide a greater persistence. If both bending and torsion fatigue strengths have been investigated and their ration is found to differ from √3, the von Mises criterion shall be excluded.

If only bending fatigue strength is investigated, the torsional fatigue strength shall be evaluated conservatively. If the bending fatigue strength is found to be x% above the fatigue strength of the unhardened material, the torsional fatigue strength shall not be assumed to be more than 2/3 of x% above that of the unhardened material.

As a result of the peening process, the maximum compressive residual stress is found in the subsurface layer. Therefore, depending on the fatigue test load and the stress gradient, it is possible to have higher working stresses at the surface in comparison to the local fatigue strength. Because of this phenomenon small cracks may appear during the fatigue testing, which will not be able to propagate in further load cycles and/or with further slight increase of the test load due to the compressive residual stress profile because the high compressive residual stresses below the surface stop small surface cracks (refer to gradient load line 2 in Fig. 6.1).

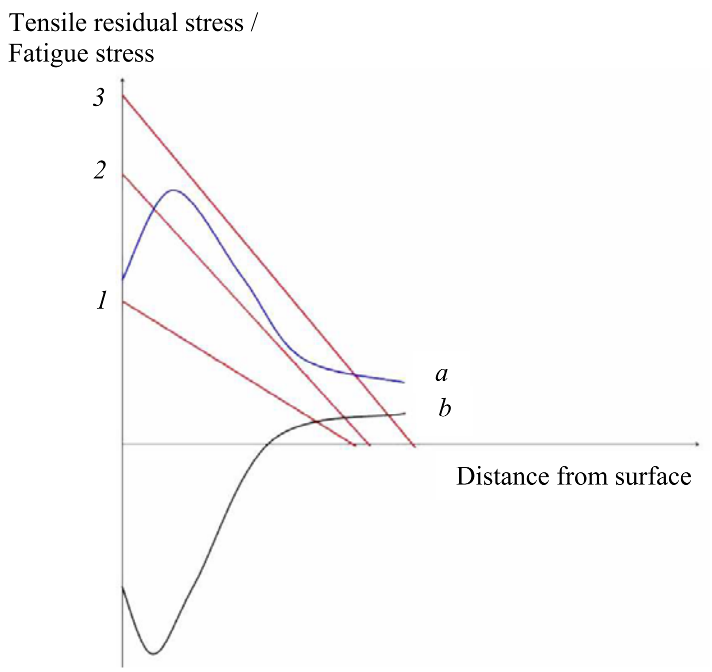


Fig. 6.1. Working and residual stresses below the stroke-peened surface. Straight lines 1 to 3 represent different possible load stress gradients

Gradiented load (e.g. bending and torsion) 1. Fatigue strength - without hairline cracks 2. Non-propagable hairline crack 3. Fatigue strength - rupture level

a. Fatigue strength (total of residual stress and base fatigue strength of quenched and tempered material) *b*. Residual stress after peening.

In fatigue testing of full-scale crankshafts, these small hairline cracks shall not be considered as cracks which can result in failure. The cracks caused by fatigue and capable of resulting in failure (stop of testing) only shall be considered in determining the failure load level. This also applies to peening of inductionhardened fillets.

In order to improve the fatigue strength of induction-hardened fillets, it is possible to apply the peening process to the crankshafts' fillets after they have been induction-hardened and tempered to the required surface hardness. If this is done, it might be necessary to adapt the peening force to the surface layer hardness and not to the base material strength limit.

The effect of induction hardening followed by peening on the fillet fatigue strength shall be determined by full-scale crankshaft testing.

6.1.1 Use of available results for similar crankshafts.

Data on change of fatigue strength resulted from surface layer peening may be utilized in calculation of other crankshafts if the following requirements are fulfilled:

ball size relative to fillet radius shall be within ±10 % of that for the tested crankshaft;

the shaft area subjected to surface hardening shall be equal to or exceed the similar area of the tested shaft;

the angular length of the fillet contour relative to the fillet radius shall differ by maximum of ±15% from the tested crankshaft and be located to cover the stress concentration zone during engine operation;

the similar material, including amount of alloys and heat treatment, is used;

ball feed speed shall be of the same proportion to the radius;

force applied to a ball shall be proportional to base material hardness (if hardness values are different);

force applied to a ball shall proportional to square of ball radius.

6.2 Cold rolling.

The fatigue strength can be determined by means of full-scale crankshaft tests or by empirical methods, if these provide a greater persistence.

If both bending and torsion fatigue strengths have been investigated and their ration is found to differ from √3, the von Mises criterion shall be excluded.

If only bending fatigue strength is investigated, the torsional fatigue strength shall be evaluated conservatively. If the bending fatigue strength is found to be x % above the fatigue strength of the unhardened material, the torsional fatigue strength shall not be assumed to be more than 2/3 of x% above that of the unhardened material.

6.2.1 Use of available results for similar crankshafts.

Data on change of fatigue strength resulted from cold rolling of surface layer may be utilized in calculation of other crankshafts if the following requirements are fulfilled:

the shaft area subjected to surface hardening shall be equal to or exceed the similar area of the tested shaft;

the angular length of the fillet contour relative to the fillet radius shall differ by maximum of ±15% from the tested crankshaft and be located to cover the stress concentration zone during engine operation.

The similar material, including amount of alloys and heat treatment, is used;

force applied to a roller shall be calculated so as to achieve at least the same relative (to fillet radius) treatment depth.

APPENDIX VI

GUIDANCE FOR CALCULATION OF STRESS CONCENTRATION FACTORS IN OIL BORE OUTLETS OF CRANKSHAFTS USING FINITE ELEMENT METHOD[9]

Contents

1. GENERAL

The objective of this analysis described in this document is to substitute the analytical calculation of the stress concentration factor (SCF) at the oil bore outlets with suitable finite element method (FEM) calculated figures.

The analytical method is based on empirical formulae developed from strain gauge readings or photoelasticity measurements of various round bars.

Since use of these formulae beyond any of the parameter validity ranges can result in errors in either direction, the FEM is highly recommended.

The SCF calculated according to the rules set forth in this document is defined as the ratio of FEMcalculated stresses to nominal stresses calculated analytically.

When the method is used to make calculations according to Chapter **2.4** of this Part, principal stresses shall be calculated.

The analysis is to be conducted as linear elastic FE analysis, and unit loads of appropriate magnitude are to be applied for all load cases.

It is recommended to check the element accuracy of the FE solver in use, e.g. by modelling a simple geometry and comparing the FEM-obtained stresses with the analytical solution.

The Boundary Element Method (BEM) may be used instead of FEM.

2. MODEL REQUIREMENTS

The basic recommendations and assumptions for building the FE-model are presented in **2.1**. The final FE-model must meet one of the criteria presented in **2.3**.

2.1 Element mesh recommendations.

In order to fulfil the mesh quality criteria, the FE model for the evaluation of Stress Concentration Factors shall be built according to the following recommendations:

The model shall describe one complete crank, from the main bearing centreline to the adjacent main bearing centreline.

The following element types are used in the vicinity of the outlets:

10-node tetrahedral elements;

8-node hexahedral elements;

20-node hexahedral elements.

The following mesh properties are used in the vicinity of the oil bore outlets: maximum element size a = r/4 through the entire outlet fillet and in the oil bore direction (if 8-node hexahedral elements are used, even smaller elements are required to meet the mesh quality criteria).

Recommended element sizes in fillet depth direction:

first layer thickness equal to element size of a;

second layer thickness equal to element size of $2a$;

third layer thickness is equal to element size of $3a$.

Generally the rest of the crank shall provide the numeric stability of the solver.

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[9] Refer to IACS UR M53 (Rev.3 June 2017)

Drillings and holes for weight reduction have to be modelled. Sub-modelling may be used as far as the software requirements are fulfilled.

2.2 Material.

Chapter **2.4** of this Part does not cover material properties such as Young's modulus (E) and Poisson's ratio (ν). In FE analysis, these material parameters are required, as elastic strains are primarily calculated and stresses are derived from elastic strains using the Young's Modulus and Poisson's ratio. Valid values for material parameters have to be used, either as quoted in literature or as measured on representative material samples.

The following values are recommended for steel: $E = 2{,}05\times10^5$MPa and $\nu = 0{,}3$.

2.3 Element mesh quality criteria.

If the actual element mesh does not fulfil any of the following criteria for SCF evaluation in the examined area, then a second calculation with a refined mesh is to be performed.

2.3.1 Principal stresses criterion.

The mesh quality shall be assured by checking the stress component normal to the surface of the oil bore outlet radius. With principal stresses σ_1, σ_2 and σ_3, the following requirement shall be met:

$$\min(|\sigma_1|, |\sigma_2|, |\sigma_3|)<\max(|\sigma_1|, |\sigma_2|, |\sigma_3|)$$

2.3.2 Averaged / unaveraged stresses criterion.

The averaged / unaveraged stress criterion is based on observing the discontinuity of stress results over the fillet elements in calculation of SCFs:

unaveraged nodal stress results calculated from each element connected to a node shall differ by less than 5 % from 100 % of averaged nodal stress results at this node in the examined area.

3. LOAD CASES AND EVALUATION OF STRESS LEVEL

To substitute the analytically calculated SCFs as described in **2.4** of this Part, the following load cases have to be calculated.

3.1 Torsion.

The structure is loaded in pure torsion. Model end face warp is suppressed.

Torque is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is rigidly connected to all nodes of the end face.

Such boundary and load conditions are valid for both in-line and V-type engines.

For all nodes at the oil bore outlet, the principal stresses are obtained and the maximum value of them is taken for subsequent calculation of SCF:

$$\gamma_T = \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)/\tau_N$$

where the nominal torsion stress τ_N at the crankpin is evaluated as per 2.4.5.1of this Part at torque T:

$$\tau_N = T/W_p$$

3.2 Bending.

The structure is loaded with pure bending. Model end face warp is suppressed.

The bending moment is applied to the central node located at the crankshaft axis. This node acts as the master node with 6 degrees of freedom and is rigidly connected to all nodes of the end face.

Such boundary and load conditions are valid for both in-line and V-type engines.

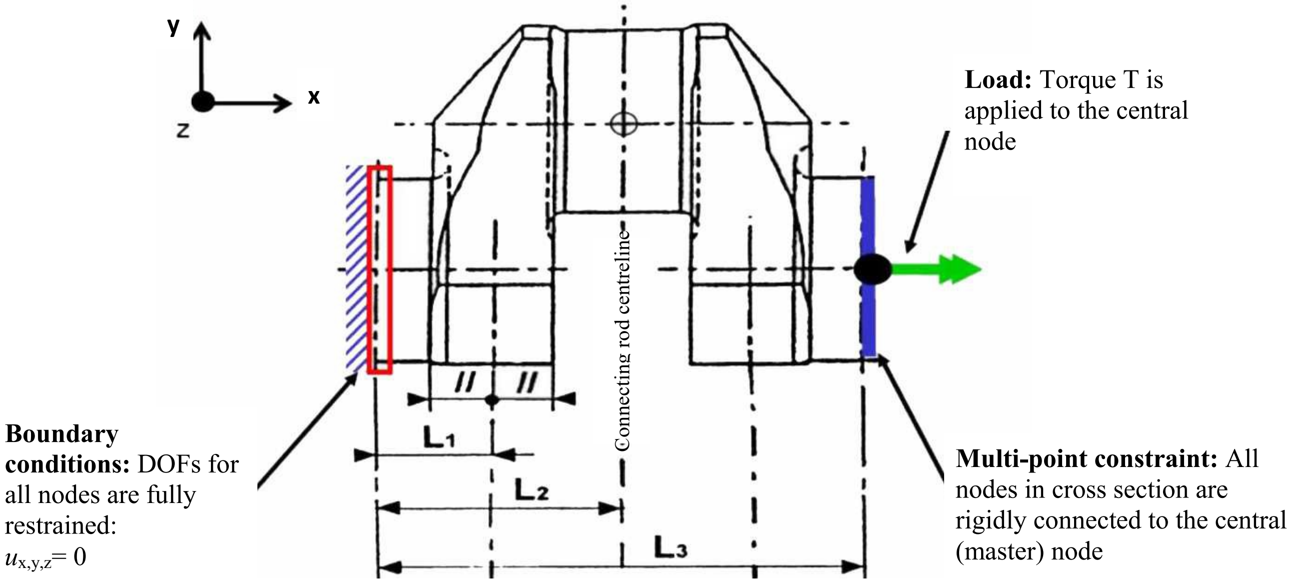


Fig. 3.1. Boundary and load conditions for torsion load case

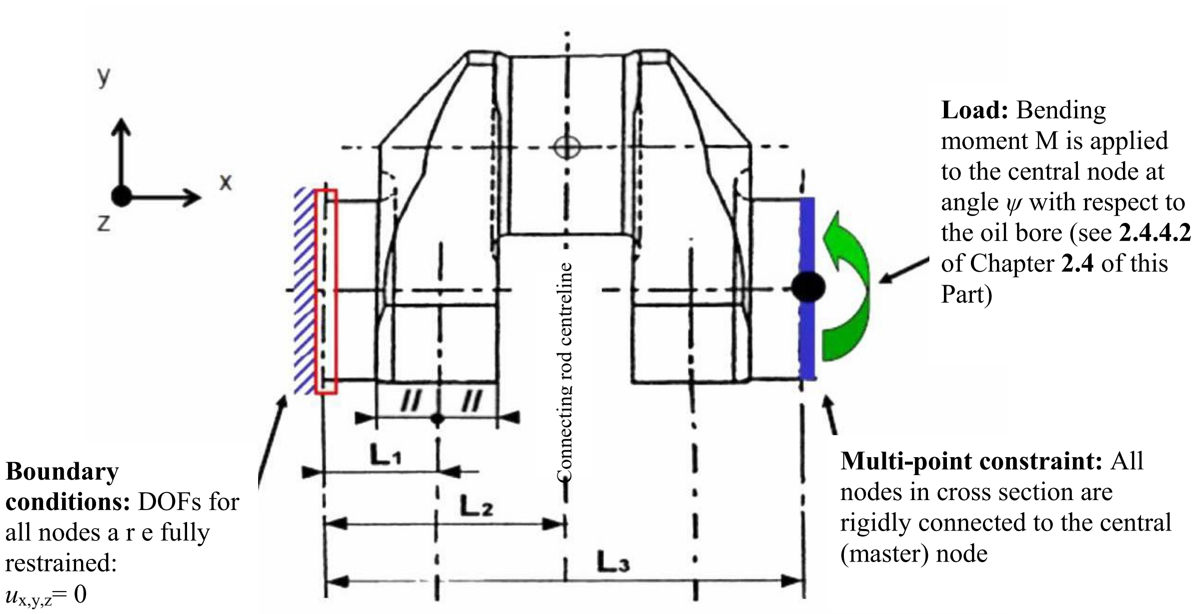


Fig. 3.2. Boundary and load conditions for pure bending load case

For all nodes at the oil bore outlet, the principal stresses are obtained and the maximum value of them is taken for subsequent calculation of SCF:

$$\gamma_B = \max(|\sigma_1|, |\sigma_2|, |\sigma_3|)/\sigma_N,$$

where the nominal bending stress σN at the crankpin is evaluated as per **2.4.4.2** of Part **2.4** at bending moment M:

$$\sigma_N = M/W_e.$$

3. STEAM TURBINES

3.1 GENERAL

3.1.1 The main geared turbine installation shall be capable of reversing from full speed ahead at the rated power to astern speed, and reversing in the opposite direction by using backsteam.

3.1.2 The turbine installation intended for propulsion shall comply also with the requirements of **2.1**, Part VII "Machinery Installations".

In multi-screw ships with a fixed-pitch propeller a turbine installation of each shaft shall be provided with an astern turbine.

3.1.3 Auxiliary turbines shall be started without preheating.

3.1.4 In single screw ships fitted with cross compound steam turbines, the arrangement shall be such as to enable safe navigation when the steam supply to anyone of the turbines is required to be isolated. For this emergency operation purpose the steam may be led directly to the L.P. turbine, and either the H.P. or M.P. turbine can exhaust direct to the condenser.

Adequate arrangements and controls shall be provided for these operating conditions so that the pressure and temperature of the steam will not exceed those, which the turbine and condenser can safely withstand.

All piping and valves of these arrangements shall be readily available and properly marked. A fit up test of all combinations of pipes and valves shall be performed prior to the first sea trials. The permissible power/speeds when deactivating one of the turbines; appropriate information shall be provided on board. The operation of the turbines under emergency conditions shall be assessed for potential influence on shaft alignment and gear teeth loading conditions.

3.2 ROTOR

3.2.1 The strength of rotor parts shall be calculated for maximum power, as well as for other possible loads at which stresses may rise to maximum values.

Moreover, a check calculation of stresses shall be made for the rotor and parts thereof at a speed exceeding the maximum values by 20 %.

3.2.2 The critical speed of the rotor shall be in excess of the rated speed corresponding to the rated power by not less than 20 %.

The critical speed of the rotor may be reduced, provided there is an ample proof of the reliability of the turbine under all operating conditions.

3.2.3 Each new design of blading requires a calculation of vibration with subsequent verification of vibration characteristics by experiments.

3.2.4 The construction of blade tenon with detachable part of the disc side and other similar constructions, which may cause considerable local loosening of the rim are not allowed.

3.2.5 Completely assembled turbine rotors shall be dynamically balanced in a machine of sensitivity appropriate to the size and the mass of the rotor.

3.3 CASING

3.3.1 In cast steel turbine casings it is permitted for some cast elements and branches for connecting receivers, pipes and valves to be joined by welding.

3.3.2 The connection of the astern turbine steam inlet branch with the turbine casing shall not be rigid.

3.3.3 Gaskets between the flanges of horizontal and vertical joints of turbines shall not be used.

Planes of the joints are allowed to be coated with graphite paste for the purpose of sealing.

3.3.4 The diaphragms fixed in the turbine casing shall have a possibility of radial thermal expansion within permissible misalignment.

3.3.5 The diaphragms shall be designed for a load corresponding to the maximum pressure drop in the stage.

The actual deflection of the diaphragms shall be less than that, which may cause touching of the discs or of the rotor shaft sealing.

3.3.6 The low pressure turbine casing shall be provided with openings for the inspection of blading in the last stages.

The turbines with built-in condensers shall be provided with openings for the inspection of the upper rows of condenser tubes, and, where possible, for access inside the condenser.

3.3.7 The turbine shall be so designed as to allow lifting bearing caps without dismantling the turbine casing, ends of sealing arrangements and pipelines.

3.4 BEARINGS

3.4.1 In main turbines sleeve bearings shall be used. For turbines designed for quick starting when in cold condition, it is recommended to use bearings with self-aligning shells.

3.4.2 Thrust bearings of the main turbines shall, as a rule, be of a single-collar type. The use of bearings of other types shall be approved by the Register.

The bearings loaded with specific pressure of more than 2 MPa are recommended to be fitted with pivoted races or with devices for automatic equalization of pressure exerted on the pads.

3.4.3 The thickness of antifriction lining of thrust bearing pads shall be less than the minimum axial clearance in the turbine blading, but not less than 1 mm.

3.5 SUCTION, GLAND-SEALING AND BLOWING SYSTEMS

3.5.1 The main turbine installation shall be provided with a steam suction and gland-sealing system, with automatic control of pressure of the sealing steam.

In addition to automatic control, provision shall also be made for manual control of the steam suction and gland-sealing system.

3.5.2 Each turbine shall have a blowing system to ensure complete removal of condensate from all stages and spaces of the turbine.

The blowing system shall be so arranged as to prevent the condensate from entering the turbines being at standstill.

3.6 CONTROL, PROTECTION AND REGULATION

3.6.1 Each main turbine installation shall be provided with a manoeuvring gear designed for control and manoeuvring purposes.

Manoeuvring valves for turbine installation of 7500 kW and over shall be power-driven, emergency manual control of the valves shall be provided as well.

3.6.2 The time required for resetting the controls of the turbine installation manoeuvring gear from full ahead to full astern or vice versa shall not be in excess of 15 s.

The manoeuvring gear shall be so designed as to exclude the possibility of simultaneous steam supply both to the ahead and astern turbines.

3.6.3 The main and auxiliary turbines shall be provided with overspeed devices acting on an automatic safety device (quick-closing stop valve) automatically shutting off the admission of steam into the turbine when the rotor speed is in excess of the speed corresponding to the maximum power by 15 %.

The quick-closing stop valve shall be actuated by the overspeed device directly connected with the turbine shaft. An oil actuator receiving impulse from an impeller directly driven by the turbine shaft may be used as an overspeed device.

In case of turbine installations with several cylinders each turbine shaft shall be fitted with an overspeed device.

The turbine installations intended for use in the plants incorporating reverse gear, controllable-pitch propeller or other arrangements disengaging the turbine from the shafting, in addition to the overspeed device, shall be fitted with a speed governor limiting the turbine speed when the load is changed before the overspeed device is put into operation.

The speed governors of auxiliary turbines intended for driving electric generators shall comply with the requirements of **2.11.3** – **2.11.7**.

3.6.4 Each turbine shall be fitted with a hand-operated device to shut off the steam in emergency by closing the quick-acting stop valve.

In case of main turbine installation, this device shall be operated from two positions, one located on one of the turbines and the other in the control station. In case of auxiliary turbine installation, this device shall be located adjacent to the overspeed device.

3.6.5 The steam pipelines between the manoeuv-ring gear and nozzle box shall be of the volume as small as practicable to eliminate impermissible overspeed of the turbine when the quick-closing stop valve is shut in emergency.

3.6.6 In extraction turbines, bleed pipelines shall be fitted with non-return stop valves to automatically close simultaneously with the quick-closing valve.

Where exhaust steam from auxiliary systems is led to the turbines of the main turbine installation, it shall be cut off in case of emergency operation of the quick-closing stop valve.

3.6.7 The main turbine installations and turbines for driving electric generators in addition to the overspeed device shall be fitted with devices capable of automatically actuating the quick-closing stop valve and shutting off the admission of steam into the turbine in the following cases:

.1 drop of the lubricating oil pressure in the system below the value specified by the manufacturer;

.2 rise of pressure in the condenser above the value specified by the manufacturer;

.3 maximum shifting of rotor in any turbine incorporated in the propulsion turbine set.

For main turbine installations shutting off the steam supply to the ahead turbines in case of lowering of pressure in lubricating oil system shall not prevent the admission of steam to the astern turbine.

3.6.8 To prevent inadmissible rise of the lubricating oil temperature in any of the main turbine bearings, provision shall be made for a warning alarm system.

3.6.9 Safety valve or an equivalent arrangement shall be provided at the exhaust end of all turbines.

The safety valve discharge outlets shall be visible and suitably guarded if necessary.

3.6.10 Efficient steam strainers shall be provided close to the inlets to ahead and astern highpressure turbines or alternatively at the inlets to the manoeuvring valves.

3.6.11 For main turbine installations a slow-turning device, which operates automatically, shall be provided. Discontinuation of this automatic turning from the bridge shall be possible.

3.7 INSTRUMENTATION

3.7.1 The main turbine installation control stations shall be fitted with instruments for measuring:

.1 speed of the turbine shaft and shafting;

.2 steam pressure and temperature after the manoeuvring valve, in the nozzle boxes of ahead and astern turbines, in the governing stage chamber, bleed mains and the suction and gland-sealing system;

.3 outlet lubricating oil temperature in each bearing (the use of remote temperature indicators does not eliminate the necessity of fitting local thermometers);

.4 conditions of prestarting, reversing, stand-by keeping and bringing to prolonged inoperative state;

.5 lubricating oil pressure in the pressure pipelines after the oil cooler;

.6 vacuum in compliance with **19.4.1.2**, Part VIII "Systems and Piping".

3.7.2 Apart from the instruments specified in 3.7.1, the main turbine installation shall be provided with:

.1 instruments for checking lubricating oil supply to each bearing;

.2 indicators for determining the axial position of the rotor;

.3 regular devices for measuring the wear of white metal of shells and segments of each journal and thrust bearing;

.4 bridge gauges or other instruments for checking vertical and horizontal positions of each rotor;

.5 instruments for checking the steam pressure and temperature under emergency conditions with any turbine cylinder being shut of.

3.7.3 The auxiliary turbines for driving generators shall be fitted with instruments in compliance with **3.7.1**.

3.7.4 The turbine installation shall be fitted with the warning alarms for the following parameters:

.1 drop of the lubricating oil pressure in the lubricating oil system;

.2 rise of the lubricating oil temperature at each bearing outlet;

.3 rise of the lubricating oil pressure at the turbine installation inlet;

.4 rise of the pressure in the condenser;

.5 axial shift of rotors;

.6 on exceeded levels of vibration on bearings (considering the manufacturer's recommendations).

4. GEARS, DISENGAGING AND ELASTIC COUPLINGS

4.1 GENERAL

4.1.1 The reverse-reduction gearing intended for propulsion shall also comply with the requirements of **2.1**, Part VII "Machinery Installations".

4.1.2 Parts rotating at speeds 5 to 20 m/s shall be statically balanced, while those rotating at speeds over 20 m/s shall be dynamically balanced.

The accuracy of dynamic balancing shall be determined on the basis of the formulae:

$$v = 24000/n \text{ for } \upsilon > 300\text{m/s}; \qquad (4.1.2\text{-}1)$$

$$v = 63000/n \text{ for } \upsilon = 20\text{m/s}, \qquad (4.1.2\text{-}2)$$

where:

v – distance between the centre of gravity and the geo-metrical axis of rotation of the part concerned, μm;

n – rotational speed, min^{-1};

υ – peripheral velocity, m/s.

For peripheral velocities between 20 and 300 m/s, shall be determined by interpolation.

The rigid elements of couplings shall be balanced together with the parts they rigidly adjoin.

4.1.3 The design of the main gearing shall provide an access to all bearings.

The gear cases shall have a sufficient number of sight openings with easily detachable covers for carrying out internal inspection.

The sight openings shall be so arranged as to allow an inspection of the teeth over their full length and of the bearings inside the gearing.

The application of this requirement to the planetary gear shall be performed as far as their design allows.

4.1.4 The gear cases shall be provided with venting arrangements.

The vent pipes shall be led to the upper weather deck or other positions where uptake is provided.

The ends of the vent pipes shall be fitted with flame-arresting devices and arranged so as to prevent water from getting into the gearing.

4.1.5 Where the main thrust bearing is housed in the gearing case, the lower part of the case shall have proper strengthening.

4.2 GEARING

4.2.1 General.

4.2.1.1 The requirements of the Chapter cover external and internal cylindrical involute spur, helical and double helical gears and bevel gears with straight, tangent and circular arc teeth, operating with lubrication and intended both as components of propulsion plants (main gearing) and auxiliaries (auxiliary gearing) on board ships of various types.

The above requirements shall be satisfied in the case of units with parallel and intersecting shaft gears and multipliers of train and epicyclic type applied for one or more machine plants with any type of engine, and also for marine auxiliary drives.

These requirements apply to enclosed gears whose gear set is intended to transmit a maximum continuous power equal to, or greater than:

220 kW for gears intended for main propulsion;

110 kW for gears intended for essential auxiliary services.

These requirements, however, may be applied to the enclosed gears, whose gear set is intended to transmit a maximum continuous power less than those specified above at the request of the Register.

4.2.1.2 Epicyclic gear shall be fitted with equalizers.

The rim of epicyclic wheel with more than 3 planetary pinions shall be flexible in the radial direction.

4.2.2 Gears.

4.2.2.1 The pinions of main gearing shall be manufactured from alloy steel with the ultimate tensile strength of 620 MPa and above.

For auxiliary gears, both constructional steels with lower physical and chemical properties and cast iron, bronze and non-metallic materials may be used.

4.2.2.2 The hardness of pinion teeth shall be at least 15 % greater than that of wheel teeth. This requirement does not apply to surface hardened gears (carburized, nitrided, face-hardened, etc.).

4.2.2.3 Tooth fillet radius shall not be less than $0{,}3m_n$.

4.2.2.4 The strength of teeth and other pinion and wheel elements shall be proved by calculations.

These calculations of steel gear teeth for the basic criteria of durability (contact surface endurance and bending endurance) and for depth strength (for gears with chemically and thermally hardened teeth and with a large module) shall be based on the requirements of the Chapter.

In some cases, for high loads and speeds a calculation of the scuffing load capacity may be required.

For high power gearing, gears rotating at speeds higher than 30 m/s, epicyclic main propulsion gears and kinematically sophisticated gears specific calculation technique may be permitted, subject to agreement with the Register.

In cases of unique geometry, arrangement or manufacture of the gearing, the Register may permit a departure from the serviceability criteria determined by the formulae to be found in the Chapter on condition relevant calculations or experimental data are submitted as substantiation.

4.2.2.5 Technical documentation on gears to be submitted to the Register shall cover the following parameters:

type of gearing, engine and coupling;

a_p – number of engagements;

load spectrum;

T_1 – torque of pinion at the maximum long-acting load, N·m.

For gears, during the operation of which a possibility exists for an action of instantaneous maximum loads $T_{1\max} > K_A T_1$ with a number of stress reversal cycles not in excess of 103 throughout the service period, the maximum torque of pinion at the maximum load, $T_{1\max}$, N·m, shall be additionally indicated;

n_1 – pinion rotational speed, min^{-1};

m_n – normal module, mm;

Z_1, Z_2 (z_1, z_2) – number of teeth of pinion, wheel;

b_1 and b_2 – face width of pinion, wheel, mm;

b_w – active face width, mm;

h_a^* – addendum ref. to module;

c^* – bottom clearance ref. to module;

β – helix angle at reference cylinder, deg.;

$\alpha_л$ – normal pressure angle at reference cylinder, deg.;

x_1 and x_2 – addendum modification coefficient of pinion, wheel;

Q – grade of accuracy;

f_f – profile form error in accordance with current standards, μm;

f_{pb} – base pitch error in accordance with current standards, μm;

F_β – total tooth alignment deviation in accordance with current standards, μm;

ρ_{a0} – tip radius of tool, mm;

h_k – buckling height of protuberance profile, mm;

α_0 – protuberance angle, deg.;

d_{a0} – tip diameter of teeth of gear-shaper cutter for manufacturing internal gearing, mm;

Z_0 – number of teeth of gear-shaper cutter;

x_0 – addendum modification coefficient of cutter;

materials of pinion and wheel teeth;

σ_{B1} and σ_{B2} – ultimate tensile strength of tooth core, MPa;

σ_{T1} and σ_{T2} – yield strength of tooth core, MPa;

E_1 та E_2 – modulus of elasticity of the pinion and wheel teeth materials, MPa;

ν_1 та ν_2 – Poisson's ratio of the pinion and wheel teeth materials;

method of heat treatment of pinion and wheel teeth;

R_{a1} and R_{a2} – arithmetic average roughness of the pinion and wheel contact surface and root fillet, μm;

HV_1 and HV_2 – Vickers hardness of the pinion and wheel contact surface;

HB_1 and HB_2 – Brinell hardness of the pinion and wheel contact surface;

HB_{C1} and HB_{C2} – Brinell hardness of the pinion and wheel teeth core;

h_{t1} and h_{t2} – depth of core hardness of pinion, wheel, mm;

ν_{40} and ν_{50} – kinematic oil viscosity at 40°C and 50°C, mm^2/s.

Besides general parameters, the initial data for bevel gearing shall include:

tooth form in longitudinal section;

$\delta_1(\delta w_1)$, $\delta_2(\delta w_2)$ – pitch cone angle, deg.;

m_{te} – outer transverse module, mm;
R_{we} – outer pitch cone distance, mm;
β_m – middle helix angle, deg.

4.2.2.6 The nominal tangential load F_t, in N, is calculated by the equation

$$F_t = \frac{2000\,T_1}{d_1 a_p},$$

the maximum tangential load $F_{t\max}$, in N, is calculated by the equation

$$F_{t\max} = \frac{2000\ T_{1\max}}{d_1 a_p},$$

where for spur and helical gears

$$d_1 = Z_1 m_t,\ m_t = \frac{m_n}{\cos\beta}; \qquad (4.2.2.6\text{-}1)$$

for bevel gears

$$d_1 = d_{m1} = m_{te} Z_1 \left(1 - \frac{0{,}5 b_1}{R_{we}}\right). \qquad (4.2.2.6\text{-}2)$$

4.2.2.7 The gear shall satisfy the conditions of contact tooth surface endurance

$$\sigma_H \le \sigma_{Hp}$$

and tooth bending endurance

$$\sigma_F \le \sigma_{Fp},$$

where:
for σ_H and σ_F – refer to **4.2.2.7.1**, **4.2.2.7.3**;
for σ_{Hp} and σ_{Fp} – refer to **4.2.2.7.2**, **4.2.2.7.4**.

The rated stresses for bevel gearing are determined by formulae for equivalent cylindrical gearing. The parameters of the equivalent gearing for midsection are given in **4.2.2.7.6**.

For gears subjected to peak loads the following conditions shall be satisfied:
statical strength of contact tooth surface

$$\sigma_{H\max} \le \sigma_{HP\max}$$

and statical tooth bending strength

$$\sigma_{F\max} \le \sigma_{FP\max},$$

where:
for $\sigma_{H\max}$ and $\sigma_{F\max}$ – refer to **4.2.2.7.1**, **4.2.2.7.3**;
for $\sigma_{HP\max}$ and $\sigma_{FP\max}$ – refer to **4.2.2.7.2**, **4.2.2.7.4**.

4.2.2.7.1 The rated contact stresses, in MPa, for the pinion and wheel teeth are calculated by the following formula

$$\sigma_H = \sigma_{HO}\sqrt{K_A K_\gamma K_{H\beta} K_{H\alpha}}, \qquad (4.2.2.7.1)$$

where:
for σ_{HO} – refer to **4.2.2.7.1.1**;
for K_A – refer to **4.2.2.7.1.7**;
for K_γ – refer to **4.2.2.7.1.8**;
for K_v – refer to **4.2.2.7.1.9**;
for $K_{H\beta}$ – refer to **4.2.2.7.1.10**;
for $K_{H\alpha}$ – refer to **4.2.2.7.1.11**.

The rated maximum contact stresses, in MPa, for the pinion and wheel teeth are calculated by the formula

$$\sigma_{H\max} = \sigma_{HO\max}\sqrt{K_\gamma K_{H\beta} K_{H\alpha}},$$

where: $\sigma_{HO\max}$ – refer to **4.2.2.7.1.1**.

4.2.2.7.1.1 At nominal load, the contact stress for the pinion teeth is calculated by the equation

$$\sigma_{HO_1} = Z_K Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{w_t}{d_1}\frac{u \pm 1}{u}}, \qquad (4.2.2.7.1.1\text{-}1)$$

For wheel teeth

$$\sigma_{HO_2} = \frac{Z_D}{Z_B}\sigma_{HO_1},$$

where:

$$w_t = \frac{F_1}{\tau b_w},$$

$\tau = 1$ – for spur gears;
$\tau = 0{,}85$ – for bevel gears;
$u = Z_2/Z_1$ – gear ratio;
for Z_1, Z_2, b_w – refer to **4.2.2.5**;
for F_1, d_1 – refer to **4.2.2.6**;
for Z_B (Z_D) – refer to **4.2.2.7.1.2**;
for Z_H – refer to **4.2.2.7.1.3**;
for Z_E – refer to **4.2.2.7.1.4**;
for Z_ε – refer to **4.2.2.7.1.5**;
for Z_β – refer to **4.2.2.7.1.6**;
$Z_K = 1$ – for spur gears,
$Z_K = 0{,}85$ – for bevel gears.

In Formula (4.2.2.7.1.1) and later the above sign is for external meshing, the below sign - internal meshing.

The maximum contact stresses at $T_{1\max}$, in MPa, for the pinion teeth are calculated by the formula

$$\sigma_{HO\max 1} = Z_K Z_B Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{w_t}{d_1}\frac{u \pm 1}{u}}, \qquad (4.2.2.7.1.1\text{-}2)$$

for wheel teeth

$$\sigma_{HO\max 2} = \frac{Z_D}{Z_B}\sigma_{HO\max 1},$$

where the parameters involved shall be calculated at $F_t = F_{t\max}$, $K_A = 1{,}0$ and $K_v = 1{,}0$.

4.2.2.7.1.2 The single-pair mesh factors Z_B (Z_D) are used for converting contact stresses at the pitch point to contact stresses at the inner point of single-pair contact of a pinion (wheel) and they are determined as follows:

for spur gears:

$$Z_B = M_1 = \frac{\mathrm{tg}\,\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - \frac{2\pi}{Z_1}\right]\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} \mp (\varepsilon_\alpha - 1)\frac{2\pi}{Z_2}\right]}},$$

where:
ε_α – refer to Formula (4.2.2.7.1.2-11);
if $Z_B < 1$, then $Z_B = 1$;

$$Z_D = M_2 = \frac{\mathrm{tg}\,\alpha_{tw}}{\sqrt{\left[\sqrt{\left(\frac{d_{a2}}{d_{b2}}\right)^2 - 1} \mp \frac{2\pi}{Z_2}\right]\left[\sqrt{\left(\frac{d_{a1}}{d_{b1}}\right)^2 - 1} - (\varepsilon_\alpha - 1)\frac{2\pi}{Z_1}\right]}},$$

if $Z_D < 1$, then $Z_D = 1$;

for helical gears with $\varepsilon_\beta \geq 1$

$$Z_B = Z_D = 1;$$

if $\varepsilon_\beta < 1$

$$Z_B = M_1 - \varepsilon_\beta(M_1 - 1) \geq 1;$$

$$Z_D = M_2 - \varepsilon_\beta(M_2 - 1) \geq 1,$$

where for ε_β refer to Formula (4.2.2.7.1.2-12).

The transverse pressure angle at working pitch cylinder α_{tw} is determined by the equation

$$\operatorname{inv}\alpha_{tw} = \operatorname{inv}\alpha_t + \frac{2(x_2 \pm x_1)\,\mathrm{tg}\alpha_n}{Z_2 \pm Z_1}, \qquad (4.2.2.7.1.2\text{-}1)$$

where inv α = tg$\alpha - \alpha$;
α_t = arctg (tgα_n/cosβ).

Tip diameters of the pinion and wheel are calculated by the equations:
for external gearing

$$d_{a1} = d_1 + 2(h^*_a + x_1 - \Delta y)m_n, \qquad (4.2.2.7.1.2\text{-}2)$$

$$d_{a2} = d_2 + 2(h^*_a + x_2 - \Delta y)m_m; \qquad (4.2.2.7.1.2\text{-}3)$$

for internal gearing

$$d_{a1} = d_1 + 2(h^*_a + x_1 + \Delta y - \Delta y_{02})m_n, \qquad (4.2.2.7.1.2\text{-}4)$$

$$d_{a2} = d_2 - 2(h^*_a - x_2 + \Delta y - k_{x2})m_n, \qquad (4.2.2.7.1.2\text{-}5)$$

In this case, for d_1, refer to Formula (4.2.2.6-1) and

$$d_2 = Z_2\, m_t, \qquad (4.2.2.7.1.2\text{-}6)$$

where for m_t – refer to Formula (4.2.2.6-1);

coefficients of displacement

$$\Delta y = x_2 \pm x_1 - y$$

$$y = (a_w - a)/m_n,$$

where:

$$a_w = a \cos\alpha_t/\cos\alpha_{tw}, \qquad (4.2.2.7.1.2\text{-}7)$$

$$a = 0{,}5(Z_2 \pm Z_1)m_t.$$

coefficients of displacement for cutter and wheel meshing

$$\Delta y_{02} = x_2 - x_0 - y_{02}$$

$$y_{02} = (a_{w02} - a_{02})/m_n$$

where

$$a_{w02} = a_{02}\cos\alpha_t/\cos\alpha_{tw02}, \qquad (4.2.2.7.1.2\text{-}8)$$

$$a_{02} = 0{,}5(Z_2 - Z_0)m_t;$$

$$\operatorname{inv}\alpha_{tw02} = \operatorname{inv}\alpha_t + \frac{2(x_2 - x_0)\,\mathrm{tg}\,\alpha_n}{Z_2 - Z_n}$$

$k_{x2} = 0$ if $x \geq 2$ and $k_{x2} = 0{,}25 - 0{,}125x_2$ if $x_2 < 2$.

Base diameters of the pinion and wheel

$$d_{b1} = d_1\cos\alpha_t; \qquad (4.2.2.7.1.2\text{-}9)$$

$$d_{b2} = d_2\cos\alpha_t. \qquad (4.2.2.7.1.2\text{-}10)$$

Transverse contact ratio

$$\varepsilon_\alpha = \frac{0{,}5\sqrt{d_{a1}^2 - d_{b1}^2} \pm 0{,}5\sqrt{d_{a2}^2 - d_{b2}^2} \pm a_w \sin\alpha_{tw}}{\pi m_t \cos\alpha_t}, \qquad (4.2.2.7.1.2\text{-}11)$$

and overlap ratio

$$\varepsilon_\beta = \frac{b_w \sin\beta}{\pi m_n}. \qquad (4.2.2.7.1.2\text{-}12)$$

4.2.2.7.1.3 The zone factor, which accounts for the tooth flank curvature, is determined by the following formula

$$Z_H = \sqrt{\frac{2\cos\beta_b}{\cos^2\alpha_t \ \mathrm{tg}\alpha_{tw}}},$$

where the helix angle at base cylinder is

$$\beta_b = \arcsin(\sin\beta\cos\alpha_n).$$

4.2.2.7.1.4 The elasticity factor, which accounts for the material properties of the pinion and wheel material is, for all cases, equal to

$$Z_E = \sqrt{\frac{1}{\pi\left(\frac{1-\nu_1^2}{E_1}+\frac{1-\nu_2^2}{E_2}\right)}}.$$

For steel gears ($E_1 = E_2 = 2{,}06 \cdot 10^5$ MPa, $\nu_1 = \nu_2 = 0{,}3$)

$$Z_E = 189{,}8 \text{ MPa}^{0,5}.$$

4.2.2.7.1.5 The contact ratio factor, which accounts for the total contact line, is determined by the following formulae:

for spur gears

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}}; \qquad (4.2.2.7.1.5\text{-}1)$$

for helical gears with $\varepsilon_\beta < 1$

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta)+\frac{\varepsilon_\beta}{\varepsilon_\alpha}}, \qquad (4.2.2.7.1.5\text{-}2)$$

if $\varepsilon_\beta \geq 1$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}}. \qquad (4.2.2.7.1.5\text{-}3)$$

4.2.2.7.1.6 The helix angle factor is

for spur gears:

$$Z_b = (1/\cos\beta)^{0,5}$$

for bevel gears::

$$Z_\beta = (\cos\beta_m)^{0,5}.$$

4.2.2.7.1.7 The application factor K_A, which accounts for externally generated overloads on the gearing, is chosen from Table 4.2.2.7.1.7 in the absence of special procedures for its determination.

Table 4.2.2.7.1.7

Type of gearing	Engine	Type of coupling on input shaft	K_A	$K_{st\,\max}$
Main propulsion	Electric motor	Any type	1	1,1
	Turbine			
	ICE	Hydraulic or equivalent coupling	1	1,1
		High elastic (flexible) coupling	1,3	1,4
		Other types	1,5	1,6
Auxiliary	Electric motor	Any type	1	1,1
	Turbine	Any type	1	1,1
	ICE	Hydraulic or equivalent coupling	1	1,1
		High elastic (flexible) coupling	1,2	1,3
		Other types	1,4	1,5

For ships strengthened for ice navigation, the factor K_A for main gearing is determined as a product of $K_A \cdot K'_A$, where K'_A is obtained from Table 4.2.3.2.

The maximum load T_{1max} shall be determined by one of the following methods:

experimentally;

by dynamic calculation having regard to elastic and dampening characteristics of the system elements, on agreement with the Register;

basing on technical documentation or testing data of devices restricting the limiting value of the torque to be transmitted.

In the absence of the listed data, T_{1max} value may be determined using the maximum load factor $K_{st\,max}$ by the formula

$$T_{1max} = K_{st\,max} \cdot T_{1max\,eff},$$

where:

$T_{1max\,eff}$ – maximum effective torque delivered to the gearing from the engine or actuator (e.g. the maximum torque developed by a driving unit or the windlass shaft torque);

$K_{st\,max}$ – maximum load factor obtained from Table 4.2.2.7.1.7.

4.2.2.7.1.8 For multiple-path transmissions, the load sharing factor K_γ, , which accounts for the maldistribution of load among paths, is equal to 1,15.

For double helical, high power main propulsion gearing the factor K_γ shall be specified with due regard to the maldistribution of load among helices of the gear. In other cases $K_\gamma = 1$.

4.2.2.7.1.9 The dynamic factor K_v, shall be determined by the following formulae:

.1 for spur gears and for helical gears with overlap ratio $\varepsilon_\beta \geq 1$:

$$K_v = 1 + \left(\frac{K_1}{K_A F_t / b} + K_2\right) \frac{v z_1}{100} K_3 \sqrt{u^2/(1+u^2)}.$$

If $K_A F_t / b < 100$ N/mm, this value is assumed to be equal to 100 N/mm.

Numerical values for the factor K_1 shall be as specified in Table.

Table 4.2.2.7.1.9-1

Accuracy grades	K_1 (According to ISO 1328)					
	3	4	5	6	7	8
Spur gears	2,1	3,9	7,5	14,9	26,8	39,1
Helical gears	1,9	3,5	6,7	13,3	23,9	34,8

For all accuracy grades, the values of the factor K_2 shall be in accordance with the following:

for spur gears $K_2 = 0{,}0193$;

for helical gears $K_2 = 0{,}0087$.

The values of the factor K_3 shall be determined as follows:

$$K_3 = 2{,}0 \text{ if } \frac{v z_1}{100} \sqrt{u^2/(1+u^2)} \leqslant 0{,}2$$

$$K_3 = 2{,}071 - 0{,}357 \frac{v z_1}{100} \sqrt{u^2/(1+u^2)} \text{ if } \frac{v z_1}{100} \sqrt{u^2/(1+u^2)} > 0{,}2;$$

.2 for helical gears with overlap ratio $\varepsilon_\beta < 1$ the value of the factor K_v shall be determined by linear interpolation between values determined for spur gears ($K_{v\alpha}$) and helical gears ($K_{v\beta}$) in accordance with:

$$K_v = K_{v\alpha} - \varepsilon_\beta (K_{v\alpha} - K_{v\beta}) \qquad (4.2.2.7.1.9.2)$$

where:

$K_{v\alpha}$ - K_v value for spur gears, in accordance with **4.2.2.7.1.9.1**;

$K_{v\beta}$ - K_v value for helical gears, in accordance with **4.2.2.7.1.9.1.**

This method may be applied only to cases where all the following conditions are satisfied:

running velocity in the subcritical range, i.e.

$$\frac{v z_1}{100} \sqrt{u^2/(1+u^2)} < 10 \text{m/s};$$

spur gears ($\beta = 0°$) and helical gears ($\beta \le 30°$);

pinions with relatively low number of teeth $z_1 < 50$;

solid disc wheels or heavy steel gear rim, and to all types of gears if

$$\frac{vz_1}{100}\sqrt{u^2/(1+u^2)} < 3\text{m/s},$$

((as well as to helical gears where $\beta > 30°$).

The factor K_v, accounting for the internally generated dynamic loads in case where the pinion speed exceeds $0{,}8n_{E1}$, accounting for the internally generated dynamic loads in case where the pinion speed exceeds 4.2.2.7.1.9-2.

For bevel gears with tangent and circular arc teeth with $\varepsilon_{v\beta} \ge 1$ with straight teeth if

$$v_{mt}\frac{Z_1}{100}\sqrt{u^2/\left(1+u^2\right)} \le 3 \text{ m/s}$$

as well as when the gears are made of steel and they have the width of toothing close to the width of disc, $Z_1 < 50$ and

$$v_{mt}\frac{Z_1}{100}\sqrt{u^2/\left(1+u^2\right)} \le 10 \text{ m/s},$$

where: $v_{mt} = \dfrac{d_{m1}n_1}{19098}$

the values of the factor K_v are determined by the equation

$$K_v = 1 + \left(\frac{K_1K_2}{F_t/b_{eH}K_A} + K_3\right)v_{mt}\frac{Z_1}{100}\sqrt{u^2/(1+u^2)}. \qquad (4.2.2.7.1.9.2\text{-}2)$$

The values of K_1, K_2, and K_3 3 shall be obtained from Table 4.2.2.7.1.9-5. Where $F_t/b_{eH}K_A$ <100 N/mm, the value 100 N/mm shall be used.

For bevel gears with $\varepsilon_{\tau\beta} < 1$ K_v the factor Kv is calculated by Formula (4.2.2.7.1.9.2-1) where K_α and K_β – are relevant values of K_v determined by Formula (4.2.2.7.1.9.2-2).

Table 4.2.2.7.1.9-2

Parameter	Notation	Method of determination
1	**2**	**3**
1. Resonance speed of pinion (main resonance) min^{-1}	n_{E1}	$n_{E1} = \dfrac{30 \cdot 10^3}{\pi Z_1}\sqrt{\dfrac{C_\gamma}{m_{red}}}$
1.1 tooth mesh stiffness of a gear pair per unit face width, N/(mm·µm)	C_γ	from Formula (4.2.2.7.1.10-2)
1.2 single tooth mesh stiffness per unit face width, N/(mm·µm)	C	$C = C_\gamma/(0{,}75\varepsilon_\alpha + 0{,}25)$

1.3 reduced mass, kg/mm	m_{red}	$m_{red}=\dfrac{\dfrac{\theta_1}{(d_{b1}/2)^2}\dfrac{\theta_2}{(d_{b2}/2)^2}}{\dfrac{\theta_1}{(d_{b1}/2)^2}+\dfrac{\theta_2}{(d_{b2}/2)^2}}\cdot\dfrac{1}{b_w}$, where: θ1 i θ2 – mass moments of inertia about axis of rotation of the pinion and gear, kg·mm^2 . For approximate calculations, the reduced mass may be determined from the formula $m_{red} = 3{,}25\cdot10^{-6}\ d_2^2/(u^2 + 1)$. If an additional mass is added to the pinion with a moment of inertia of γ times greater than that of the pinion $m_{red} = 3{,}25\cdot10^{-6}\ d_2^2\ (1 + \gamma)/(u^2 + 1+ \gamma)$.
2. Relative proximity between actual speed and resonance speed	n_1/n_{E1}	Depending on the ratio n_1/n_{E1} 4 zones are identified, namely: *а*) n_1/n_{E1}<0,85 – subcritical zone determined according to **4.2.2.7.1.9**; *б*) 0,85 ≤ n_1/n_{E1}≤ 1,15 – critical zone determined according to item 3 of this Table; *в*) 1,15 < n_1/n_{E1}< 1,5 – intermediate zone determined according to item 5 of the Table; *г*) n_1/n_{E1}≥ 1,5 – intermediate zone determined according to item 5 of the Table.
3. Factor accounting for the dynamic loads generated in the critical zone	K_v	From the formula $K_v = 1 + C_{v1}B_p + C_{v2}B_f + C_{v4}B_k$, where: C_{v1} , C_{v2} and C_{v4} are determined from Table4.2.2.7.1.9-3
3.1 factor accounting for pitch error, running-in and tooth loading influence	B_p	From the formula $B_p = \dfrac{C'(f_{pb} - y_\alpha)}{(F_t/b_w)K_AK_\gamma}$, where: f_{pb} – pitch error (if not specified, the permissible value of f_{pbr} shall be taken), µm; y_a – reduction in pitch error due to runningin, mm, determined according to **4.2.2.7.1.11.**
3.2 factor accounding for profile error, runningin and tooth loading influence	B_f	From the formula $B_f = \dfrac{C'(f_f - y_\alpha)}{(F_t/b_w)K_AK_\gamma}$, where: f_f – profile error (if not specified, the permissible value of f_{fr} shall be taken), µm.
3.3 factor accounting for tip relief influence	B_k	From the formula $B_k = \left\|1 - \dfrac{C'C_a}{(F_t/b_w)K_AK_\gamma}\right\|$, where: C_a=1,5 + [(σ/97 – 18,45)^2 /18] *Note.* If gears are made of different materials $C_a = (C_{a1} + C_{a2})/2$
4. Factor accounting for dynamic loads generated in the supercritical zone	K_v	From the formula $K_v = C_{v5}B_p + C_{v6}B_f + C_{v7}$, where: C_{v5}, C_{v6} and C_{v7} are determined from Tables 4.2.2.7.1.9-3 and 4.2.2.7.1.9-4

5. Factor accounting for dynamic loads generated in the intermediate zone	K_v	Kν is determined by linear interpolation between the values in the critical zone for $n_1 = 1{,}15n_{E1}$ according to item 3 of the Table and in the supercritical zone for $n_1 = 1{,}15n_{E1}$ according to item 5 of the Table: $K_v = K_{v(n_1=1{,}15n_{\varepsilon1})} + \frac{K_{v(n_1=1{,}15n_{\varepsilon1})}}{0{,}35}\left(1{,}5 - \frac{n_1}{n_{E1}}\right) - \frac{K_{v(n_1=1{,}15n_{\varepsilon1})}}{0{,}35}\left(1{,}5 - \frac{n_1}{n_{E1}}\right)$

Table 4.2.2.7.1.9-3

Factor	Total contact ratio	
	$1 < \varepsilon_\gamma \le 2$	$\varepsilon_\gamma > 2$
C_{v1}	0,32	0,32
C_{v2}	0,34	$\frac{0{,}57}{\varepsilon_\gamma - 0{,}30}$
C_{v4}	0,90	$\frac{0{,}57 - 0{,}05\varepsilon_\gamma}{\varepsilon_\gamma - 1{,}44}$
C_{v5}	0,47	0,47
C_{v6}	0,47	$\frac{0{,}12}{\varepsilon_\gamma - 1{,}74}$

Table 4.2.2.7.1.9-4

Factor	Total contact ratio		
	$1 < \varepsilon_\gamma \le 1{,}5$	$1{,}5 < \varepsilon_\gamma < 2{,}5$	$\varepsilon_\gamma \ge 2{,}5$
C_{v7}	0,75	$0{,}125\sin[\pi(\varepsilon_\gamma - 2)] + 0{,}875$	1,0

Table 4.2.2.7.1.9-5

Type of tooth	K_1							K_2	K_3
	3	4	5	6	7	8	9	3–9	
Straight	2,19	3,18	7,49	15,34	27,02	58,43	106,64	1,0645	0,0193
Tangent and circular								1,0000	0,0100

4.2.2.7.1.10 The face load distribution factor, which accounts for the effect of non-uniform distribution of load along the face width, is defined as follows

$$K_{H\beta} = 1 + \frac{F_{\beta y} C_\gamma}{2 w_t K_A K_\gamma K_v}, \qquad (4.2.2.7.1.10\text{-}1)$$

where:
$F_{\beta y}$ – in µm,
C_g – in N/mm·µm).

$F_{\beta y}$ is estimated by means of the relationships:

$$F_{\beta y} = F_{\beta x} - y_\beta;$$
$$F_{\beta x} = 1{,}33 f_{sh} + f_{ma};$$
$$f_{sh} = f_{sho} w_t K_A K_\gamma K_v.$$

In all cases f_{sho} accounts for the bending and torsion deformation of pinion and wheel and depends on many factors.

If the wheel is placed symmetrically close between the seats:
$f_{sho} = 2{,}3\gamma_H \cdot 10^{-2}$ (µm·mm)/N – for the gearing without helix correction and without end relief;
$f_{sho} = 1{,}6\gamma_H \cdot 10^{-2}$ (µm·mm)/N – for the gearing without helix correction, but with end relief

where: $\gamma_H = (bw/d_1)^2$ – for the helical and spur gearing;

$\gamma_H = 3(b_w/2d_1)^2$ – for the double helical gearing (b_w – w is the total active face width);

For the gearings with helix correction, the following minimum values shall be applied:

$f_{sho} = 5\cdot10^{-3}$ (μm·mm)/N – for the spur gearing;

f_{sho}=1,3·10^{-2} (μm·mm)/N – for the helical gearing;

the last values of f_{sho} are minimum design values for all cases.

For all the types of gearing without helix correction

$$f_{ma} = 2F_\beta / 3,$$

but for the gearing with helix correction

$$f_{ma} = F_\beta / 3,$$

where: F_β – =the greatest value of $F_{\beta1}$ and $F_{\beta2}$ for pinion and wheel respectively.

In the case of contact of steel through-hardened teeth and the contact of surface hardened with throughhardened teeth,

$$y_\beta = \frac{320}{\sigma_{H\,lim}} F_{\beta x}$$

where: for $\sigma_{H\,lim}$ – In the case of contact of steel through-hardened teeth and the contact of surface hardened with throughhardened teeth **4.2.2.7.2.1**.

If $v \le 5$ m/s, the maximum value of y_β is not limited.

With 5 m/s < $v \le 10$ m/s

$$y_\beta = \frac{25800}{\sigma_{Hlim}}.$$

When $v > 10$ m/s,

$$y_\beta = \frac{12800}{\sigma_{Hlim}}.$$

For surface-hardened and nitrided teeth

$$y_\beta = 0{,}15F_{\beta x},$$

At any speed y_β shall not exceed 6 μm.

If the pinion and wheel teeth are surface-hardened by different procedures

$$y_\beta = 0{,}5(y_{\beta1} + y_{\beta2}),$$

where: $y_{\beta1}$ and $y_{\beta2}$ are the values for pinion and wheel, respectivel.

The tooth mesh stiffness of a gear pair is calculated by the following formula

$$C_\gamma = \frac{(1+3\varepsilon_\alpha)}{q'} C_{BS} \cos\beta,$$

where:

$$C_{BS} = [1 + 0{,}5(0{,}2 - c^*)][1 - 0{,}02(20 - \alpha_n)];$$

$$q' = 0{,}23615 + \frac{0{,}7755}{Z_{v1}} + \frac{1{,}28955}{Z_{v2}} - 0{,}03175x_1 - \frac{0{,}5827x_1}{Z_{v1}} - 0{,}00965x_2 - \frac{1{,}2094x_2}{Z_{v2}} + 0{,}02645x_1^2 + 0{,}0091x_2^2;$$

$$Z_{v1} = \frac{Z_1}{\cos^2\beta_b \cos\beta};\quad Z_{v2} = \frac{Z_2 Z_{v1}}{Z_1}. \qquad (4.2.2.7.1.10\text{-}2)$$

For the internal gearing $Z_{v2} = \infty$.

If $(F_t / b_w)K_A < 100$ N/mm,

$$C_{\gamma} = \frac{(1+3\varepsilon_{\alpha})}{q'} C_{BS} \cos\beta \frac{(F_t / b_w) K_A}{100}.$$

For the cylindrical helical gears, by virtue of polar stress concentration (variability of stiffness along the contact line) $K_{H\beta} \geq 1{,}2$ shall apply.

For bevel gears, the factor $K_{H\beta}$ shall be determined by the following formula

$$K_{H\beta} = 1{,}5 K_{H\beta be},$$

where for $K_{H\beta be}$ refer to Table 4.2.2.7.1.10.

Table 4.2.2.7.1.10

Neither pinion nor wheel overhung when mounted	One of the wheels overhung when mounted, other between seats	Both pinion and wheel overhung when mounted
1,1	1,20	1,5

4.2.2.7.1.11 The transverse load distribution factor $K_{H\alpha}$ for the simultaneously contacting teeth paris may be determined by one of the formulae:

with $\varepsilon_{\gamma} \leq 2$

$$K_{H\alpha} = \varepsilon_{\alpha}(0{,}45 + K_4), \qquad (4.2.2.7.1.11\text{-}1)$$

with $\varepsilon_{\gamma} > 2$

$$K_{H\alpha} = 0{,}9 + 2K_4 \sqrt{\frac{2(\varepsilon_{\gamma} - 1)}{\varepsilon_{\gamma}}}, \qquad (4.2.2.7.1.11\text{-}2)$$

where:

$$K_4 = \frac{C_{\gamma}(f_{pb} - y_{\alpha})}{5 w_{tH}};$$

$$w_{tH} = w_t K_A K_{\gamma} K_v K_{H\beta};$$

f_{pb} – is equal to the maximum of f_{pb1} or f_{pb2} for the pinion and wheel, respectively;
if $f_{pb} < f_f$, f_{pb} is substituted by the maximum value of f_{f1} or f_{f2};
for gears with tip relief, 0,5 f_{pb} can be introduced,

$$\varepsilon_{\gamma} = \varepsilon_{\alpha} + \varepsilon_{\beta}, \qquad (4.2.2.7.1.11\text{-}3)$$

where:
ε_{α} – refer to Formula (4.2.2.7.1.2-11);
ε_{β} – refer to Formula (4.2.2.7.1.2-12).

For through-hardened teeth

$$y_{\alpha} = \frac{160}{\sigma_{H\lim}} f_{pb},$$

With $v \leq 5$ m/s, the maximum value of y_{α} is not limited.

If 5 m/s $< v \leq 10$ m/s, the maximum value is limited by the condition

$$y_{\alpha} \leq \frac{12800}{\sigma_{H\,lim}};$$

with $v > 10$ m/s

$$y_{\alpha} \leq \frac{6400}{\sigma_{H\,lim}}.$$

For surface-hardened or nitrided teeth

$$y_{\alpha} = 0{,}075 f_{pb},$$

At any speed y_{α} shall not exceed 3 μm.

If the pinion and wheel teeth are surface-hardened by different procedures

$$y_\alpha = 0{,}5(y_{\alpha 1} + y_{\alpha 2}),$$

where:
$y_{\alpha 1}$ –for the pinion;
$y_{\alpha 2}$ – for the wheel.

The rated values of $K_{H\alpha}$ are limited by the condition

$$1 \le K_{H\alpha} \le \frac{\varepsilon_\gamma}{\varepsilon_\alpha Z_\varepsilon^2},$$

where:
ε_γ is determined by Formula (4.2.2.7.1.11-3);
Z_ε is determined by one of Formulae (4.2.2.7.1.5-1)– (4.2.2.7.1.5-3).

4.2.2.7.2 The permissible contact stresses for pinion and wheel are determined by the following formula

$$\sigma_{Hp} = \frac{\sigma_{H\,lim} Z_N}{S_{H\min}} Z_L Z_v Z_R Z_W Z_X, \qquad (4.2.2.7.2)$$

where:
for $\sigma_{H\,lim}$ – refer to **4.2.2.7.2.1**;
for Z_H – refer to **4.2.2.7.2.2**;
for $S_{H\,\min}$ – refer to **4.2.2.7.2.3**;
for Z_L – refer to **4.2.2.7.2.4**;
for Z_v – refer to **4.2.2.7.2.5**;
for Z_R – refer to **4.2.2.7.2.6**;
for Z_W – refer to**4.2.2.7.2.7**;
for Z_X – refer to **4.2.2.7.2.8**.

The permissible contact stresses at maximum load are determined by the following formula

$$\sigma_{HP\max} = \frac{\sigma_{H\,\lim} Z_N}{S_{HST}} Z_W,$$

where: S_{HST} – refer to **4.2.2.7.2.3**.

4.2.2.7.2.1 In the absence of test results, the endurance limits for contact stress $\sigma_{H\,lim}$ shall be taken from Table 4.2.2.7.2.1.

Table 4.2.2.7.2.1

Thermal or chemical and thermal treatment of teeth		σ_{Hlim}, MPa
Pinion	Wheel	
Through-hardened	Through-hardened	$0{,}46\sigma_{B2}$+255
Surface-hardened		$0{,}42\sigma_{B2}$+415
Carburized, induction-hardened or nitrided	Soft-bath nitrided	1000
	Induction-hardened	$0{,}88HV_2$+675
Carburized or nitrided	Nitrided	1300
Carburized		1500
Note. With the number of cycles of at least $5 \cdot 10^7$, the values of $\sigma_{H\,lim}$ correspond to a failure probability of 1 % or less. The criterion, which accounts for $\sigma_{H\,lim}$, is the pitting damage of not less than 2 % for the total active flank area without surface-hardening and not less than 5 % for that with surface-hardening.		

4.2.2.7.2.2 For ahead running, the life factor Z_N = 1.
For astern running and in other cases of a limited life Z_N is recommended to take as 1,1.
At the maximum load $T_{1\max}$ the life factor Z_N is equal to:
1,6 – for through-hardened or surface-hardened steel;
1,3 – for gas-nitrided steel;
1,1 – for bath-nitrided steel.
4.2.2.7.2.3 The minimum safety factors for contact stress $S_{H\min}$, for bending stress $S_{F\min}$, for static strength of contact teeth surfaces S_{HST} and for bending teeth strength S_{FST} are taken from Table 4.2.2.7.2.3.

Table 4.2.2.7.2.3

Type of gearing	Type of ship	$S_{H\min}$	$S_{F\min}$	S_{HST}[1]	S_{FST}[1]
Main propulsion	All ships except pleasure craft	1,4	1,8	1,4	1,8
	Single-screw pleasure craft	1,25	1,5	1,25	1,5
	Multiple-screw pleasure craft	1,2	1,45	1,2	1,45
Auxiliary	All ships	1,15	1,4	1,1÷1,35[2]	1,4÷1,7[2]

[1] For forged or hot rolled steel wheels. For rolled blanks these values shall be increased by 15 %, for castings _ by 30 %.

[2] The maximum values for gearing, the failure of which could have grave consequences.

Note. By pleasure craft are meant ships up to 24 m in length not engaged in trade and passenger carriage or not intended for charter service.

4.2.2.7.2.4 The lubricant factor, which accounts for the effect of lubricant viscosity, is determined by one of the formulae:

$$Z_L = C_{ZL} + \frac{1 - C_{ZL}}{\left(0{,}6 + \frac{40}{v_{50}}\right)^2}$$

or

$$Z_L = C_{ZL} + \frac{1 - C_{ZL}}{\left(0{,}6 + \frac{67}{v_{40}}\right)^2};$$

With 850 MPa ≤ $\sigma_{H\,lim}$ ≤ 1200 MPa

$$C_{ZL} = 0{,}83 + 0{,}08\left(\frac{\sigma_{H\,lim} - 850}{350}\right)$$

4.2.2.7.2.5 The speed factor, which accounts for the linear speed effect, is determined by the following formula

$$Z_v = C_{Zv} + \frac{1 - C_{Zv}}{\sqrt{0{,}2 + 8/v}}.$$

With 850 MPa ≤ σ_{Hlim} ≤ 1200 MPa

$$C_{Zv} = C_{ZL} + 0{,}02.$$

4.2.2.7.2.6 The roughness factor accounting for the effects of surface roughness is determined by the following formula

$$Z_R = (3/R_{Z100})^{CZR}.$$

The condition $Z_R \le 1{,}15$ shall be considered.

R_{Z100} is determined by means of equations:

$$R_{Z100} = R_Z\sqrt[3]{100/a_w};$$

$$R_Z \cong 6R_a;$$

$$R_a = 0{,}5(R_{a1} + R_{a2}).$$

With 850 MPa ≤ σ_{Hlim} ≤ 1200 MPa

$$C_{ZR} = 0{,}12 + \frac{1000 - \sigma_{H\,lim}}{5000}$$

If σ_{Hlim} < 850 MPa:

$$C_{ZL} = 0{,}83;\ C_{Zv} = 0{,}85;\ C_{ZR} = 0{,}15,$$

and if σ_{Hlim} > 1200 MPa:

$$C_{ZL} = 0{,}91;\ C_{Zv} = 0{,}93;\ C_{ZR} = 0{,}08.$$

4.2.2.7.2.7 The hardness ratio factor, which accounts for the increase of surface durability of teeth of lower hardness when meshing with surface-hardened smooth teeth (R_Z < 6 μm) is determined by the following formula:

.1 surface-hardened pinions with through-hardened wheels:

$$Z_w=1{,}23(3/R_{zH})^{0{,}15} \text{ if } HB < 130;$$

$$Z_w=\{1{,}2-[(HB-30)/1700]\}\ (3/R_{zH})^{0{,}15} \text{ if } 130 \le HB \le 470;$$

$$Z_w= (3/R_{zH})^{0{,}15} \text{ if } HB > 470,$$

where:

HB – Brinell hardness of the tooth flanks of the softer gear of the pair;

R_{zH} – equivalent roughness, μm;

$R_{zH} = R_{z1}(10/\rho_{red})^{0{,}33}\ (R_{z1}/R_{z2})^{0{,}66}/(\nu v_{40}/1500)^{0{,}33}$;

ρ_{red} – relative radius of curvature;

$\rho_{red}\ = \rho_{red}\ \rho_{red}(\rho_1+\rho_2)$, $\rho_{1,2}=0{,}5db_{1,2}\,\mathrm{tg}\alpha_{tw}$;

.2 through-hardened pinions and wheels:

when the pinion is substantially harder than the wheel, the work hardening effect increases the load capacity of the wheel flanks.

The factor Z_W applies to the wheel only:

$$Z_W=1, \text{ якщо } HB_1/HB_2< 1{,}2;$$

$$Z_W=1+[(0{,}00898\ HB_1/HB_2)- 0{,}00829)\ (u-1)]\ , \text{ if } 1{,}2 \le\ HB_1/HB_2\le 1{,}7;$$

$$Z_W=1+0{,}00829\ (u-1)\ , \text{ if } HB_1/HB_2 >\ 1{,}7.$$

If gear ratio u > 20, then the value u = 20 shall be used.

In any case, if calculated Z_W < 1 then the value Z_W=1 shall be used.

4.2.2.7.2.8 The size factor Z_X, which accounts for the effect of tooth size, is chosen from Table 4.2.2.7.2.8

Table 4.2.2.7.2.8

Thermal or chemical and thermal treatment of pinion teeth	Module, mm	Z_X
Carburizing or surface-hardening	$m_n \le 10$ $10 < m_n < 30$ $m_n \ge 30$	1 $1{,}05 - 0{,}005m_n$ 0,9
Nitriding	$m_n \le 7{,}5$ $7{,}5 < m_n < 30$ $m_n \ge 30$	1 $1{,}08 - 0{,}011m_n$ 0,75
Through-hardening	–	1

4.2.2.7.3 The rated values of bending stress in the critical section, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula

$$\sigma_F = \sigma_{FO} K_A K_\gamma K_{F\beta} K_{F\alpha}, \quad (4.2.2.7.3)$$

where:

for σ_{FO} – refer to **4.2.2.7.3.1**;

for K_A – refer to **4.2.2.7.1.7**;

for K_γ – refer to **4.2.2.7.1.8**;

for K_v – refer to **4.2.2.7.1.9**;

for $K_{F\beta}$ – refer to **4.2.2.7.3.5**;

for $K_{F\alpha}$ – refer to **4.2.2.7.3.6**.

The rated values of maximum bending stresses $\sigma_{F\max}$, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula

$$\sigma_{Fmaf} =\sigma_{Fomax}\ K_\gamma\ K_{F\beta}\ K_{F\alpha},$$

where: for $\sigma_{FO\max}$ – refer to **4.2.2.7.3.1**.

4.2.2.7.3.1 Bending stress under nominal loading

$$\sigma_{FO}= F_t Y_F Y_s Y_\beta Y_B Y_{DT}/\tau b m_n, \qquad (4.2.2.7.3.1)$$

where:
for b and m_n – refer to **4.2.2.5**;
for F_t – refer to **4.2.2.6**;
for τ – refer to **4.2.2.7.1.1**;
for Y_F – refer to **4.2.2.7.3.2**;
for Y_s – refer to **4.2.2.7.3.3**;
for Y_β – refer to **4.2.2.7.3.4**;
Y_B – rim thickness factor, refer to **4.2.2.7.3.8**;
Y_{DT}– deep tooth factor, refer to **4.2.2.7.3.9**.

The maximum bending stresses at $T_{1\max}$, in MPa, are calculated separately for the pinion teeth and wheel teeth by the following formula

$$\sigma_{FO\max} = \frac{F_{t\max}}{\tau b m_n} Y_F Y_S Y_\beta .$$

The values of the parameters involved shall be determined at $F_t = F_{t\max}$, $K_A = 1{,}0$ and $K_v = 1{,}0$.

4.2.2.7.3.2 The tooth form factor applied to the external gears, for $\alpha \le 25^\circ$ and $\beta \le 30^\circ$ 8 is calculated by the formula:

$$Y_F = \frac{6h_F^* \cos\alpha_{en}}{\left(S_{Fn}^*\right)^2 \cos\alpha_n} ,$$

where: $h_F^* = h_{Fe}/m_n$, $S^*_{Fn} = S_{Fn}/m_n$;
for h_{Fe}, S_{Fn}, α_{en} – refer to Fig. 4.2.2.7.3.2-1.

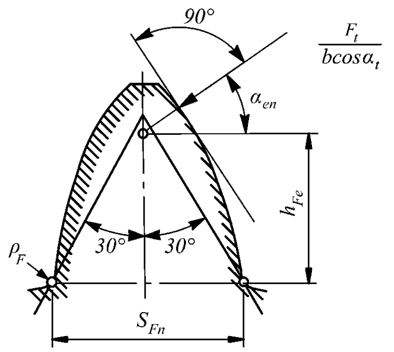


Fig. 4.2.2.7.3.2-1 Illustration to the definition of Y_F for external tooth

To determine h_F^* and s_{Fn}^* the following equation shall be used

$$p_{bt} = \pi m_t \cos\alpha_t ,$$

where: α_t is determined by Formula (4.2.2.7.1.2-1);

and

$$d_e = 2\sqrt{\left[p_{bt}\left(1-\varepsilon_\alpha\right)+0{,}5\sqrt{d_a^2-d_b^2}\,\right]^2 + \left(0{,}5 d_b\right)^2}$$

where:
ε_α is determined by Formula (4.2.2.7.1.2-11);
d_a and d_b for the pinion are determined by Formulae (4.2.2.7.1.2-2), (4.2.2.7.1.2-9), and for the wheel, from Formulae (4.2.2.7.1.2-3), (4.2.2.7.1.2-10).

$$\alpha_e = \arccos\left(d_b / d_e\right);$$

$$\gamma_e = \frac{1}{Z}\left(\frac{\pi}{2} + 2x\,\mathrm{tg}\,\alpha_n + 2x_{sm}\right) + \mathrm{inv}\,\alpha_t - \mathrm{inv}\,\alpha_e;$$

$$\alpha_{et} = \alpha_e - \gamma_e ;$$

$$G = \rho_{a0}^* - h_{a0}^* + x ,$$

where:

$\boldsymbol{\rho^*_{a0} = \rho_{a0}/m_n,\ h^*_{a0} = h_{a0}/m_n = h^*_a + c^*}$;

for ρ_{a0} and h_{a0} – refer to Fig. 4.2.2.7.3.2-2; Fig. 4.2.2.7.3.2-3;

x_{sm} is equal to zero for cylindrical gears, as to bevel gears, refer to **4.2.7.6**;

$$e = \frac{\pi}{4} m_n - m_n x_{sm} - h_{a0} \operatorname{tg} \alpha_n + h_k (\operatorname{tg} \alpha_n - \operatorname{tg} \alpha_0) - \frac{(1 - \sin \alpha_0)}{\cos \alpha_0} \rho_{a0},$$

where for h_{a0} and α_0 – refer to Fig. 4.2.2.7.3.2-3;

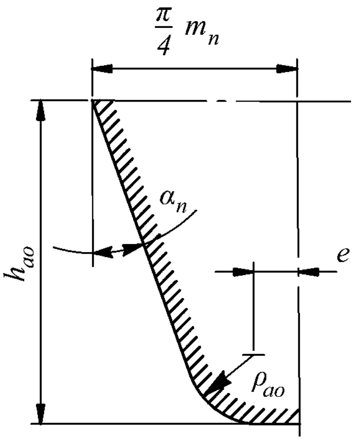


Fig. 4.2.2.7.3.2-2. Non-protuberance hob

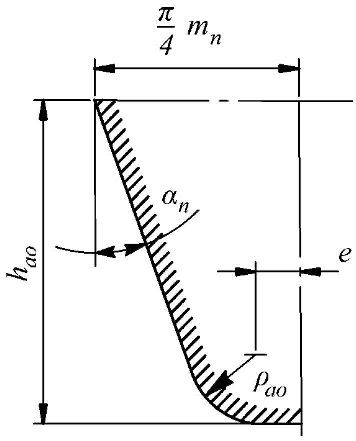


Fig. 4.2.2.7.3.2-3. Non-protuberance hob

when the tool has no protuberance

$$h_k = 0,\ \alpha_0 = \alpha_n;$$

$$H = \frac{2}{Z_v}\left(\frac{\pi}{2} - \frac{e}{m_n}\right) - \frac{\pi}{3},$$

where: Z_v is determined by Formula (4.2.2.7.1.10-2);

$$\psi = \frac{2G}{Z_v} \operatorname{tg}\psi - H;$$

when solving this equation as an approximation take $\psi = \pi/6$;

$$\beta_e = \operatorname{arctg}\left(\frac{d_b}{d \cos \alpha_{et}} \operatorname{tg} \beta\right),$$

where: d for the pinion is determined by Formula (4.2.2.7.1.2-6); and for the wheel, by Formula (4.2.2.7.1.2-6);

$$\alpha_{en} = \operatorname{arctg}(\operatorname{tg} \alpha_{et} \cos \beta_e);$$

$$S^*_{Fn} = Z_v \sin\left(\frac{\pi}{3} - \psi\right) + \sqrt{3}\left(\frac{G}{\cos\psi} - \rho^*_{a0}\right);$$

$$h^*_F = \frac{1}{2}\left\{\frac{Z}{\cos\beta}\left(\frac{\cos\alpha_t}{\cos\alpha_{et}} - 1\right) + Z_v\left[1 - \cos\left(\frac{\pi}{3} - \psi\right)\right] - \frac{G}{\cos\psi} + \rho^*_{a0}\right\}.$$

In the case of internal gearing,

$$Y_F = \frac{6 h^*_{F2} \cos \alpha_{en}}{\left(S^*_{Fn2}\right)^2 \cos \alpha_n}$$

To determine $h^*_{F2} = h_{F2}/m_n$ i $S^*_{Fn2} = S_{Fn2}/m_n$, (h_{F2} and S_{Fn2} – refer to Fig. 4.2.2.7.3.2- 4.) the following equations are calculated:

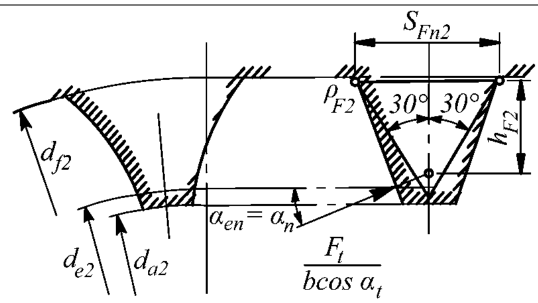


Fig.4.2.2.7.3.2-4. Illustration to the definition of Y_F for internal tooth

$$d_{f_2} = 2a_{w02} + d_{a_0},$$

where: a_{w02} is determined by Formula (4.2.2.7.1.2-8);

$$h^*_{a_{02}} = h_{a_{02}} / m_n = \left(d_{f_2} - d_2\right) / 2m_n;$$

$$c = 0{,}5\left(d_{f_2} - d_{a_1}\right) - a_w,$$

where:
d_{a1} is determined by Formula (4.2.2.7.1.2-4);
α_w is determined by Formula (4.2.2.7.1.2-7);

$$\rho^*_{a_{02}} = \frac{c}{m_n\left(1 - \sin\alpha_n\right)};$$

$$d_{e_2} = 2\sqrt{\left[-p_{bt}(1-\varepsilon_\alpha) + 0{,}5\sqrt{d^2_{a_2} - d^2_{b_2}}\;\right]^2 + \left(0{,}5 d_{b_2}\right)^2},$$

where: d_{a2} is determined by Formula (4.2.2.7.1.2-5);

$$h^*_{F_2} = \frac{d^*_{f_2} - d^*_{e2}}{2\cos^2 a_n} - \left(\frac{\pi}{4} + h^*_{a_{02}} \operatorname{tg}\alpha_n\right)\operatorname{tg}\alpha_n - 0{,}5\rho^*_{a_{02}};$$

$$S^*_{Fn_2} = \frac{2(\rho^*_{a_{02}} - \delta^*_0)}{\cos\alpha_n} + 2(h^*_{a_{02}} - \rho^*_{a_{02}})\operatorname{tg}\alpha_n - \sqrt{3}\rho^*_{a_{02}} + 0{,}5\pi,$$

where: $d^*_{f2} = d_{f2}/m_n$, $d^*_{e2} = d_{e2}/m_n$, $\delta^*_0 = \delta_0 / m_n$.

$$\delta_0 = \left[\frac{h_k - \rho_{a0}\left(1 - \sin\alpha_0\right)}{\cos\alpha_0}\right]\sin\left(\alpha_n - \alpha_0\right),$$ refer to Fig. 4.2.2.7.3.2-3.

If α_m=20°

$$h^*_{F_2} = 0{,}56624(d^*_{f_2} - d^*_{e_2}) - 0{,}13247 h^*_{a_{02}} - 0{,}5\rho^*_{a_{02}} - 0{,}28586;$$

$$S^*_{Fn_2} = 0{,}72794 h^*_{a_{02}} - 0{,}33163\rho^*_{a_{02}} + 0{,}939698\delta^*_0 + 1{,}5708.$$

4.2.2.7.3.3 The stress correction factor, which accounts for stress concentration, is determined by the following formula

$$Y_S = \left(1{,}2 + 0{,}13L\right) q_S^{\left(\frac{1}{1{,}21 + 2{,}3/L}\right)}.$$

In the case of external gearing,

$$L = \frac{S^*_{Fn}}{h^*_F};\quad q_S = \frac{S^*_{Fn}}{2\rho^*_F}, \qquad (4.2.2.7.3.3\text{-}1)$$

where:

$$\rho^*_F = \rho^*_{a_0} + \frac{2G^2}{\left(Z_v\cos^2\psi - 2G\right)\cos\psi}$$

In the case of internal gearing,

$$L = \frac{S^*_{Fn_2}}{h^*_{F_2}}; \quad q_s = \frac{S^*_{Fn_2}}{\rho^*_{a_{02}}}. \qquad (4.2.2.7.3.3\text{-}2)$$

In case of external and internal gearing the following condition shall be met

$$1 \le q_s < 8.$$

For equivalent cylindrical gears of bevel gearing, the expression $Y_F Y_S$ shall be substituted for the product $Y_{FA} Y_{SA}\ Y_{F\varepsilon}$, in Formula (4.2.2.7.3.1) where Y_{FA} and Y_{SA} are determined on the basis of relationships valid for Y_F and Y_S , in which the index e at the parameters is replaced by the index a corresponding to the pressure angle in case of load application to the tooth tip; $Y_\varepsilon = 0{,}25 + 0{,}75/\varepsilon_{v\alpha}$.

For standard basic racks Y_{FA} and Y_{SA} may be determined on the basis of special diagrams.

4.2.2.7.3.4 The helix angle factor is determined as follows

$$Y_\beta = 1 - \varepsilon_\beta \frac{\beta}{120},$$

where:

for ε_β – refer to Formula (4.2.2.7.1.2-12);

β is in degrees; if $\varepsilon_\beta > 1$, then $\varepsilon_\beta = 1$ shall be introduced.

The minimum value of Y_β is limited by the condition

$$Y_\beta = 1 - 0{,}25\varepsilon_\beta \ge 0{,}75.$$

4.2.2.7.3.5 The factor $K_{F\beta}$ is determined by the relationship

$$K_{F\beta} = (K_{H\beta})^N,$$

where: $K_{H\beta}$ b is determined by Formula (4.2.2.7.1.10-1);

$$N = \frac{(b/h)^2}{1 + b/h + (b/h)^2}. \quad (4.2.2.7.3.5)$$

The lowest value of b_1/h and b_2/h, is taken when solving Formula (4.2.2.7.3.5), and in the case of double helical gears b/2 shall be substituted for b;

$h = (2h^*_a + c^*)m_n - \Delta y m_n$ is the tooth depth. When $b/h < 3$, the value b/h=3 shall be used.

For cylindrical gears with end relief and crowning and for bevel gears, $N = 1$ shall be used.

4.2.2.7.3.6 The design values of $K_{F\alpha} = K_{H\alpha}$, where $K_{H\alpha}$ is determined by Formulae (4.2.2.7.1.11-1) or (4.2.2.7.1.11-2), shall satisfy the condition

$$1 \le K_{F\alpha} \le \frac{\varepsilon_\gamma}{0{,}25\varepsilon_\alpha + 0{,}75}.$$

4.2.2.7.3.7 Where gear-cutting tools other than standard tools are used, it is recommended that the parameters S_{Fn}, ρ_F and h_{Fe} be determined using the actual tooth profile.

4.2.2.7.3.8 The rim thickness factor, Y_B, is a simplified factor used to de-rate thin rimmed gears and shall be determined:

.1 for external gears:

$$Y_B = 1, \text{ if } s_R/h \ge 1{,}2;$$

$$Y_B = 1{,}6 \times \ln(2{,}242h/s_R), \quad \text{if} \quad 0{,}5 < s_R/h < 1{,}2,$$

where:

s_R – rim thickness of external gears, in mm;

h – tooth height, in mm.

The case $s_R/h \le 0{,}5$ shall be avoided;

.2 for internal gears:

$$Y_B = 1, \text{ if } s_R/m_n \ge 3{,}5;$$

$$Y_B = 1{,}6 \times \ln(8{,}32\ m_n/s_R), \quad \text{if} \quad 1{,}75 < s_R/m_n < 3{,}5,$$

where: s_R – rim thickness of internal gears, in mm.

The case $s_R/m_n \le 1{,}75$ shall be avoided.

For critically loaded applications, this method shall be replaced by a more comprehensive analysis.

4.2.2.7.3.9 The deep tooth factor Y_{DT} adjusts the tooth root stress to take into account high precision gears and contact ratios within the range of virtual contact ratio

$$2{,}05 \le \varepsilon_{\alpha n} \le 2{,}5,$$

where: $\varepsilon_{\alpha n} = \varepsilon_{\alpha} / \cos^2\beta_b$.

The factor Y_{DT} shall be determined:

.1 if accuracy grade Q ≤ 4 and $\varepsilon_{\alpha n} > 2{,}5$

$$Y_{DT} = 0{,}7;$$

.2 if accuracy grade Q ≤ 4 and $2{,}05 < \varepsilon_{\alpha n} \le 2{,}5$

$$Y_{DT} = 2{,}366 - 0{,}666\varepsilon_{\alpha n};$$

.3 in all other cases $Y_{DT} = 1{,}0$.

4.2.2.7.4 The permissible bending stresses for the pinion and wheel teeth are calculated separately by the formula

$$\sigma_{FP} = \sigma_{Flim} Y_{ST} Y_N\, Y_{RrelT}\, Y_{\delta relT} Y_X / S_{F\min} Y_D, \quad (4.2.2.7.4)$$

where:
for $\sigma_{F\,lim}$ – refer to **4.2.2.7.4.1**;
for Y_{ST} – refer to **4.2.2.7.4.2**;
for Y_N – refer to **4.2.2.7.4.3**;
for Y_D – refer to **4.2.2.7.4.4**;
for $Y_{\delta relT}$ – refer to **4.2.2.7.4.5**;
for Y_{RrelT} – refer to **4.2.2.7.4.6**;
for Y_X – refer to **4.2.2.7.4.7**;
for $S_{F\min}$ – refer to **4.2.2.7.2.3**.

The permissible bending stresses for the pinion and wheel teeth under the maximum load are calculated by the formula

$$\sigma_{FP\max} = \sigma_{Flim} Y_{ST} Y_N\, Y_{\delta relT} / S_{FST} Y_D$$

4.2.2.7.4.1 1 In the absence of test data, the values of endurance limit of teeth in bending are taken from Table 4.2.2.7.4.1.

Table 4.2.2.7.4.1

Thermal or chemical and thermal treatment of teeth	σ_{Flim}, MPa	Y_N
1	**2**	**3**
Through hardened carbon steel	$0{,}09\sigma_B+150$	2,5
Through hardened alloy steel	$0{,}1\sigma_B+185$	2,5
Soft-bath nitrided steel	330	1,2
Surface hardened steel	$0{,}35HV+125$	2,5
Surface hardened steel	390	1,6
Gas nitrided steel Cr, Ni and Mo carburized steel	450	2,5
Other carburized steel	410	2,5
Note: The values of σ_{Flim} are determined during the bending endurance test of wheel teeth under unidirectional pulsating stress with a minimum stress of zero and they correspond to a failure probability of 1 % or less with the number of cycles $3\text{x}10^6$.		

4.2.2.7.4.2 The factor

$$Y_{ST} = \sigma_{FE} / \sigma_{Flim} = 2,$$

where: σ_{Flim} is the tooth material bending endurance limit under the unidirectional pulsating stress with a minimum stress of zero.

4.2.2.7.4.3 For basic ratings, the life factor Y_N=1.

For limited life (when running astern, for instance), Y_N>1 may be permitted on agreement with the Register.

For the maximum load $T_{1\max}$ condition, the values of $Y_{1\max}$ are given in Table 4.2.2.7.4.1.

4.2.2.7.4.4 The values of the factor Y_D are adopted as follows:

for idler gears, $Y_D = 1,5$;

for gears with occasional part load in the reverse direction, $Y_D = 1,1$;

for gears (except idler gears) with shrink-fitted gear rings, $Y_D = 1,25$;

or if the shrink diameter d_S and radial pressure p_r on the shrinkage surface are known,

$$Y_D = 1 + \frac{0,2 d_s^2 d p_r b}{F_t \sigma_{F\,lim}\left(d_f^2 - d_s^2\right)}$$

where: d and d_f – =reference diameter and root diameter of the wheel;

in other cases, $Y_D = 1$.

4.2.2.7.4.5 The relative notch sensitivity factor $Y_{\delta relT}$, taking into consideration the material sensitivity to stress concentrations is taken from Table 4.2.2.7.4.5.

Table 4.2.2.7.4.5

Thermal or chemical and thermal treatment of transition tooth surfaces	$Y_{\delta relT}$, $Y_{\delta relT}=\{1+[0,2p'(1+2q_s)]^{0,5}/[1+(1,2p')]^{0,5}$		$Y_{\delta relT}$, at T_{1max}
	σ_t, MPa	p':	
Through-hardened carbon steel: forgings or rolled steelcasting	500	0,0281	$1+\left(Y_S-2\right)\times$ $\times\left(0,5-0,00015\sigma_T\right)$
	600	0,0194	
	800	0,0064	
Castings	1000	0,0014	$0,86+0,07Y_S$
Surface hardening		0,0030	$0,4+0,3Y_S$
Nitriding		0,1005	$0,6+0,2Y_S$

Note. The value of q_s is determined either by Formula (4.2.2.7.3.3-1) or (4.2.2.7.3.3-2) depending on the type of gearing. For the range $1,5 < q_S < 4$, may be taken to be $Y_{\delta relT} = 1$.

4.2.2.7.4.6 The relative surface condition factor Y_{RrelT}, which considers the influence of the transition surface roughness of the tooth, is taken from Table 4.2.2.7.4.6.

Table 4.2.2.7.4.6

Thermal or chemical and thermal treatment of teeth	Y_{RrelT}	
	$R_Z < 1$	$1 \le R_Z \le 40$
Through- or surface- hardening, carburizing	1,12	$1,675 - 0,53 \times (R_Z + 1)^{0,1}$
Nitriding	1,025	$4,3 - 3,26(R_Z+1)^{0,005}$

4.2.2.7.4.7 The size factor Y_X, which considers the influence of teeth size, is taken from Table 4.2.2.7.4.7.

The minimum value of bending endurance margin factor is chosen from Table 4.2.2.7.2.3.

4.2.2.7.5 The rated values of safety factors for contact stress and tooth root bending stress of the pinion and wheel teeth shall satisfy the conditions:

$$S_H = \frac{\sigma_{H\,lim} Z_N}{\sigma_H} Z_L Z_v Z_R Z_W Z_X \ge S_{H\min};$$

$$S_F = \frac{\sigma_{F\,lim} Y_{ST} Y_N}{\sigma_F Y_D} Y_{\delta relT} Y_{R\,relT} Y_X \ge S_{F\min}$$

Table 4.2.2.7.4.7

Thermal or chemical and thermal treatment of teeth	Module, mm	Y_X
Through-hardening	$5 < m_n < 30$ $m_n \ge 30$	$1,03–0,006m_n$ 0,85
Surface-hardening	$5 < m_n < 25$ $m_n \ge 25$	$1,05 - 0,01m_n$ 0,80
Note. With $m_n \le 5$ and any kind of surface hardening, $Y_X = 1$.		

4.2.2.7.6 Durability of bevel gears is determined on the basis of equivalent cylindrical gears using the geometry of the midsection.

4.2.2.7.6.1 The relevant formulae to determine the parameters of equivalent cylindrical gears in the edge section (index *v*) are given below:

number of teeth,

$$Z_{v1,2} = Z_{1,2} / \cos\delta_{1,2}.$$

reference (working) diameters,

$$d_{v1,2} = d_{m1,2} / \cos\delta_{1,2}.$$

centre distance and equivalent gear ratio,

$$a_v = 0{,}5\left(d_{v_1} - d_{v_2}\right),$$

$$u_v = \frac{Z_{v2}}{Z_{v_1}} = u\frac{\cos\delta_1}{\cos\delta_2}$$

tip diameter,

$$d_{va} = d_v + 2h_{am},$$

where:

h_{am} – addendum for bevel gears with constant addenda;

$$h_{am} = m_{mn}\left(1 + x_{hm}\right);$$

$$m_{mn} = m_{te}\cos\beta_m \frac{R_{wm}}{R_{we}};$$

for bevel gears with variable addenda,

$$h_{am_{1,2}} = h_{ae_{1,2}} - 0{,}5b\,\mathrm{tg}\left(\delta_{a1,2} - \delta_{1,2}\right),$$

where:

h_{ae} – addendum at outer end;

δ_a – outer cone angle;

addendum modification coefficients (shall be known),

$$x_{hm_{1,2}} = \frac{h_{am1,2} - h_{am2,1}}{2m_{mn}}.$$

tooth thickness modification coefficients (shall be known),

$$x_{sm_1} = -x_{sm_2}.$$

base diameters of equivalent cylindrical gears,

$$d_{vb_{1,2}} = d_{v_{1,2}}\cos\alpha_{vt},$$

where:

$$\alpha_{vt} = \mathrm{arctg}\left(\frac{\mathrm{tg}\alpha_n}{\cos\beta_m}\right).$$

contact ratios of equivalent cylindrical gearing:

transverse contact ratio,

$$\varepsilon_{v\alpha} = \frac{g_{v\alpha}\cos\beta_m}{m_{mn}\pi\cos\alpha_{vt}},$$

where:

$$g_{v\alpha} = 0{,}5\left(\sqrt{d_{va_1}^2 - d_{vb_1}^2} + \sqrt{d_{va_2}^2 - d_{vb_2}^2}\right) - a_v\sin\alpha_{vt};$$

overlap contact ratio,

$$\varepsilon_{v\beta} = \frac{b\sin\beta_m}{m_{mn}\pi}\tau; \qquad \tau = \frac{b_{eH}}{b} = 0{,}85;$$

total contact ratio,

$$\varepsilon_{v\gamma} = \varepsilon_{v\alpha} + \varepsilon_{v\beta}.$$

equivalent revolutions per minute,

$$n_{v1} = \frac{d_{m1}}{d_{v1}} n_1.$$

4.2.2.7.6.2 The rated formulae determining the parameters of equivalent cylindrical gears in the normal section (index *vn*) are:
number of teeth,

$$Z_{vn1} = \frac{Z_{v1}}{\cos^2\beta_{vb}\cos^2\beta_m};$$

$$Z_{vn2} = u_v Z_{vn1},$$

where:

$$\beta_{vb} = \arcsin(\sin\beta_m \cos\alpha_n).$$

Reference (working) diameters of equivalent cylindrical gears:

$$d_{vn1} = \frac{d_{v1}}{\cos^2\beta_{vb}} = Z_{vn1} m_{mn};$$

$$d_{vn2} = u_v d_{vn1} = Z_{vn2} m_{mn}.$$

Tip diameter

$$d_{van} = d_{vn} + d_{va} - d_v = d_{vn} + 2h_{am} = \\ = m_{mn} Z_{vn} + (d_{va} - d_v).$$

Base diameter

$$d_{vbn} = d_{vn}\cos\alpha_n = Z_{vn} m_{mn}\cos\alpha_n.$$

Transverse ratio

$$\varepsilon_{v\alpha n} = \varepsilon_{v\alpha} / \cos^2\beta_{vb}.$$

4.2.2.8 Gears with chemically and thermally hardened teeth of a large module ($v_n \geq 7{,}5$mm) shall be additionally examined for depth strength.

The rated safety factor for contact depth strength S_{Hd} shall be determined separately for pinion and wheel and shall satisfy the following condition

$$S_{Hd} = \frac{\sigma_{Hdlim}}{\sigma_H} \geqslant S_{Hd\min}$$

where:
σ_H – determined by Formula (4.2.2.7.1);
σ_{Hdlim} – depth strength limit determined by the formulae

$$\sigma_{H\text{гл}.lim} = 5{,}5HBc \text{ if } \varphi \leq 0{,}6$$

and

$$\sigma_{H\text{гл}.lim} = (4{,}58 + 1{,}57\varphi - 0{,}06\varphi^2)HBc\mu_T \text{ if } \varphi > 0{,}6.$$

where μ_T – a coefficient, which accounts for the probability of arising fatigue cracks not in the core, but in the hardened layer and which is determined from the diagrams in Fig. 4.2.2.8;

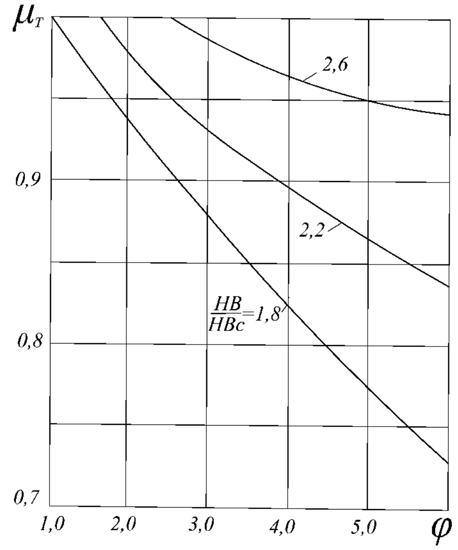


Fig. 4.2.2.8. 8 Diagram for determining the factor μ_T versus φ and *HB/HBc*

parameter

$$\varphi = \frac{h_t \cdot 10^4}{\rho_c HBc};$$

where: $\rho_c = \frac{a_w \sin\alpha_{tw}}{\cos\beta_b} \frac{u}{(u \pm 1)^2}$ – equivalent radius of curvature at the pitch point.

The minimum safety factor for depth strength $S_{Hd.\min}$ = 1,4.

4.2.3 Shafts.

4.2.3.1 The shaft diameter of a larger wheel shall not be less than 1,1 of the intermediate shaft diameter when the driving pinions are set at an angle of 120° and more and not less than 1,15 of the intermediate shaft diameter in all other cases, the mechanical properties of the wheel shaft and intermediate shaft being taken into consideration.

4.2.3.2 For icebreakers, polar, Baltic ice class ships, the shafts, pinions and wheels of main gearing shall be calculated for a torque

$$T = K'_A \cdot T_1,$$

where: K'_A refer to Table 4.2.3.2 (refer also to **2.1.2**, Part VII "Machinery Installations").

Table 4.2.3.2

Factor	Ice class ships				
	Ice3	**Ice4**	**Ice5**	**Ice6**, **Icebreaker1, Icebreaker2, PC4, PC5, IA Super, IA**	**Icebreaker3, Icebreaker4, PC1– PC3**
K'_A	1,15	1,25	1,75	2,0	2,5

To check the static strength of main propulsion gearing in **Ice6** ice class ships, Polar classes **PC1 – PC6** ships, Baltic classes **IA Super, IA** ships and icebreakers the maximum load $T_{1\max}$ shall be taken on agreement with the Register, having regard to relative strength of the "propeller-shafting" system elements and availability of devices restricting the torque transmitted.

4.2.4 Lubrication.

4.2.4.1 Provision shall be made for forced lubrication of the toothing and sleeve bearings of main gears.

The possibility of oil pressure regulation shall be provided.

A safety device shall be fitted to exclude oil pressure rise above the permissible value.

4.2.4.2 Lubricating oil shall be delivered to the toothing through sprayers.

The sprayers shall provide an oil feed in the form of a fanned-out compact jet with the adjacent jets overlapping.

The sprayers shall be so arranged that, while running ahead or astern, oil is captured in the toothing.

Oil supply to and withdrawal from the bearings and sprayers shall be so arranged that there is no oil foaming or emulsification.

4.2.4.3 Lubricating oil system shall comply with the requirements of Section **14**, Part VIII "Systems and Piping".

4.2.5 Control, protection and regulation.

4.2.5.1 Control stations shall comply with the requirements of **3.2**, Part VII "Machinery Installations".

4.2.5.2 Provision shall be made for pressure meters at the inlet to the gearing lubrication systems and for temperature meters at inlet and outlet, as well as for a meter of oil level within the reduction gear casing.

4.2.5.3 Each sleeve and thrust bearing shall be provided with a temperature measuring device.

For transferring power of less than 2250 kW, oil temperature measurement at outlet may be permitted for journal bearings.

When required by the Register, the temperature measuring device may also be provided for rolling bearings.

4.2.5.4 To prevent an inadmissible rise of lubricating oil temperature in bearings or drop of the lubricating oil pressure, provision shall be made for a warning alarm system.

4.3 ELASTIC AND DISENGAGING COUPLINGS

4.3.1 General.

4.3.1.1 The requirements of the Chapter apply to the elastic and disengaging couplings of main and auxiliary machinery.

As far as practical, these requirements apply to electromagnetic and hydraulic disengaging couplings as well.

4.3.1.2 As far as their material is concerned, the rigid components of shafting couplings shall satisfy the requirements of **2.4**, Part VII "Machinery Installations".

4.3.1.3 Coupling bolts and coupling flanges shall satisfy the requirements of **5.2** and **5.3** and, keyless-fitted shaft couplings shall satisfy the requirements of **5.4**, Part VII "Machinery Installations".

4.3.1.4 The elastic and disengaging couplings intended for ice class ships shall satisfy the requirements of **4.2.3.2**.

4.3.1.5 In ships with one main engine, the shaft coupling design shall ensure, in case of coupling failure, the ship running at a speed sufficient for easy steering.

4.3.2 Elastic couplings.

4.3.2.1 Where **4.3.1.5** cannot be complied with, the ultimate static moment of the elastic component material, i.e. rubber or similar synthetic material, being in shear or tension shall be at least eight times the torque transmitted by the coupling.

4.3.2.2 For the purpose of main machinery and diesel generator sets analysis, additional loads due to torsional vibrations shall be considered (refer to Section 8, Part VII "Machinery Installations").

4.3.2.3 The elastic couplings of diesel generator sets shall withstand moments arising as a result of short-circuit.

Where no such information is available, the maximum torque shall be at least 4,5 times the nominal torque transmitted by the coupling.

4.3.2.4 The possibility shall be provided of fully loading the elastic components, made of rubber or another similar synthetic material, of main machinery plant and diesel generator sets couplings within the temperature range +5 to +60°C.

4.3.3 Disengaging couplings.

4.3.3.1 The disengaging couplings of main machinery shall be provided with devices to prevent slipping during appreciable periods of time.

4.3.3.2 It shall be possible to control the disengaging couplings of main machinery from the stations from which the main machinery is controlled.

Directly at the disengaging couplings, local emergency control arrangements shall be provided.

4.3.3.3 Where two or more engines devoted to a common propeller shaft are driving it through disengaging couplings, their control arrangement shall make a simultaneous engagement of the engines impossible when running in opposite directions.

4.4 TURNING GEAR

4.4.1 A power-driven turning gear shall be provided with an interlocking to preclude the possibility of the drives and couplings engagement when the turning gear is engaged (besides, refer to **3.1.6**, Part VII "Machinery Installations" and **2.11.1.4** of the present Part).

5. AUXILIARY MACHINERY

5.1 POWER-DRIVEN AIR COMPRESSORS

5.1.1 General.

5.1.1.1 The air inlets of compressors shall be fitted with strainers.

5.1.1.2 The compressors shall be so designed that the air temperature at the outlet of the compressor last stage air cooler is not in excess of 90°C and they shall be provided with a signalling device or warning alarm system for exceeding of the maximum temperature.

5.1.1.3 The compressor cooling water spaces shall be fitted with drain arrangements.

5.1.2 Safety devices.

5.1.2.1 Each compressor stage or directly after it shall be fitted with a safety valve preventing the pressure rise in the stage above 1,1 of the rated pressure when the delivery pipe valve is closed.

The safety valve design shall prevent any possibility of its adjustment or disconnection after being fitted on the compressor.

5.1.2.2 The compressor crankcases of more than 0,5 m^3 in volume shall be fitted with safety valves meeting the requirements of **2.3.5**.

5.1.2.3 The casings of the coolers shall be fitted with safety devices providing for a free escape of air in case the pipes are broken.

5.1.3 Crankshaft.

5.1.3.1 The calculation method specified in **5.1.3.3** and **5.1.3.4** applies to the steel crankshafts of ship air compressors and refrigerant compressors with in-line, V- and W-shaped arrangements of cylinders and with single- and multi-stage compression.

Cast iron crankshafts, as well as departures from the dimensions of steel crankshafts calculated by Formulae (5.1.3.3) and (5.1.3.4) may be allowed on agreement with the Register, provided the confirming calculations or test data are submitted.

5.1.3.2 The crankshafts shall be made of steel having tensile strength 410 to 780 MPa.

During use of steel having a tensile strength over 780 MPa a technical justification shall be submitted to the Register for review confirming the structure reliability.

Cast iron crankshafts shall be manufactured of the spheroidal graphite cast iron of ferrite-perlite structure according to Table 3.9.3.1, Part XIII "Materials".

5.1.3.3 Crankpin diameter d_c, in mm, of the compressor shall not be less than that determined by the formula

$$d_c = 0{,}25k'\sqrt[3]{D_{cal}^2 \quad p_c\sqrt{0{,}3L_{cal}^2 \quad f + (s\varphi_1)^2}} \quad , \qquad (5.1.3.3)$$

where:

D_{cal} – = calculated diameter of the cylinder, mm; for single-stage compression, $D_{cal} = D$;

D – = diameter of the cylinder, mm; for two- and multi-stage compression in separate cylinders $D_{cal} = D_{h.p}$;

$D_{h.p}$ – diameter of high-pressure cylinder, mm; for two-stage compression by a tandem piston $D_{cal} = 1{,}4\, D_{h.p}$;
for two-stage compression by a differential piston

$$D_{cal} = \sqrt{D_{l.p}^2 \quad - D_{h.p}^2} \, ;$$

$D_{l.p}$ – diameter of low-pressure cylinder, mm;

P_c – delivery pressure of high-pressure cylinder for air compressors, MPa, for refrigerant compressors, the value p_c shall be taken in accordance with 2.2 of Part XII "Refrigerating Plants";

L_{cal} – calculated span between main bearings, mm, equal to:

$L_{cal} = L'$ – when one crank is arranged between two main bearings;

$L_{cal} = 1{,}1\, L'$ – when two cranks are arranged between two main bearings;

L' – = actual span between centres of the main bearings, mm;

s – piston stroke, mm;

k', f, φ_1 – coefficients taken in accordance with Tables 5.1.3.3-1, 5.1.3 3-2 and 5.1.3.3-3.

Table 5.1.3.3-1 **Values of coefficient *k***

Tensile strength R_m, MPa	390	490	590	690	780	900
k'	1,43	1,35	1,28	1,23	1,2	1,18

Table 5.1.3.3-2 **Values of coefficient *f***

Angle between the cylinder axes	0° (рядний)	45°	60°	90°
f	1,0	2,9	1,96	1,21

Table 5.1.3.3-3 **Values of coefficient φ_1**

Number of cylinders	1	2	4	6	8
φ_1	1,0	1,1	1,2	1,3	1,4

5.1.3.4 Thickness of crank web h, in mm, shall be not less than that determined by the formula:

$$h = 0{,}105 k_1 D_{cal} \sqrt{(\psi_1 \psi_2 + 0{,}4) p_c c_1 f_1 / b}, \qquad (5.1.3.4)$$

where:

$k_1 = a \sqrt[3]{R_m / (2R_m - 430)}$;

R_m – tensile strength of material, MPa; where the tensile strength exceeds 780 MPa, R_m equal to 780 MPa shall be adopted for calculation purposes;

$a = 0{,}9$ – 0,9 in the case of shafts, the surface of which is nitrided as a whole or hardened by another method approved by the Register;

$a = 0{,}95$ – in the case of shafts forged by closed-die or continuous grain-flow method;

$a = 1$ – 0 in the case of shafts not subjected to hardening;

ψ_1, ψ_2 – coefficients taken in accordance with Tables 5.1.3.4-1 and 5.1.3.4-2;

p_c – delivery pressure taken in accordance with **5.1.3.3**;

c_1 – = distance from the centre of the main bearing to mid-plane of the web; for cranks arranged between two main bearings, the distance is taken to the mid-plane of the web remotest from the support, mm;

b – web thickness, mm;

f_1 – coefficient taken in accordance with Table 5.1.3.4-3.

D_{cal} – calculated diameter of the cylinder taken according to **5.1.3.3**.

Intermediate values of coefficients given in the tables are determined by linear interpolation.

Table 5.1.3.4-1 **Values of coefficient ψ_1**

r/h	*ε /h*						
	0	0,2	0,4	0,6	0,8	1,0	1,2
0,07	4,5	4,5	4,28	4,10	3,70	3,30	2,75
0,10	3,5	3,5	3,34	3,18	2,88	2,57	2,18
0,15	2,9	2,9	2,82	2,65	2,40	2,07	1,83
0,20	2,5	2,5	2,41	2,32	2,06	1,79	1,61
0,25	2,3	2,3	2,20	2,10	1,90	1,70	1,40

Note. r – fillet radius, mm; ε – absolute amount of overlapping, mm (Fig. 5.1.3.4); for crankshafts having the distance x between journals and pins the values of coefficient ψ_1 shall be taken valid for ratio $\varepsilon / h = 0$.

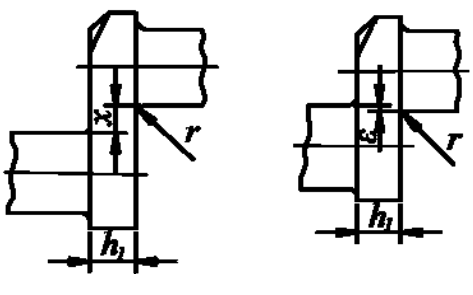


Fig. 5.1.3.4

***Table 5.1.3.4-2* Values of coefficient ψ_2**

b/d	1,2	1,4	1,5	1,8	2,0	2,2
Ψ_2	0,92	0,95	1,0	1,08	1,15	1,27

***Table 5.1.3.4-3* Values of coefficient f_1**

Angle between the cylinder axes	0° (in line)	45°	60°	90°
f_1	1,0	1,7	1,4	1,1

5.1.3.5 Shaft designing and manufacturing shall comply with the requirements specified in **2.4.12 – 2.4.13**.

5.1.4 Instruments.

5.1.4.1 A pressure gauge shall be fitted after each stage of the compressor.

5.1.4.2 Provision shall be made to measure the air temperature at the delivery pipe immediately after the compressor.

5.1.4.3 The instrumentation of the attached compressors shall comply with the requirements of **5.1.4.1** and **5.1.4.2** as far as their design allows.

5.2 PUMPS

5.2.1 General.

5.2.1.1 Provision shall be made to prevent the pumped fluid from penetration to the bearings.

However, this does not apply to the pumps where the pumped fluid is employed for lubrication of bearings.

5.2.1.2 The pump glands arranged on the suction side are recommended to be fitted with hydraulic seals.

5.2.2 Safety devices.

5.2.2.1 If the design of the pump does not preclude the possibility of pressure rising above the rated value, a safety valve shall be fitted on the pump casing or on the pipe before the first stop valve.

5.2.2.2 In pumps intended for transferring flammable liquids, the by-pass from safety valves shall be effected into the suction side of the pump or to the suction portion of the pipe.

5.2.2.3 Provision shall be made to prevent hydraulic impacts; use of the by-pass valves for this purpose is not recommended.

5.2.3 Strength calculations.

5.2.3.1 The critical speed of the pump rotor shall not be less than 1,3 of the rated speed.

5.2.3.2 The pump elements shall be checked for strength under the stresses corresponding to the pump rated parameters. In this case, the reference stresses in the elements shall not exceed $0,4R_{eH}$ of the element material.

5.2.4 Self-priming pumps.

5.2.4.1 The pumps provided with self-priming devices shall ensure operation under "dry suction" conditions and shall be fitted generally with arrangements preventing the self-priming device from operating with contaminated water.

5.2.4.2 The self-priming pumps shall have the place for connecting a vacuum pressure gauge.

5.2.5 Additional requirements for the pumps transferring flammable liquids.

5.2.5.1 Sealing of the shaft shall be such that the leakages occurred will not cause the formation of vapours and gases in the amount sufficient to produce the flammable air/gas mixture.

5.2.5.2 The possibility of excessive heating and ignition in sealing of the rotating parts due to friction energy shall be excluded.

5.2.5.3 When the materials of low electrical conductivity (plastics, rubber, etc.) are used in the pump structure, provision shall be made for removal of the electrostatic charges by insertion of the conductive additives into them or use of the devices for removal of the charges and for their transfer to the body.

5.2.6 Additional requirements for cargo, stripping and ballast pumps of oil tankers.

The casings of pumps installed in the cargo pump rooms in accordance with **4.2.5**, Part VII "Machinery Installations" shall be provided with temperature sensors.

5.3 FANS, BLOWERS AND TURBOCHARGERS

5.3.1 General.

5.3.1.1 The requirements of the present Chapter shall be complied with when designing and manufacturing fans intended to complete the systems specified in Part VIII "Systems and Piping", as well as boiler fans and internal combustion engine turboblowers (refer also to **2.5.7**).

5.3.1.2 2 The rotors of fans and air blowers with couplings as well as turbocharger rotor assemblies shall be dynamically balanced in accordance with **4.1.2**.

5.3.1.3 The suction pipes of fans, blowers and turbochargers shall be protected against entry of foreign objects.

5.3.1.4 The lubricating oil system of the turbocharger bearings shall be so arranged as to prevent the oil from getting into the supercharging air.

5.3.2 Strength calculation.

The impellers of the turbines and blowers shall be so dimensioned that at a speed equal to 1,3 of the rated speed the reference stresses at any section are not in excess of $0{,}95R_{eH}$ of the element material.

The impellers of the turbines and blowers shall be also tested for strength during at least 3 min at a speed equal to 1,2 times of the designed speed.

Such testing of the prototype of the turbine and blower impellers is mandatory.

Series specimens may not be subjected to such testing, provided each impeller forging shall be tested by one of the approved non-destructive testing methods.

On agreement with the Register other safety factors for the turboblowers may also be permitted if the calculation procedures are used taking account of the stress concentrations and plasticity (finite element method).

5.3.3 Additional requirements for the ventilators of cargo pump rooms in oil tankers, spaces intended for the carriage of dangerous goods and spaces in which motor vehicles are carried with fuel in their tanks.

5.3.3.1 The air gap between the impeller and the casing shall not be less than 0,1 of the impeller shaft bearing diameter, but not less than 2 mm (it is permitted to be not more than 13 mm).

5.3.3.2 Protection screens of not more than 13 mm square mesh shall be fitted in the inlet and outlet of ventilation ducts at the open deck to prevent the entrance of objects into the fan housing.

5.3.3.3 To prevent electrostatic charges both in the rotating body and casing, they shall be made of antistatic materials. Furthermore, the installation on board of the ventilation units shall be such as to ensure their safe bonding to the ship's hull according to requirements of Part XI "Electrical Equipment".

5.3.3.4 The impeller and the housing (in way of the impeller) shall be made of materials, which are recognized as being sparkproof.

The following combinations of materials of impeller and housing are considered sparkproof:

.1 non-metallic antistatic materials;

.2 non-ferrous-based alloys;

.3 austenitic stainless steel;

.4 impeller is made of aluminium alloy or magnesium alloy and housing is made of cast iron steel (austenitic stainless steel included), if a ring of suitable thickness of non-ferrous materials is fitted inside the housing in way of impeller;

.5 any combination of cast iron and steel impellers and housings (including the case when impeller or housing is made of austenitic stainless steel), provided the tip clearance is not less than 13 mm.

5.3.3.5 Other combinations of materials of impellers and housings, not specified in **5.3.3.4**, may also be permitted if they are recognized as non-sparking by appropriate tests.

5.3.3.6 The following combinations of materials of impeller and housing are not permitted:

.1 impellers are made of aluminium alloy or magne-sium alloy and housings are made of ferrousbased alloys;

.2 impellers are made of ferrous-based alloys and housings are made of aluminium or magnesium alloys;

.3 impellers and housings are made of ferrous-based alloys with less than 13 mm tip clearance.

5.4 CENTRIFUGAL SEPARATORS

5.4.1 General.

5.4.1.1 The separator design shall preclude the leakage of oil products and vapours thereof under any conditions of the separation.

5.4.1.2 The separator bowls shall be dynamically balanced.

The position of the removable parts shall be marked.

The design of the disc holder and bowl shall preclude the possibility of misassembly thereof

5.4.1.3 "Rotor-stator" systems shall be so designed that the critical speed exceeds the operating speed both in empty and in filled condition.

The critical speed less than the rated speed may be allowed only provided that proofs of continuous safe operation of the separator are submitted.

5.4.1.4 The design of coupling shall preclude the possibility of sparking and impermissible heating under all conditions of the separator operation.

5.4.2 Strength calculation.

5.4.2.1 Besides, the strength of rotating separator parts shall be checked under stresses arising at rotational speeds exceeding the design speed at least by 30 %; in this case, the total stresses in the parts shall not exceed 0,95*ReH* of the material, of which they are made.

5.4.2.2 At the manufacturer's test bench, the strength of the rotating parts of the prototype separator shall be tested by a rotation speed exceeding the design speed by 30 % at least.

5.4.3 Instrumentation and protection.

5.4.3.1 A device for the control over the separation process shall be provided.

5.4.3.2 It is advisable that the separators be provided with a device automatically shutting off the drive and stopping the separator when inadmissible vibration occurs.

5.5 NATURAL GAS (METHANE) COMPRESSORS

5.5.1 Compressors installed on board the gas carriers carrying methane and used for supply of methane to dual-fuel internal combustion engines (refer to **9**), to GTE (refer to **8.10**) of this part and to boilers, using gas as fuel (refer to **3.6**, Part X «Boilers, heat exchangers and pressure vessels») Boilers, heat exchangers and pressure vessels – 163°C.

6. DECK MACHINERY

6.1 GENERAL

6.1.1 The brake straps and their fastenings shall be resistant to sea water and petroleum products.

The brake straps shall be heat-resistant at temperatures up to 250°C.

The permissible heat resistance of connections between the brake strap and the frame shall be above the temperature of heating of the connections for all possible operating conditions of the machinery.

6.1.2 The machinery having both manual and power drives shall be provided with interlocking arrangements preventing their simultaneous operation.

6.1.3 The deck machinery control arrangements shall be so made that heaving-in is performed when the handwheel is turned to the right or when the lever is shifted backwards while veering out is carried on when the handwheel is turned to the left or the lever is shifted forwards.

Locking of brakes shall be carried out by turning the handwheels to the right while releasing is effected by turning to the left.

6.1.4 The control devices, as well as the instrumentation shall be so arranged as to provide the observation of them from the control place.

6.1.5 The machinery with the hydraulic drive or control shall additionally comply with the requirements of Section **7**.

6.1.6 Winch drums having the multilayer rope winding with the ropes that can be subjected to the load in several layers shall have flanges protruding above the upper layer of winding by not less than 2,5 times the rope diameter.

6.1.7 If used for oil-recovery operations, cargo winches and topping of derricks, cargo-lifting appliances, luffing gear, slewing and travelling machinery of cranes and hoists, and other deck machinery installed in danger zones 0, 1 and 2 shall be intrinsically safe, and relevant safety certificates shall be issued for them by a competent body (for the definition of danger zones refer to **19.2**, Part XI "Electrical Equipment").

6.1.8 Additional requirements for deck machinery of ships designed for long-term operation at low temperature.

6.1.8.1 Materials used for manufacture of deck machinery components shall comply with the requirements of XIII «Materials».

6.1.8.2 the Register certificates issued for deck machinery intended for installation onboard the ships with distinguishing marks **WINTERIZATION(-40)** and **WINTERIZATION(-50)**, shall contain an indication whether it is allowed to use it at appropriate design ambient temperature.

6.1.8.3 Hydraulic liquids and lubricating oils shall be suitable for use at design ambient temperature.

6.2 STEERING GEAR

6.2.1 Geneeral.

6.2.1.1 Main and auxiliary steering gear (refer to **1.2.9**, Part III "Equipment, Arrangements and Outfit") shall be so arranged that a single failure in one of them will not render the other one inoperative.

6.2.1.2 Main steering gear comprising two or more identical power units (refer to **2.9.4**, Part III "Equipment, Arrangements and Outfit") shall be so arranged that a single failure in its piping or in one of the power units will not impair the integrity of the remaining part of the steering gear. In oil tankers, oil tankers (≥ 60°C), chemical tankers or gas carriers of 10000 gross tonnage and upwards, hydraulic steering gear shall be provided with audible and visual alarms to give the indication of hydraulic fluid leakage in any part of the hydraulic system as well as with the arrangements of automatic isolation of the defective part of the system so that the steering capability shall be regained in not more than 45 s after the loss of the defective port of the hydraulic system.

6.2.1.3 The design of the gears shall provide in emergency for changing from the main steering gear to the auxiliary one during not more than 2 min.

6.2.1.4 Steering gears shall provide for a continuous operation under the most severe service conditions. The design of the steering gear shall exclude the possibility of its failure with a ship running astern at maximum speed.

6.2.1.5 As a rated torque of the steering gear M_r the torque is taken corresponding to the rudder (steering nozzle) angle equal to 35° for the main steering gear and 15° for the auxiliary steering gear when operating under the nominal parameters (nominal pressure in the inner spaces of hydraulic and electrohydraulic gears, nominal current and voltage in the electric steering gear motors, etc.).

In this case, the torque corresponding to the rudder angle 08 shall not be less than 0,82 M_r.

6.2.1.6 The requirements of equipping the ships with the steering gears are specified in **2.9**, Part III "Equipment, Arrangements and Outfit".

6.2.1.7 In case of the hydraulic steering gear, provision shall be made for the fixed storage tank for hydraulic fluid with the capacity sufficient to fill at least one power actuating system, the equalizing tank included.

This fixed tank shall be provided with a water level indicator and connected to the hydraulic gear by the piping so as its hydraulic systems can be filled directly from the tiller room.

Each equalizing tank shall be provided with a minimum water level alarm.

6.2.1.8 Every oil tanker, oil tanker (≥ 60°C), chemical tanker or gas carrier of 10000 gross tonnage and upwards shall comply with the following requirements (refer also to **6.2.1.9**):

.1 the main steering gear shall be so arranged that in the event of loss of steering capability due to a single failure in any part of one of the power actuating systems of the main steering gear excluding the tiller, quadrant or components serving the same purpose as well as seizure of the rudder actuators, steering capability could be regained in not more than 45 s after the loss of one power actuating system;

.2 the main steering gear shall comprise either:

.2.1 two independent and separate power actuating systems each capable of meeting the requirements of **2.9.2**, Part III "Equipment, Arrangements and Outfit"; or

.2.2 at least two identical power actuating systems which, acting simultaneously in normal operation, are capable of meeting the requirements of **2.9.2**, Part III "Equipment, Arrangements and Outfit".

In this case the interconnection of hydraulic systems shall be provided. Loss of hydraulic fluid from any power actuating system shall be capable of being detected and the defective system automatically isolated so that the other actuating system (systems) is (are) to remain fully operative;

.3 steering gears other than of the hydraulic type shall achieve equivalent standards.

6.2.1.9 Hydraulic steering gear shall comply with the requirements of Section **7** of the present Part, Part III "Equipment, Arrangements and Outfit" and Part XI "Electrical Equipment".

6.2.1.10 The pipes of hydraulic steering gear systems shall comply with the requirements of Part VIII "Systems and Piping" for Class I piping system.

The requirements for flexible joints used for the hydraulic steering gear systems are specified in **2.5**, Part VIII "Systems and Piping".

6.2.1.11 For oil tankers, oil tankers (≥60°C), chemical carriers or gas carriers of 10000 gross tonnage and upwards but of less than 100000 tons deadweight, at the Register discretion, solutions other than those set out in **6.2.1.8**, which need not apply the single failure criterion to the rudder actuator or actuators, may be permitted provided, that an equivalent safety standard is achieved and that:

.1 following loss of steering capability due to a single failure of any part of the piping system or of one of the power units, steering capability shall be regained within 45 s; and

.2 where a steering gear includes only a single rudder actuator, special consideration is given to stress analysis for the design including fatigue and fracture mechanics analysis, as appropriate, to the material used, the installation of sealing arrangements and testing and inspection as well as to the provision of effective maintenance.

6.2.1.12 Hydraulic system components in the power actuating or hydraulic servo systems controlling the power systems of the steering gear (e.g. solenoid valves, magnetic valves) shall be considered as part of the steering gear control system and shall be duplicated and separated.

Hydraulic system components in the steering gear control system that are part of a power unit may be regarded as being duplicated and separated when there are two or more separate power units provided and the piping to each power unit can be isolated.

6.2.1.13 3 Steering gear of passenger ships having length, as defined in **1.2.1** of the Load-Line Rules for Sea-Going Ships, of 120 m or more or having three or more main vertical zones, shall comply with the requirements of **2.2.6.7.2** and 2.2.6.8, Part VI "Fire Protection".

6.2.2 Power of steering gear.

6.2.2.1 The main steering gear shall be capable of putting the rudder (steering nozzle) over from 35° on one side to 30° on the other side in not more than 28 s when the rudder stock is affected by a rated torque of the steering engine at maximum operational draught and maximum operational speed of the ship.

6.2.2.2 The auxiliary steering gear shall be capable of putting the rudder (steering nozzle) over from 15° on one side to 15° on the other side in not more than 60 s under conditions stipulated by **2.9.3**, Part III "Equipment, Arrangements and Outfit".

6.2.2.3 The steering gear power units shall permit a torque overload of at least 1,5 times the rated torque for a period of 1 min.

The steering gear electric motors shall comply with the requirements of 5.5, Part XI "Electrical Equipment".

6.2.3 Hand-operated steering gear.

6.2.3.1 The main hand-operated steering gear shall be of self-braking design.

The auxiliary hand-operated steering gear shall be either of self-braking design or shall have a locking device provided that it is reliably controlled from the control station.

6.2.3.2 The main hand-operated steering gear shall meet the requirements of **6.2.2.1** when handled by one man with a force of not over 120 N applied to the steering wheel handles and with the number of rotations, when shifting the rudder from hard over to hard over, not more than $9/R$ during shifting the rudder from hard over to hard over, where R is arm (radius) of the steering wheel handle up to the middle of its length, m.

6.2.3.3 The auxiliary hand-operated steering gear shall meet the requirements of **6.2.2.2** when handled by not more than four men with a force of not more than 160 N per helmsman applied to the steering wheel handles.

6.2.4 Protection against overload and reverse rotation.

6.2.4.1 The main and auxiliary steering gears shall have protection against overloads of the gear elements and assemblies when a rudder stock torque equal to 1,5 times the corresponding rated value arises. In case of hydraulic steering gear the safety valves may be used set to a pressure meeting the above-mentioned requirements, but not in excess of 1,25 times the corresponding maximum working pressure in the inner spaces of the hydraulic steering gear.

The design of the safety device shall permit its sealing.

The minimum capacity of the relief valves shall exceed the total pump capacity by 10 %; in this case, the pressure of the hydraulic steering gear cavities shall not exceed the pressure, to which the relief valves are adjusted.

6.2.4.2 For the main hand-operated steering gear it is sufficient to provide the gear with buffer springs instead of the protection against overload required by **6.2.4.1**.

For the auxiliary hand-operated steering gear the fulfilment of the requirement for protection against overload is not compulsory.

6.2.4.3 The pumps of hydraulic steering engines shall be provided with protective devices preventing rotation of the inoperative pump in the opposite direction or with an automatic arrangement shutting out the flow of liquid through the inoperative pump.

6.2.5 Braking device.

6.2.5.1 The steering gear shall be fitted with a brake or some other device, which provides keeping the rudder (the steering nozzle) steady at any position when the latter exerts a rated torque without allowing for the efficiency of the rudder stock bearings.

6.2.5.2 Where the pistons or blades of the hydraulic steering gear can be locked by closing the oil pipeline valves, a special braking device may be omitted.

6.2.6 Limit switches.

Each power-operated steering gear shall be provided with a device discontinuing its operation before the rudder (the steering nozzle) reaches the rudder (the steering nozzle) stops.

6.2.7 Rudder (steering nozzle) indicators.

The steering gear segment rack or the hydraulic steering engine crosshead guide, or the element rigidly coupled with the rudder stock shall be fitted with a dial calibrated in not more than 1° to indicate the actual position of the rudder (the steering nozzle).

6.2.8 Strength calculation.

6.2.8.1 The main and auxiliary steering gear components to be used in flux of force lines shall be checked for strength under the stress corresponding to the rated torque, and the piping and other steering gear components subjected to internal hydraulic pressure - to the rated pressure.

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. In this case, at the discretion of the Register fatigue criterion shall be applied for the design of piping and components, taking account of pulsating pressures due to dynamic loads.

In all above cases the reference stresses in the components shall not exceed $0{,}4R_{eH}$ for the steel components and $0{,}18\sigma_B$ for the components of spheroidal cast iron.

6.2.8.2 The stresses in the elements common for both the main and auxiliary steering gears (viz., tiller, segment, reduction gear, etc.) shall not exceed 80 % of the stresses tolerable in compliance with **6.2.8.1**.

6.2.8.3 The steering gear elements unprotected from overloads by safety devices specified in **6.2.4** shall have strength corresponding to the rudder stock strength.

6.2.9 Connection with rudder stock.

6.2.9.1 The connection of the steering engine or gear with the elements rigidly coupled with the rudder stock shall eliminate the possibility of breakdown on the steering gear when the rudder stock is shifted in the axial direction.

6.2.9.2 Connecting of the tiller hub or segment rack with the rudder stock shall be designed to transmit no less than double rated torque M_r stated in **6.2.1.5**.

The height of the hubs of loose segment racks and auxiliary tillers shall not be less than 0,8 of the diameter of the rudder stock head.

In case of press keyless fitted solid hubs on the rudder stock the friction coefficient shall be taken not more than 0,13.

6.2.9.3 The split hubs shall be fastened with at least two bolts on each side and have two keys. The keys shall be arranged at an angle of 90° to the split joints plane.

6.2.9.4 Additional requirements for the AMSS turning or thrust angle changing mechanisms - refer to Section **7**, Part VII "Machinery Installations".

6.3 ANCHOR MACHINERY

6.3.1 General.

6.3.1.1 The design, construction and testing of windlasses shall conform to an acceptable standard, or code of practice. To be considered acceptable, the standard or code of practice shall specify criteria for stresses, performance and testing.

The following plans showing the design specifications, the standard of compliance, engineering analyses and details of construction, as applicable, shall be submitted for evaluation (refer to **1.2.3.2** of the Part):

windlass design specifications; anchor and chain cable particulars; anchorage depth; performance criteria; standard of compliance; windlass arrangement plan showing all of the components of the anchoring/mooring system such as the prime mover, shafting, cable lifter, anchors and chain cables; mooring winches, wires and fairleads, if they form part of the windlass machinery; brakes; controls; etc;

dimensions, materials, welding details, as applicable, of all torque-transmitting (shafts, gears, clutches, couplings, coupling bolts, etc.) and all load bearing (shaft bearings, cable lifter, sheaves, drums, bedframes, etc.) components of the windlass and of the winch, where applicable, including brakes, chain stopper (if fitted) and foundation;

hydraulic system, to include:

piping diagram along with system design pressure;

safety valves arrangement and settings;

material specifications for pipes and equipment;

typical pipe joints, as applicable, and;

technical data and details for hydraulic motors;

electric one line diagram along with cable specification and size; motor controller; protective device rating or setting; as applicable; control, monitoring and instrumentation arrangements;

engineering analyses for torque-transmitting and load-bearing components demonstrating their compliance with recognized standards or codes of practice.

Analyses for gears are to be in accordance with a recognized standard;

plans and data for windlass electric motors including associated gears rated 100 kW and over;

calculations demonstrating that the windlass prime mover is capable of attaining the hoisting speed, the required continuous duty pull, and the overload capacity are to be submitted if the "load testing" including "overload" capacity of the entire windlass unit is not carried out at the shop.

6.3.2 Materials and Fabrication.

6.3.2.1 Materials.

Materials used in the construction of torque-transmitting and load-bearing parts of windlasses shall comply with Part XIII "Materials" or of a national or international material standard. The proposed materials shall be indicated in the construction plans and shall be approved in connection with the design.

All such materials shall be certified by the material manufacturers and shall be traceable to the manufacturers' certificates.

6.3.2.2 Welded Fabrication.

Weld joint designs shall be shown in the construction plans and shall be approved in association with the approval of the windlass design.

Welding procedures and welders shall be qualified in accordance with the requirements of Part XIV "Welding".

Welding consumables shall be type-approved by the class society.

The degree of non-destructive examination of welds and post-weld heat treatment, if any, shall be specified and submitted for consideration.

6.3.3 Design.

Along with and notwithstanding the requirements of the chosen standard of compliance, the following requirements are also to be complied with. In lieu of conducting engineering analyses and submitting them for review, approval of the windlass mechanical design may be based on a type test, in which case the testing procedure is to be submitted for consideration.

6.3.3.1 Mechanical Design.

6.3.3.1.1 Design Loads:

.1 Holding Loads.

Calculations shall be made to show that, in the holding condition (single anchor, brake fully applied and chain cable lifter declutched), and under a load equal to 80 % of the specified minimum breaking strength of the chain cable, the maximum stress in each load bearing component will not exceed yield strength (or 0,2 % proof stress) of the material. For installations fitted with a chain cable stopper, 45 % of the specified minimum breaking strength of the chain cable may instead be used for the calculation.

.2 Inertia Loads.

The design of the drive train, including prime mover, reduction gears, bearings, clutches, shafts, cable lifter and bolting is to consider the dynamic effects of sudden stopping and starting of the prime mover or chain cable so as to limit inertial load.

6.3.3.1.2 The windlass prime mover shall be able to exert for at least 30 min a continuous duty pull (e.g., 30-minute short time rating), Z_{cont1} corresponding to the grade and diameter, d, of the chain cables according to Table 6.3.3.1.2:

Table 6.3.3.1.2

Grade of Z_{cont1}	Z_{cont1}	
	Н	кгс
1	$37{,}5d^2$	$3{,}82d^2$
2	$42{,}5d^2$	$4{,}33d^2$
3	$47{,}5d^2$	$4{,}84d^2$
Unit of d	mm	mm

The values given in table. 6.3.3.1.2, applicable when using conventional rodless anchors for anchorage depth up to 82.5 m.

For anchorage depth deeper than 82,5 m, a continuous duty pull pull Z_{cont2} is:

$$Z_{cont2}[\text{Н}] = Z_{cont1}[\text{Н}]+(D - 82{,}5)\cdot 0{,}27d^2$$

or

$$Z_{cont2}[\text{кгс}] = Z_{cont1}[\text{кгс}] + (D - 82{,}5)\cdot 0{,}0275d^2$$

where: D — is the anchor depth, in m.

The anchor masses shall be assumed to be the masses as given in Section 3 of Part III "Equipment, Arrangements and Outfit". Also, the value of Z_{cont} shall be based on the hoisting of one anchor at a time, and that the effects of buoyancy and hawse pipe efficiency (assumed to be 70 %) have been accounted for.

In general, stresses in each torque-transmitting component are not to exceed 40 % of yield strength (or 0,2 % proof stress) of the material under these loading conditions.

6.3.3.1.3 Overload Capability.

The windlass prime mover is to be able to provide the necessary temporary overload capacity for breaking out the anchor. This temporary overload capacity or "short term pull" shall be at least 1,5 times the continuous duty pull applied for at least 2 min. The speed in this period may be lower than normal.

6.3.3.1.4 Hoisting Speed.

The mean speed of the chain cable during hoisting of the anchor and cable shall be at least 0,15 m/sec. For testing purposes, the speed shall be measured over two shots of chain cable and initially with at least three shots of chain (82,5 m or 45 fathoms in length) and the anchor submerged and hanging free.

6.3.3.1.5 Brake Capacity.

The capacity of the windlass brake is to be sufficient to stop the anchor and chain cable when paying out the chain cable. Where a chain cable stopper is not fitted, the brake shall produce a torque capable of withstanding a pull equal to 80 % of the specified minimum breaking strength of the chain cable without any permanent deformation of strength members and without brake slip. Where a chain cable stopper is fitted, 45 % of the breaking strength may instead be applied.

6.3.3.1.6 Chain Cable Stopper.

Chain cable stopper, if fitted, along with its attachments shall be designed to withstand, without any permanent deformation, 80 % of the specified minimum breaking strength of the chain cable (refer to **3.6.1.3** of Part III "Equipment, Arrangements and Outfit").

6.3.3.1.7 Support Structure. For hull supporting structures of windlass and chain cable stoppers, refer to Sections **3** and **4** of Part III "Equipment, Arrangements and Outfit".

6.3.3.2 Hydraulic Systems. Hydraulic systems where employed for driving windlasses shall comply with the provisions of Section **7** of the Part.

6.3.3.3 Electrical Systems.

6.3.3.3.1 Electric Motors.

Electric motors shall meet the requirements of **5.6**, Part XI "Electrical Equipment" and shall be certificated by the Register according to the form specified in the Nomenclature of Items of the Register Technical Supervision.

Motors exposed to weather shall have enclosures suitable for their Location and have minimum degree of protection as provided for in the requirements of **2.4.4.2** Part XI "Electrical Equipment". Where gears are fitted, they shall meet the requirements of **4.2** and those rated 100 kW and over shall be certified.

6.3.3.3.2 Electrical Circuits.

Motor branch circuits shall be protected in accordance with the provisions of 8.3, Part XI "Electrical Equipment" and cable sizing shall be in accordance with the requirements 16.8.2, Part XI "Electrical Equipment".

Electrical cables installed in locations subjected to the sea shall be provided with effective mechanical protection.

6.3.3.4 Protection of Mechanical Components.

To protect mechanical parts including component housings, a suitable protection system shall be fitted to limit the speed and torque at the prime mover.

Consideration shall be given to a means to contain debris consequent to a severe damage of the prime mover due to overspeed in the event of uncontrolled rendering of the cable, particularly when an axial piston type hydraulic motor forms the prime mover.

6.3.3.5 Couplings.

Windlasses are to be fitted with couplings which are capable of disengaging between the cable lifter and the drive shaft.

Hydraulically or electrically operated couplings shall be capable of being disengaged manually.

6.3.4 Testing and Marking.

Windlasses shall be surveyed during fabrication at the manufacturers' facilities by a Surveyor for conformance with the approved plans and during acceptance tests.

6.3.5 Strength calculation.

6.3.5.1 1 The machinery elements shall be checked for strength when fastening to the ship's foundation, including protection against wave forces as specified in **1.4.6.1**, Part VIII "Systems and Piping" (refer to **6.3.5.3 — 6.3.5.8**).

6.3.5.2 The anchor machinery elements situated in lines of force flow shall be checked for strength when affected by stresses corresponding to the rated pull on the sprocket P_1 or P_2. In this case, the reference stresses in the elements shall not exceed $0{,}4R_{eH}$ of the element material.

6.3.5.3 The following pressures and associated areas shall be applied (refer to Fig. 6.3.5.3):

200 kN/m^2 normal to the shaft axis and away from the forward perpendicular, over the projected area in this direction;

150 kN/m^2 parallel to the shaft axis and acting both inboard and outboard separately, over the multiple of f times the projected area where *f* is determined by the formula

$$f = 1 + B/H, \qquad (6.3.5.3)$$

where:
B — width of machinery measured parallel to the shaft axis;
H — overall height of machinery,

but not more than 2,5.

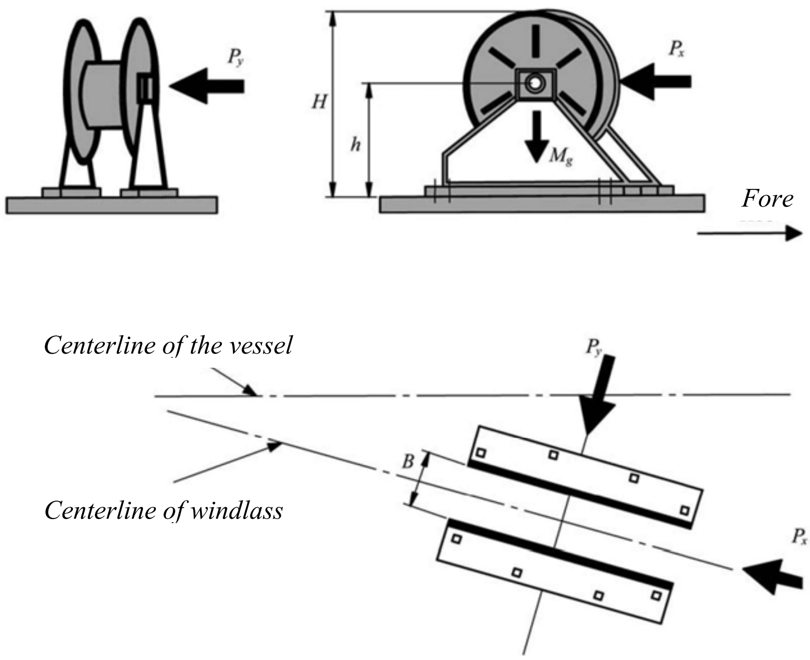


Fig. 6.3.5.3 Direction of forces

Note: P_y shall be examined from both inboard and outboard directions separately, refer to **6.3.5.3**.
The sign convention for y_i is reversed when P_y is from the opposite direction as shown in Fig. 6.3.5.4.

6.3.5.4 Forces in bolts, chocks and stoppers securing the machinery to the deck shall be calculated.
The machinery is supported by N bolt groups, each containing one or more bolts (refer to Fig. 6.3.5.4).

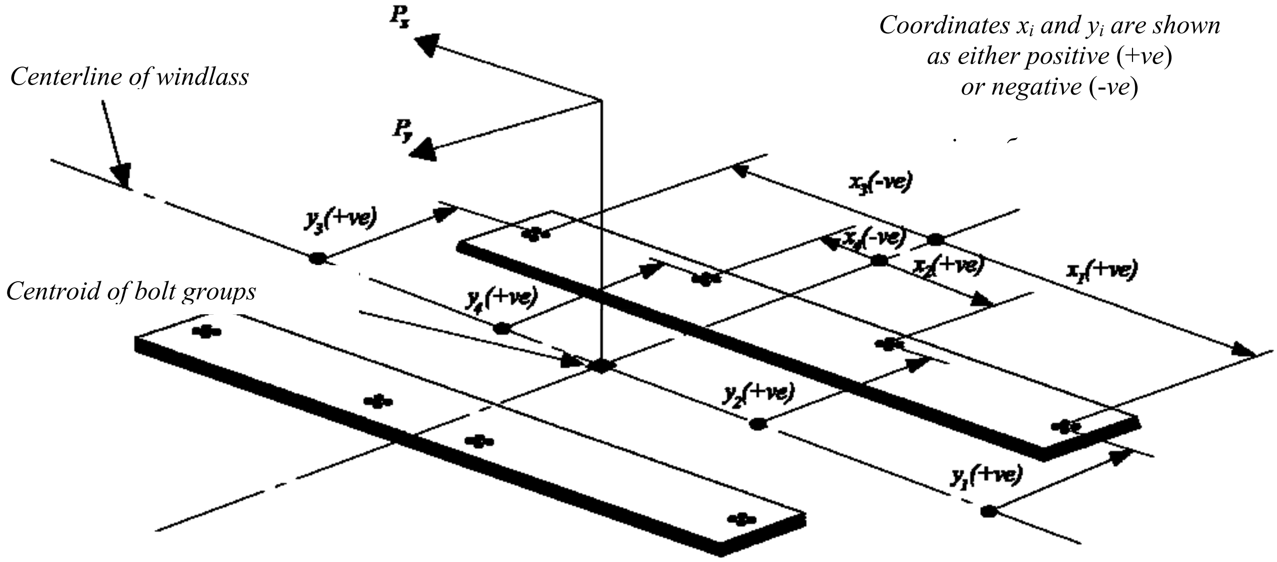


Fig. 6.3.5.4. Sign convention

6.3.5.5 The axial force R_i in the bolt group or one bolt, positive in tension, may be determined by the formula

$$R_i = R_{xi} + R_{yi} - R_{si}, \qquad (6.3.5.5)$$

where:
$R_{xi} = P_x\, h\, x_i\, A_i / I_x$;
$R_{yi} = P_x\, h\, y_i\, A_i / I_y$;
P_x – force acting normal to the shaft axis, kN;
A_i– cross sectional area of all bolts in *i* group, cm²;
I_x − $\Sigma A_i x_i^2$ for *N* bolt groups;
I_y − $\Sigma A_i y_i^2$ for *N* bolt groups;
R_{si} − static reaction at *i* bolt group, due to weight of windlass.
P_y - force acting parallel to the shaft axis, either inboard or outboard, whichever gives the greater force in i bolt group, kN;
h – shaft height above the windlass mounting, cm;
x_i, y_i − *x* and *y* coordinates of *i* bolt group from the centroid of all *N* bolt groups, positive in the direction opposite to that of the applied force, cm.

6.3.5.6 Shear forces F_{xi} and F_{yi}, applied to *i* bolt group, and the resultant combined force F_i may be determined by the formulae:

$$F_{xi} = (P_x - \alpha g W)/N; \quad (6.3.5.6\text{-}1)$$

$$F_{yi} = (P_y - \alpha g W)/N; \quad (6.3.5.6\text{-}2)$$

$$F_i = (F^2_{xi} + F^2_{yi})^{0,5}; \quad (6.3.5.6\text{-}3)$$

where:
α – coefficient of friction equal to 0,5;
W – = mass of windlass, t;
g – gravity acceleration, m/s²;
N - number of bolt groups.

6.3.5.7 Axial tensile and compressive forces in **6.3.5.5** and lateral forces in **6.3.5.6** shall be considered in the design of supporting structure.

6.3.5.8 Tensile axial stresses in the individual bolts in each i bolt group shall be calculated. The horizontal forces F_{xi} and F_{yi} shall normally be reacted by shear chocks. Where "fitted" bolts are designed to support these shear forces in one or both directions, equivalent stresses in the individual bolts shall be calculated, and compared to the allowable stresses.

Where synthetic compounds are incorporated in the holding down arrangements, due account shall be taken in the calculations. The safety factor against bolt proof strength shall not be less than 2,0.

6.3.6 Additional requirements.

6.3.6.1 The anchor machinery intended for handling with mooring operations shall comply with the requirements of **6.4**, in addition to those of the Chapter.

6.3.6.2 The requirements of the Chapter apply to the remote-controlled anchor machinery chosen in accordance with **3.1.5**, Part III "Equipment, Arrangements and Outfit".

6.3.6.3 If the provision is made for remote control of paying out the chain cable with the sprocket disconnected from the anchor machinery drive, a device shall be fitted ensuring an automatic braking by the band brake in order that the maximum speed of paying out will not exceed 3 m/s.

In ships with Equipment Number of 400 and less it is permissible not to install a device for an automatic braking by the band brake.

6.3.6.4 The chain sprocket brake shall provide for smooth stopping of the chain cable when paying it out for a period of not more than 5 s and not less than 2 s from the moment of initiation of the signal from the control station.

6.3.6.5 Provision shall be made at the remote control station for an indicator of the length of the chain cable payed out and the indicator of the paying out speed of the cable with the mark of 3 m/s of the maximum permissible speed.

6.3.6.6 Machinery and machinery elements, for which the remote control is provided, shall be manually operated from the local position. The failure of any element or the whole remote control system shall not affect adversely the normal operation of the anchor machinery and equipment manually operated from the local position (refer also to **5.1.3**, Part XI "Electrical Equipment").

6.4 MOORING MACHINERY

6.4.1 Drive.

6.4.1.1 The mooring machinery drive shall provide for an uninterrupted heaving-in of a mooring line at a rated pull with the rated speed for a period of not less than 30 min.

The speed, v, of heaving-in of a mooring line on the first rope winding layer on the drum with the nominal pulling force F shall not be less than stated in Table6.4.1.1.

Table 6.4.1.1 **The speed of heaving-in *v* of a mooring line**

v, m/s	0,25	0,2	0,16	0,13
F, kN	до 80	81–160	161–250	Above 250

The speed of heaving-in of a mooring line by the use of a warping drum at the rated pull shall not be over 0,3 m/s. Instructions on the choice of the rated pull are given in **4.4.2**, Part III "Equipment, Arrangements and Outfit".

6.4.1.2 Under the rated conditions of the mooring machinery (refer to **6.4.1.1**) its drive shall develop the pull on the first rope winding layer on the drum equal at least to 1,5 times the rated value in 2 min.

6.4.2 Overload protection.

If the maximum torque of the drive may bring about a larger load on the mooring machinery elements than that specified in **6.4.4**, an overload protection shall be provided.

6.4.3 Brake.

6.4.3.1 The mooring machinery shall be provided with an automatic brake ensuring a hold, without a slip on the mooring line at a pull equal to 1,5 times the rated one when the driving energy disappears or the driving engine fails.

Winches with hydraulic and steam drives with no driving energy shall withstand a tension force of 1,25 times the design pull.

Speed of cable paying out shall be checked within 1,0 m/min.

6.4.3.2 The mooring machinery drum shall be provided with a brake, a braking torque of which shall ensure keeping the mooring line from unreeling at a pull in the line equal to 0,8 times the breaking load of the line on the first rope winding layer on the drum.

The force applied to the brake drive handle shall not exceed 740 N.

If the drum is fitted with an arresting or other safety device, the possibility shall be provided for disengaging the drum by an approved means when the mooring cable is under the load.

6.4.4 Strength calculation.

6.4.4.1 The mooring machinery elements situated in lines of force flow shall be checked for strength under the rated pull on the mooring drum. In this case, the reference stresses in the elements shall not exceed $0,4R_{eH}$ of the element material.

6.4.4.2 The elements of the mooring machinery and the elements of its fastening to foundation shall be checked for strength under the effect of the maximum torque of the drive and when the drum is affected by an effort equal to breaking force of the mooring cable.

Besides, the strength of the warping drum shaft under the load applied in the middle of its length, equal to the breaking force of the mooring cable shall be checked. In all above-mentioned cases, the stress in the elements shall not exceed $0,95R_{eH}$ of the element material.

The strength of the mooring machinery elements shall allow for all possible kinds and geometrical directions of the loads that may arise during operation.

The strength of the mooring rope intended for operation with the mooring machinery shall be indicated on the machinery.

6.4.5 Automatic mooring winches.

6.4.5.1 The performance characteristics and durability of the automatic mooring winches shall not be inferior to the similar-purpose non-automatic machinery.

6.4.5.2 Automatic winches shall be equipped with the manual control to provide the possibility of non-automatic operation.

6.4.5.3 The following shall be provided:

sound warning alarm operating with the maximum permissible length of the mooring rope veered out;

an indicator of the actual pull in the mooring rope under the automatic operation.

For pull measuring it is recommended to install sensors with electric output signal.

6.5 TOWING WINCHES

6.5.1 Where automatic devices are used for governing the tension of the towline, provision shall be made to enable checking the value of tension at every moment. The tension indicators shall be installed at the towing winch and on the bridge.

For pull measuring it is recommended to install sensors with electric output signal.

6.5.2 Sound warning alarm operating when the maximum permissible length of the towline is veered out or visual monitoring shall be provided. It is recommended to install a towline counter.

Рекомендується установлення лічильника довжини попущеного троса.

6.5.3 The drums of the towing winches shall comply with the requirements of **6.1.6** and shall be provided with fairleads (except in cases of use of reduced length cable in accordance with **5.6.1** of Part III "Equipment arrangements and outfit").

If two or more drums are provided, the fairleads shall be independent.

Rope drum shall be fitted with a coupling to ensure its disconnection from the driving machinery.

Geometrical dimensions of the winch heads shall provide the possibility for paying out of the towline.

6.5.4 The design of the winch shall provide for quick releasing of the drum in order to ensure free paying-out of the towing line.

6.5.5 Brakes.

6.5.5.1 The towing winches shall be provided with an automatic brake ensuring holding of a line at a pull equal to at least 1,25 times the rated one when the driving energy disappears or is switched off.

6.5.5.2 The drum brake controlled by any type of energy shall be provided with manual control as well.

The brake design shall ensure the possibility of quick releasing for the purpose of loosing paying out of the towline.

6.5.6 The towing winch elements situated in lines of force flow shall be checked for strength under the rated rope pull applied to the middle layer of winding.

The reference stresses in the elements shall not exceed $0,4R_{eH}$ of the element material in this case.

6.5.7 The elements shall be checked for strength when the drum is affected by efforts corresponding to the maximum torque of the drive, as well as when the drum is affected by an effort equal to the towline breaking force on the upper layer of winding.

The reference stresses in elements, which may be subjected to efforts caused by the above-mentioned loads, shall not exceed $0,95R_{eH}$ of the element material.

7. HYDRAULIC DRIVES

7.1 GENERAL

7.1.1 1 Connecting of hydraulic steering gear pipelines and those of the hydraulic power systems of CPP to other hydraulic systems is not permitted.

Connecting of pipelines of the engine-room trunk closures hydraulic drive systems to other hydraulic systems is not permitted.

In passenger ships and special purpose ships, the connection of the pipeline systems of power-operated sliding watertight doors to other hydraulic systems is not permitted.

7.1.2 Where the pipeline servicing hydraulic anchor machinery is connected to other hydraulic system pipelines, the latter shall be serviced by two separate pump units, each of which shall ensure the anchor gear operation with nominal pull and at nominal heaving-in speed.

7.1.3 The hydraulic system failure shall not cause the failure of machinery or arrangement.

7.1.4 Fluids to be used in the hydraulic systems shall be selected with regard to temperature conditions that may occur during operation (refer to Table 2.3.1-2, Part VII "Machinery Installations").

7.1.5 In passenger ships and special purpose ships, the hydraulic systems of power-operated sliding watertight doors may be centralized or independent for each door.

The centralized systems shall be provided with a low-level alarm for hydraulic fluid reservoirs serving the system and a low gas pressure alarm for hydraulic accumulators. Other effective means of monitoring loss of stored energy in hydraulic accumulators may be provided. These alarms shall be audible and visual and shall be situated on the operating console at the navigation bridge.

The centralized systems shall be designed to minimize the possibility of a failure in the operation of more than one door caused by damage to a single part of the system.

An independent hydraulic system for each sliding watertight door shall have a low gas pressure group alarm or other effective means of monitoring loss of stored energy in hydraulic accumulators, situated at the operating console on the navigation bridge. Loss of stored energy indication shall be provided at each local control station.

Besides, the hydraulic systems of power-operated sliding watertight doors in passenger ships and special purpose ships shall comply with the requirements of **7.12.5.7**, Part III "Equipment, Arrangements and Outfit".

7.2 STRENGTH CALCULATION

7.2.1 The hydraulic machinery elements situated in lines of force flow shall be checked under the stresses corresponding to the working pressure.

In this case, the reference stresses in elements shall not exceed $0,4R_{eH}$ of the element material.

7.2.2 In cases specified in **6.2.4.1**, **6.3.4** and **6.4.2**, the elements shall be checked for strength under the stresses corresponding to the opening pressure of the safety valves.

In this case, the reference stresses in elements shall not exceed $0,95R_{eH}$ of element material.

7.2.3 The pipelines and valves of the hydraulic systems shall comply with the requirements specified in Sections **2**, **4** and **5**, Part VIII "Systems and Piping".

7.3 SAFETY AND OTHER ARRANGEMENTS

7.3.1 The hydraulic machinery shall be protected by safety valves, whice operating pressure shall not exceed 1,1 times the maximum rated pressure, except for the cases specified in **6.2.4.1**, **6.3.4**, **6.4.2**.

7.3.2 The working fluid from the safety valve shall be led to the drain pipeline or to the oil tank.

7.3.3 Arrangements for complete air expulsion when filling the machinery and the pipeline with the working fluid, as well as for leakage replenishment and drainage shall be provided.

7.3.4 The hydraulic systems shall be provided with the filters of appropriate capacity and filtration purity of the working fluid.

For continuously operating hydraulic systems (hydraulic steering gear, hydraulic couplings, etc.) provision shall be made for filter cleaning without interruption of the system operation.

7.3.5 Oil seals between fixed parts forming a part of external pressure limit shall be of "metal on metal" type.

Oil seals between moving parts forming a part of external pressure limit shall be doubled in such a way that the failure of one seal would not disable the executive actuator.

The alternative arrangements providing the equivalent leakage protection shall be agreed upon with the

Register.

7.3.6 Hydraulic working cylinder rods that are heavity affected by dust and subject to icing shall be protected against such effects.

7.3.7 The hydraulic machinery shall be provided with a sufficient amount of the instruments to monitor its operation.

8. GAS TURBINES

8.1 GENERAL

8.1.1 Requirements of the Section apply to main and auxiliary marine gas turbines of 100 kW power and above.

Application of these requirements to gas turbines of less than 100 kW power shall be performed in the scope agreed with the Register with due regard to the gas turbines purpose.

The present requirements cover converted aircraft, marine and stationary gas turbines, if installed aboard sea-going ships.

The field of applying the gas turbines covered by the present requirements is as follows:

displacement ships, high-speed craft;

dynamically supported ships;

mobile offshore drilling units (MODU) and fixed offshore platforms (FOP).

8.1.2 Design output refers to design conditions, i.e. specified values of ambient air and water temperatures, air humidity, atmospheric pressure and exhaust and suction resistance adopted for gas turbine design.

It is recommended that the following parameters shall be adopted as design conditions (accordance with the requirements of ISO 2314):

air temperature, in ºC at gas turbine inlet – + 15;

relative air humidity, in % – 60;

air pressure, in kPa – 100.

8.1.3 In ships of unrestricted service, at least two main gas turbines shall be used, while a possibility shall exist of the ship movement with one gas turbine in operation.

When a single gas turbine is employed, the necessity of application of the emergency device to ensure ship propulsion shall be agreed with the Register regarding ship's structural features and purpose.

8.1.4 When water supply to the air cooler is completely shut off, the gas turbine with air intercooling shall develop an output not less than 20 % of the design value.

8.1.5 The gas turbine installation with a reversing device shall provide reversing from full ahead to full astern and vice versa (refer to **2.1.4**, Part VII "Machinery Installations").

The gas turbine installation without a reversing device may be installed, if the ship is equipped with other means and devices to ensure astern running.

When the astern turbine is employed, the requirements of **3.1.2** and **3.6.2** shall be followed, for reverse-reduction gear, the requirements of **4.1.1** of the Part shall be complied with and in the case of CPP application, the requirements of **6.5.5**, Part VII "Machinery Installations" shall be met.

When using the compressed air for the reverse systems, its store shall provide at least 25 resettings of the reverse.

Refuelling of the compressed air store shall be performed automatically from at least two sources.

Connection of other consumers to the high pressure compressed air systems providing the operation of the reverse systems, protection of gas turbines, bridge control is prohibited.

8.1.6 The steady operation of the gas turbines without stalling and surging under all possible operating conditions, manoeuvring included, as well as the permissible deposits on gas turbines and under tropical conditions (air temperature not less than 45°C, relative air humidity of 95 % at 35°C and sea water temperature of 35°C) shall be proved by calculations and tests.

Increases and drops of load shall be performed at the speed to ensure steady operation of gas turbine compressors throughout the operating range.

The program for testing the steady operation of the gas turbines shall be agreed with the Register in each case, and the control shall be performed both at the manufacturer's bench and after installation of the gas turbine on board.

8.1.7 Throughout the operating starting, there shall be no zones restricting the gas turbine operation due to vibrations.

Normal vibrations shall not exceed the permissible values given in Section **9**, Part VII "Machinery Installations".

8.1.8 For the gas turbines of **Ice6** ice class ships, the requirements of **2.1.2**, Part VII "Machinery Installations" shall be met, and where these requirements cannot be fulfilled, the loads on units transmitting the power from the gas turbine to the propeller shall be approved by the Register.

8.1.9 As starting devices, a.c. motors shall be used. The application of d.c. motors and starting devices of other types shall be agreed upon with the Register.

An opportunity shall be ensured of starting each gas turbine from at least two sources of power. The change-over from one source of power to the other for starting up the turbine shall be performed in not more than 60 s.

For high-speed and dynamically supported craft, power supply from one source of power is permitted.

At least four successive starts of the gas turbine shall be possible.

An opportunity shall be ensured for starting up the turbine before the rotor driven by the starting device has fully stopped.

8.1.10 When doped fuels leaving deposits of combustion products on gas turbine blades are used, provision shall be made for systems and means of cleaning the blading without stopping the turbine.

A system for washing the stopped turbine to clean the turbine blades from deposits and the compressor blades from salt deposits shall be also provided.

The gas turbines of high-speed and dynamically supported craft may be cleaned and washed in port by means of shore appliances.

A cleaning or washing of the blading shall result in the restoration of the gas turbine parameters.

The cleaning (washing) media shall not have a corrosive effect on the turbine blading and the surface of the exhaust gas boiler installed behind the turbine.

The washing waste shall be discharged to special tanks.

The gas turbine washing medium shall be issued with a sanitary approval permitting its application aboard sea-going ships.

8.1.11 The air suction inlets of the gas turbines shall be fitted with filters to preclude speeds of depositing on the compressor blading dangerous for the normal operation of the gas turbines.

The filter efficiency shall be tested at the same time as the ship delivery takes place.

The air inlets shall be so located as to prevent the entry of water, exhaust gas vapours and blowout from the fan into the compressor.

Provisions shall be made for preventing the suction duct from icing, if the risk of icing exists under the ship operating conditions.

The reserve intake of 60 % of air volume shall be provided in case of icing of the suction.

For high-speed and dynamically supported craft, measures against icing and the reserve air intake need not be taken on agreement with the Register.

The air inlets shall not produce eddies at compressor intakes, which would make the compressor operation less stable under any operating conditions.

Drainage systems of air inlets shall be provided with hydroseals.

Quick-operating devices shall be provided for closing the air inlets.

8.1.12 Gas exhaust systems shall be provided with the remote-controlled arrangements to prevent air circulation through the gas turbine both in case of fire and when in port.

If one air duct or exhaust manifold is intended for two or more engines, gas and air recirculation through non-operating engines shall be prevented.

8.1.13 Air suction and gas exhaust trunks, fuel, refrigeration and other piping shall be connected to the engine so that no expansion stresses are transmitted to the place of connection.

Piping shall withstand vibration on levels generated during the gas turbine operation.

8.1.14 All the internal components of air ducts and trunks for air supply to compressors shall be manufactured from corrosion-resistant materials.

The dimensions of the components and fastenings shall exclude the possibility of their penetration through the protective grating before the compressor. All inner mountings shall be fixed.

The trunks and ducts shall provide the possibility of periodical checking of the condition of inner surfaces.

8.1.15 All turbochargers and gas turbines shall be fitted with a turning arrangement. Provision shall be made for interlocking the shaft-turning gear with the gas-turbine starting device or for an automatic disconnection of the shaft-turning gear.

Quick-disconnecting couplings shall be provided with interlocking excluding the starting up of the gas turbine with the reduction gear being disconnected.

8.1.16 Gas turbines for driving the emergency generator and fire pump shall be fitted with independent fuel, lubricating oil and cooling systems.

In addition to automatic starting, manual starting from the local control station shall be provided.

8.1.17 Gas turbines for driving the emergency generator and fire pump shall be fitted with independent fuel, lubricating oil and cooling systems. In addition to automatic starting, manual starting from the local control station shall be provided.

8.1.17 To discharge the liquid fuel (or gas, if gas-operated) remaining in the gas turbine after failed starting or due to fuel leakage in the combustion chamber during standby condition, provision shall be made for "a cold start" (false starting without fuel supply) before each turbine starting.

The duration and number of the "cold starts" shall be sufficient for a complete discharge of unburnt fuel (gas) from the turbine.

8.1.18 To prevent lubricating oil vapour emission to the atmosphere, lubricating oil tanks shall be equipped with special separators discharging air into the exhaust gas duct (to gas vent section).

8.1.19 Each gas turbine shall be covered with a noise- and warmth-insulating case with the inner space aired by a special ventilator or as a result of exhaust gas ejection.

The temperature of the outer surface of the case shall be in agreement with the sanitary norms.

Shall be also ensured access to principal units and components for maintenance and examination of blading, compressors and combustion chambers with endoscopes.

To comply with sanitary norms for noise level in the machinery space, provision shall be made for noise muffling at air inlet and gas outlet of the turbine.

8.1.20 Each gas turbine shall have a fire extinguishing system independent of the other systems of the kind installed in the machinery space.

Where several gas turbines are installed on board, provision shall be made for the transfer of the fire-extinguishing medium from the fire-extinguishing system of one gas turbine to those of the others.

The amount of fire-extinguishing medium in the fire-extinguishing system shall be determined on the assumption of the inner volume of each gas turbine and the waste-heat boiler installed thereafter (if any) being filled.

The gas turbine shall be equipped with two detectors pertinent to the fire-extinguishing system, one for the temperature of the environment beneath the noise - and warmthinsulating case and the other for the temperature of exhaust gases behind the turbine.

8.1.21 Fuel and lubricating oil piping shall be so arranged or equipped that in case of their rupture the leakage could not get on the hot surfaces of the gas turbine.

8.1.22 The list of spares shall be compiled by the manufacturer based on the operarting experience of this type of unit.

8.1.23 Where the turbines are converted for marine service, checks on service life shall be carried out on agreement with the Register.

8.2 GAS TURBINE ROTORS

8.2.1 The strength analysis of the gas turbine rotors shall be performed for the rated output condition and for conditions when the stresses can reach their maximum values.

The check calculation of a turbine with overcapacity shall be made for a rotational speed by 20 per cent higher than the nominal one, and for the other rotors, the check calculation shall be made for a rotational speed exceeding the nominal speed by 10 %.

8.2.2 For the rotating parts of the gas turbine, the enlarged torque shall be analysed corresponding to the turbine operation at an ambient air temperature reduced by 20°C lower as compared to the design temperature.

8.2.3 The strength calculation of rotating parts of the astern gas turbines shall be performed to the maximum torque corresponding to the crush stop from full ahead to full astern at the maximum capacity output of the astern turbine.

8.2.4 The strength calculation of the units transmitting power from the gas turbine to the electric generator drives shall be made on the basis of torque corresponding to the short-circuit condition, unless special sliding couplings are used in the "engine-generator" system.

8.2.5 The critical rotor speed shall be determined with regard to brackets and shall meet the requirements of **3.2.2**. For overhanging rotors, precession calculation and additional loads from the gyroscopic moment shall be carried out.

8.2.6 The requirements of **3.2.3** to **3.2.5** shall be also complied with.

8.2.7 The dynamic stresses in the blades of compressors operating in the corrosive medium shall be experimentally determined by the manufacturer throughout operating ranges, including starting ranges, and the blading shall be so set that dangerous vibrations do not occur.

The factor of fatigue strength of the blades shall not be less than 3 for the operating ranges or less than 2,5 for transient ranges.

This requirement may be waived, if the gas turbine manufacturer supplies data on the reliability of the compressor blades in a corrosive medium with lower fatigue safety factors.

8.3 GAS TURBINE CASINGS

8.3.1 Special sight holes for inspection of the blading shall be provided in the casings of gas turbines and compressors, and the gas turbines shall be equipped with special instruments for inspection (endoscopes).

8.3.2 Where sleeve bearings are applied in the gas turbine, its casing shall be in accordance with the requirements of **3.3.7**.

8.3.3 When the internal lagging of the gas turbine casing is applied, it shall be safely fastened and covered with a sheath in order to prevent local stripping of the casing surface and the contacts between the lagging and the blading.

8.3.4 The oil seal design shall be such as to prevent the lubricating oil and oil vapours from entering into the blading of the turbines and compressors, and the blow-out of oil and vapours outside.

8.3.5 Each gas turbine shall have drain holes in the lower point of the casing, which shall have spouts connected to leakage collecting tanks via open funnels so the turbine would not be flooded in case of the leakage collecting tank overfilling.

8.3.6 The casings shall ensure impenetrability for the case of rotor blade break.

8.4 GAS TURBINE BEARINGS

8.4.1 The sleeve bearings of the gas turbines shall comply with the requirements of **3.4**.

8.4.2 For marine gas turbines irrespective of type, roller bearings may be used.

8.4.3 Each lubricating oil spout of the gas turbine supports shall be equipped with alarms for the presence of chips and with lubricating oil temperature sensors.

8.4.4 The application of inner bearings for three-bearing shafts shall be technically substantiated and agreed upon with the Register.

8.4.5 In any case, the gas turbine stop shall not damage the bearings. To this end, provision shall be made for lubricating oil supply in case of the turbine stop and for automatic activation of the rotor turning system.

8.5 COMBUSTION CHAMBERS

8.5.1 The arrangement of the combustion chamber design of the gas turbines shall provide the convenience of servicing and the possibility of replacement of burners and flame tubes at sea.

The burners shall be inter-changeable without the necessity of a substantial adjustment of the fuel oil supply system.

8.5.2 The possibility of inspection shall be provided for the flame tubes of the combustion chambers with endoscopes without disassembling.

8.5.3 The entering of the fuel into the combustion chambers of the gas turbine, while the engine is out of action, shall be excluded.

8.5.4 High-pressure fuel oil piping and main burners shall be made clean of fuel after the turbine or burner shutdown.

Starting fuel oil piping and starting burners shall be made clean of fuel after the end of the starting condition.

Making clean of fuel shall be achieved by automatic opening of discharge valves on the relevant pipe.

8.5.5 The gas turbine shall be equipped with two igniters at least.

8.6 HEAT EXCHANGERS

8.6.1 The possibility of detection of leakages and the location of the damaged member by means of a pressure test shall be provided in the heat exchangers of the gas turbines (regenerators and gas coolers).

The regenerators shall be tested for tightness both on the gas and the air side.

The method and procedure for detecting the leakages and damaged components, as well as disconnection thereof shall be set forth in special instructions.

8.6.2 Dangerous resonance vibrations and self-excited vibrations of the heat exchanger components shall be excluded.

8.6.3 The regenerator shall be provided with a fire extinguishing system in compliance with the requirements of item **11** of Table 3.1.2.1, Part VI "Fire Protection".

8.6.4 The air coolers of the gas turbines shall comply with the requirements of **1.5.6**.

8.6.5 The air coolers shall provide for the possibility of the inspection and cleaning of the tube plates and muffling without removing the covers.

8.6.6 The air coolers shall be provided with arrangements for continuous removal of moisture falling out of the air during the gas turbine operation.

8.6.7 Besides, the heat exchangers shall be in accordance with the requirements of Sections **1**, **2** and **6**, Part X "Boilers, Heat Exchangers and Pressure Vessels" except for **6.3.1** – **6.3.4** and **6.3.6**.

8.7 CONTROL, PROTECTION AND REGULATION

8.7.1 The main gas turbine shall be provided with the automatic regulation and remote control systems ensuring the following:

.1 setting the necessary rates and steady maintaining thereof throughout the whole range of operating speeds so that thermal shocks are avoided;

.2 starting and stopping under any operating conditions;

.3 maintaining of steady operation of the compressors and combustion chambers under any transient service conditions and under load;

.4 preventing a sudden increase of gas temperature;

.5 unified control of the gas turbine and propeller by the single lever or hand wheel, preserving the possibility of separate control;

.6 restriction of torque at the power take-off shaft, where necessary;

.7 purging the combustion chambers of turbines and the offtake pipe from liquid or gaseous fuel oil accumulated there before ignition at start or after unsuccessful start (refer to **8.1.17**).

The starting devices shall be designed so that the ignition process stops and the main fuel valve is closed at the ignition failure, protection being activated or gas turbine stop.

8.7.2 Each power turbine shall be provided with an overspeed device (on rotation speed) directly connected to the turbine shaft.

The overspeed device and the actuators of protection system shall have high speed and shall not allow the acceleration of the turbine above the specified "maximum permissible" speed.

The maximum permissible speed shall not exceed the rated speed by more than 15 %.

8.7.3 Main gas turbines transmitting power directly to the propeller shall have a speed governor besides the overspeed device, which shall limit the speed of the power turbine in case of load fluctuations before the overspeed device is actuated.

The speed governor shall be so adjusted that the power turbine rotation speed would not exceed the rated rotation speed by more than 8 %.

If fuel supply is reduced by the governor, stopping of the gas turbine is not permitted. Generator-driving gas turbines shall have their speed governors in compliance with the requirements of **2.11.3** – **2.11.5**.

8.7.4 The main gas turbine shall provide the standby "crush stop" condition ready for immediate use for at least 60 min ensuring beginning of ship's movement immediately after receiving the command. In a "crush stop" condition the speed of the propeller shaft shall not exceed 3 rpm.

Unlimited readiness of the gas turbine for immediate use for at least 20 min shall ensure within this period the possibility for heating of the gas turbine, its starting, as well as beginning of ship's movement.

8.7.5 The requirements of **2.4**, Part XV "Automation" shall be met.

8.7.6 Main and auxiliary gas turbines shall be fitted with an arrangement for emergency stopping under any operating conditions by at least two independent means.

When operating from the bridge control at the wheelhouse, provision shall be made for an emergency stopping of the gas turbine from the control station in the engine room in close proximity to the turbine.

8.7.7 The manoeuvring arrangement of the gas turbine installation with an astern turbine shall comply with the requirements of **3.6.1** and **3.6.2**.

The manoeuvring ahead and astern valves shall be interlocked. Irrespective of the position of manoeuvring valves, the operation of the gas turbine compressors shall be sufficiently stable.

The gas turbine installation shall be provided with a local control station for the astern turbine.

8.7.8 In addition to the overspeed device operation, the gas turbine protection system shall provide full interruption of fuel supply in case of alarm for the following parameters:

.1 lubricating oil pressure drop in the system below the permissible level;

.2 gas temperature rise above the permissible level before or after the turbine;

.3 limit level of vibration;

.4 flame-out;

.5 excess of revolutions of a low pressure compressor exceeding permissible value (for three-shaft gas turbines with a free-propeller turbine and gas reverse);

.6 limiting axial rotor shift;

.7 dangerous air pollution of the machinery and boiler room, if gas-operated.

In case of emergency, the provision shall be made for the manual interruption of fuel supply from the local control station in the vicinity of the gas turbine.

Proceeding from the gas turbine design, the manufacturer may introduce additional types of protection.

8.7.9 Automated main gas turbines shall comply with the requirements of Part XV "Automation".

8.7.10 The gas turbine control system shall also comply with the requirements of **2.5**, **3.1** to **3.3**, Part VII "Machinery Installations".

8.7.11 The working medium of the control system shall not become viscous at low temperatures or be readily flammable.

The filter and heat exchanger system shall provide the necessary temperature and purity of the working medium.

8.7.12 For main gas turbines, provision shall be made for monitoring the readings of permanent tachometers.

8.7.13 The control systems of gas turbines intended for driving generators shall be in compliance with the requirements of**2.11.3** – **2.11.7**.

8.8 INSTRUMENTATION

8.8.1 The control station of the main gas turbine shall be provided with instruments for measuring parameters in accordance with **8.7.9**, with devices specified in **3.7.2.2** to **3.7.2.4**, as well as instruments to carry out thermal check of the gas turbine operation.

8.8.2 The control stations of the auxiliary gas turbines shall be provided with instruments to measure the following parameters:

.1 rotor rotation speed;

.2 lubricating oil pressure at the gas turbine inlet;

.3 fuel oil pressure at the gas turbine inlet;

.4 lubricating oil temperature at the gas turbine inlet;

.5 gas temperature at turbine inlet or outlet.

8.8.3 Where the main gas turbine is provided with a system for monitoring and preventive diagnostics, the number of parameters within such a system shall be agreed upon with the Register.

8.9 WASTE-HEAT CIRCUIT OF GAS TURBINE

8.9.1 Where the gas turbine units are provided with waste-heat circuits, the steam turbine shall be in compliance with the requirements of Section **3** of the present Part and the waster heat boiler shall comply with the requirements of Part X "Boilers, Heat Exchangers and Pressure Vessels".

8.9.2 The waster-heat circuits shall be provided with systems to ensure evacuation in condensers before or during the gas turbine start.

Condensers shall be provided with protection against pressure rising above permissible values.

8.9.3 At the beginning of the rotor rotation, provision shall be made for an automatic disconnection of the shaft-turning gear of the steam turbine.

8.9.4 In case two gas turbines with wasteheat circuits are installed in a twin-shaft ship, an operating mode is permitted with the shaft on one side being driven by the gas turbine and the shaft on the other side being driven by the steam turbine.

In this case, quick disconnecting clutches shall be used, which serviceability shall be tested by the special program approved by the Register.

8.9.5 Steam turbine plants working on waste steam shall comply with the requirements of Sections **17** to **19**, Part VIII "Systems and Piping".

8.10 NATURAL GAS FIRED TURBINES

8.10.1 Requirements of the Chapter cover the gas turbines installed on board gas carriers and using the vapours of the natural gas (methane) carried as fuel (refer to **1.1.3**, Part VII «Machinery Installations»).

For this purpose, the gas carrier shall be provided with an installation to prepare the gas vapours for using in the gas turbine.

8.10.2 Natural gas fired turbines are subject to the requirements of **8.1 – 8.9**.

8.10.3 Natural gas is used to start the turbine and operate it in all modes. 8.10.4 The gas fuel supplied to the turbine shall not include any liquid fraction.

8.10.5 Gas fuel supply piping shall comply with the requirements of **13.12**, Part VIII "Systems and Piping".

8.10.6 For gas-fired operation, the requirements of **2.4**, Part XV "Automation" shall be met.

8.10.7 In case of stop of gas fuel supply, the gas turbine shall be shut down automatically by means of a quick shut-off valve fitted as near to the gas turbine as possible.

8.10.8 A manual gas fuel shut-off device shall be provided directly at the gas turbine. Besides, manual shutdown shall be possible from several locations in the engine room, from a space other than the engine room and from the navigation bridge.

8.10.9 In the engine room, an alarm shall be provided for the maximum permissible gas concentration corresponding to 30 % of the lower flammability limit, with an alarm to be installed at the main machinery control room.

The gas supply to the turbine shall be shut off automatically with the gas concentration in the machinery space reaching 60 % of the lower flammability limit.

The requirement of 8.4.5 shall also be met.

8.10.10 Gas turbine operation using two types of fuel (liquid and gas fuel) requiring special fuel equipment to be installed shall be approved by the Register.

The requirements for the operation of a gas turbine, specified in this section, in this case, remain.

8.10.11 Unless designed with the strength to withstand the worst-case overpressure due to ignited gas leaks, pressure relief systems shall be suitably designed and fitted to the exhaust system, taking into consideration the explosions due to gas leaks.

Pressure relief systems within the exhaust uptakes shall be lead to a safe location, away from personnel.

Gas exhaust systems shall be designed to prevent any accumulation of unburned gaseous fuel.

8.10.12 The gas turbine may be fitted in a gastight enclosure arranged in accordance with the ESD principle (refer to **2.10.4.4.3**, Part VII «Machinery Installations» and **13.11.6**, Part VIII «Systems and piping»), however a pressure above 1 MPa in the gas supply piping may be accepted within this enclosure.

8.10.13 Gas detection systems and shutdown functions shall be as outlined for ESD protected machinery spaces.

8.10.14 Ventilation for the enclosure shall be as specified in **12.14**, Part VIII «Systems and piping» for ESD protected machinery spaces, but shall in addition be arranged with full redundancy (2x100 % capacity fans from different electrical circuits).

8.10.15 For other than single-fuel gas turbines (refer to **8.10.10**), an automatic system shall be fitted to change over easily and quickly from gas fuel operation to oil fuel operation and vice-versa with minimum deviations of the engine power from the mean value.

8.10.16 Means shall be provided to monitor and detect poor combustion that may lead to unburnt fuel gas in the exhaust gas system during operation. In the event that it is detected, the fuel gas supply shall be shutdown.

8.10.17 Each turbine shall be fitted with an automatic shutdown device when maximum exhaust temperatures are exceeded.

9. GAS INTERNAL COMBUSTION ENGINES

9.1 GENERAL

9.1.1 The requirements of the present Section are applicable to dual-fuel internal combustion engines (DF engines) with ignition from compression, operated on liquid fuel and natural gas (methane) as well as to gas-fuel internal combustion engines (GF engines) operated on natural gas only.

The requirements of **9.2 — 9.11** are applicable to all crosshead-type engines as well as to trunk piston internal combustion engines operating on gas with a maximum working gas pressure of more than 1,0 MPa.

The requirements of **9.2**, **9.3**, **9.12**, **9.13** are applicable to trunk piston internal combustion engines operating on gas with a maximum working gas pressure of 1,0 MPa and less. The gas can be ignited by the combustion of a certain amount of fuel (pilot injection) or by extraneous ignition (sparking plug).

Gas can be introduced as follows:

into the air inlet manifold, scavenge space, or cylinder air inlet channel port; or

mixed with air before the turbocharger ("pre-mixed engines").

9.1.2 Individual requirements relevant to the application of the DF engines are given in **4.1 — 4.2** Part VII "Machinery Installations" and in **5.5.1** of the present Part..

9.1.3 Engines intended for installation on ships with the distinguishing mark GFS[10] in the class symbol shall additionally meet the applicable requirements of. **9.14**.

9.2 DEFINITIONS AND EXPLANATIONS

9.2.1 Definitions and explanations concerning the general terminology of the Rules are specified in the General Provisions on Classification and Other Activities and in Part I "Classification".

In this Section the following definitions are accepted:

Recognized standards mean applicable international or national standards acceptable by the Register or standards laid down and maintained by an organization which complies with the standards adopted by IMO and which are recognized by the Register.

Gas (Gas fuel) means a fluid having a vapour pressure exceeding 0,28 MPa absolute at a temperature of 37,8 °C.

Low pressure gas means gas with a pressure up to 1,0 MPa.

Gas engine means either a DF engine or a GF engine.

Gas piping means piping containing gas or air / gas mixtures, including venting pipes.

Pre-mixed engine means an engine where gas is supplied in a mixture with air before the turbocharger.

Gas fuel only engine ("GF engine") means an engine capable of operating on gas fuel only and not able to switch over to oil fuel operation.

Dual fuel engine ("DF engine") means an engine that can burn natural gas as fuel simultaneously with liquid fuel, either as pilot oil or bigger amount of liquid fuel (Gas mode), and also has the capability of running on liquid diesel fuel oil only (Diesel mode).

Pilot fuel means the fuel oil that is injected into the cylinder to ignite the main gas-air mixture on DF engines.

Double block and bleed valves mean the set of valves referred to in:

IGC Code, **16.4.5**;

IGF Code, **2.2.9** and **9.4.4 — 9.4.6**.

Gas admission valve is a valve or injector on the engine, which controls gas supply to the cylinder(s) according to the cylinder(s) actual gas demand.

IGC Code means the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (reissued in accordance with MSC.370(93)), as amended by IMO resolutions MSC.411(97) and MSC.441(99).

IGF Code means the International Code of Safety for Ships Using Gases or other Low Flashpoint Fuels (IMO resolution MSC.391(95),) as amended by IMO resolution MSC.458(101).

Safety Concept is a document describing the safety philosophy with regard to gas as fuel, risks associated with this type of fuel, risk control under reasonably foreseeable abnormal conditions, possible failure scenarios and their control measures including a detailed evaluation regarding the hazard potential of injury from a possible explosion.

Methane Number is a measure of resistance of a gas fuel to knock, which is assigned to a test fuel based upon operation in knock testing unit at the same standard knock intensity (pure methane is used as the knock resistant reference fuel, that is, methane number of pure methane is 100, and pure hydrogen is used as the knock sensitive reference fuel, methane number of pure hydrogen is 0).

Lower Heating Value ("LHV") means the amount of heat produced from the complete combustion of a specific amount of fuel, excluding latent heat of vaporization of water.

Certified safe type means electrical equipment that is certified in accordance with the recommendation published by the International Electrotechnical Commission (IEC), in particular publication IEC 60092-502:1999, or with recognized standards at least equivalent. The certification of electrical equipment is to correspond to the category and group for methane gas.

Engine room is a machinery space or enclosure containing gas fuelled engine(s).

Gas Valve Unit (GVU) is a set of manual shutoff valves, actuated shut-off and venting valves, gas pressure sensors and transmitters, gas temperature sensors and transmitters, gas pressure control valve and gas filter used to control the gas supply to each gas consumer. It also includes a connection for inert gas purging.

9.3 RISK ANALYSIS

9.3.1 Scope of the risk analysis.

The risk analysis is to address:

a failure or malfunction of any system or component involved in the gas operation of the engine;

a gas leakage downstream of the gas valve unit;

the safety of the engine in case of emergency shutdown or blackout, when running on gas;

the inter-actions between the gas fuel system and the engine.

With regard to the scope of the risk analysis it shall be noted that failures in systems external to the engine, such as fuel storage or fuel gas supply systems, may require action from the engine control and monitoring system in the event of an alarm or fault condition.

Conversely failures in these external systems may, from the ship perspective, require additional safety actions from those required by the engine limited risk analysis.

9.3.2 Form of the risk analysis. The risk analysis shall be carried out in accordance with international standard ISO 31010:2009: Risk management – Risk assessment techniques, (in Ukraine - IEC/ISO 31010:2013) or other recognized standards.

The required analysis shall be based on the single failure concept, which means that only one failure needs to be considered at the same time.

Both detectable and non-detectable failures shall be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

9.3.3 Procedure for the risk analysis.

The risk analysis shall:

.1 identify all the possible failures in the concerned equipment and systems which could lead:

to the presence of gas in components or locations not designed for such purpose, and/or to ignition, fire or explosion;

.2 evaluate the consequences;

.3 where necessary, identify the failure detection method;

.4 where the risk cannot be eliminated, identify the corrective measures in the system design (such as, redundancies safety devices, monitoring or alarm provisions which permit restricted operation of the system), in the system operation (such as initiation of the redundancy, activation of an alternative mode of operation).

The results of the risk analysis shall be documented.

9.3.4 Equipment and systems to be analysed.

The risk analysis required for engines shall cover at least the following aspects:

.1 failure of the gas-related systems or components, in particular: gas piping and its enclosure, where provided; cylinder gas supply valves.

Thus, failures of the gas supply components not located directly on the engine, such as block-andbleed valves and other components of GVU, shall not be considered in the analysis;

.2 failure of the ignition system (oil fuel pilot injection or sparking plugs);

.3 failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.);

.4 for engines where gas is injected upstream of the turbocharger compressor, failure of a component likely to result in a source of ignition (hot spots);

.5 failure of the gas combustion or abnormal combustion (misfiring, knocking)

.6 failure of the engine monitoring, control and safety systems.

Where engines incorporate electronic control systems, a failure mode and effects analysis shall be carried out in accordance with requirements of **9.3.4.1 — 9.3.4.3**;

.7 abnormal presence of gas in engine components (e.g. air inlet manifold and exhaust manifold of DF or GF engines) and in the external systems connected to the engines (e.g. exhaust duct);

.8 changes of operating modes for DF engines;

.9 hazard potential for crankcase fuel gas accumulation, for engines where the space below the piston is in direct communication with the crankcase, refer to **10.3.1.2** of the IGF Code.

9.4 CONDITIONS OF OPERATION ON TWO KINDS OF FUEL

9.4.1 When operated on two kinds of fuel DF engines shall be equipped with the arrangement for supply of starting fuel with further supply of gas fuel.

The possibility of quick change-over from gas fuel to liquid fuel shall be provided. Starting fuel shall be supplied to each cylinder in all operation modes of the DF engines.

9.4.2 Start of DF engines, astern operation shall be carried out on liquid fuel only.

9.4.3 When DF engine is run on variable modes, ships maneuvering, mooring operations, only liquid fuel shall be used.

9.4.4 In case of unexpected gas fuel cut off DF engine shall continue operation on liquid fuel without stop.

9.4.5 DF engines shall be provided with sensors for blocking simultaneous feed of gas fuel and complete supply of liquid fuel.

9.5 CRANKCASE PROTECTION

9.5.1 Crankcases of DF engines shall be fitted with safety valves in way of each crankshaft crank. Design and actuating pressure of the safety valves shall be specified with due regard to the possible explosion of gas fuel leakage accumulated in the crankcase.

9.5.2 When a trunk-piston engine is used as the DF engine, the crankcase shall be protected as follows:

.1 to prevent accumulation of gas fuel leakage, the ventilation of crankcases shall be provided.

Air pipe ends shall be led to safety place and fitted with flame arresters;

.2 detectors of gas fuel leakage or any other equivalent equipment shall be installed.

Device for automatic admission of inert gas is recommended for installation;

.3 mounting of oil mist concentration sensor in the crankcase shall be provided.

9.5.3 When a cross-head type engine is used as the DF engine, the engine crankcase shall be equipped with oil mist concentration sensor or temperature control system of the engine bearings.

9.6 PROTECTION OF SUB-BEARING SPACES OF THE CROSS-HEAD TYPE DF ENGINES

9.6.1 Sub-bearing spaces shall be provided with gas fuel leakage detectors or any other equivalent devices.

9.7 INTAKE AND EXHAUST GAS SYSTEMS

9.7.1 Intake piping and supercharging air receivers as well as exhaust gas collectors shall be fitted with safety valves or other protective devices.

For engines operating on gas with a maximum working gas pressure of not more than 1,0 MPa, the use of other design solutions is allowed provided that proving calculations or experimental data are provided.

9.7.2 Exhaust gas pipelines from DF engines shall not be combined with exhaust gas piping from other engines, boilers or incinerators.

9.7.3 The exhaust gas piping shall be provided with effective means of blowing off.

9.8 STARTING AIR PIPING

9.8.1 Branch pipes of starting air piping laid to each cylinder shall be equipped in compliance with the requirements of **2.9.2**.

9.9 COMBUSTION CONTROL

9.9.1 The range of combustion control shall be determined and presented for approval with due regard to the analysis of the origin of failures and their consequences for all the elements of DF engines affecting the combustion process.

The minimum range of control, types of automatic protection and parameter limit values are given in Table 9.9.1.

Table 9.9.1

№	Controlled parameter or DF engine component	Measurement point or monitoring conditions	Parameter limit values (alarm) or fault symptoms	Automatic shut-off of the gas fuel supply valves	Indication in main machinery control room
1	Gas fuel injection valves and starting oil fuel injectors	Each cylinder	Seizing of gas fuel injection valve in open condition	X	Constantly
		At each cylinder outlet	Ignition failure	X	Constantly
2	Exhaust gas temperature	Deviation from average	max.	X	Constantly
3	Combustion pressure	At each cylinder	max.	X	Constantly
		Deviation from average	max.	X	On call
4	Gas fuel supply pressure	At engine inlet	min.	X	Constantly

9.10 GAS FUEL SUPPLY

9.10.1 At the inlet of gas fuel supply collector to the DF engine cylinders the flame arrester shall be fitted.

9.10.2 An arrangement for manual cut-off the gas fuel supply to the DF engine from the local control station shall be provided.

9.10.3 Gas fuel supply piping shall meet the requirements of **13.12**, Part VIII "Systems and Piping".

9.10.4 The connection of the engine gas collector with the ship gas piping shall provide the necessary flexibility.

9.10.5 The connection of the gas fuel supply collector to the gas fuel injection valves shall provide complete coverage by the protection pipes or ducts.

9.11 GAS FUEL SUPPLY CUT-OFF

9.11.1 Gas fuel supply cut-off to DF engines by means of automatic closing of valves on the engine shall be performed when the DF engine has stopped due for any unknown reason or in cases stated in **9.5.2.2**, **9.5.2.3**, **9.5.3**, **9.6.1**, **9.9.1** of the present Part, and **13.12.3-1** or **13.12.3-3**, Part VIII "Systems and Piping".

9.11.2 2 It is advisable that the main cut-off valve for gas fuel supply to the collector could be automatically closed at the failure of gas fuel feed valves to DF engine combustion chambers (refer to **9.9.1** of the present Part and **13.12.6**, Part VIII "Systems and Piping")..

9.11.3 Gas fuel supply to DF engines shall be automatically terminated when the concentration of gas in the engine room reaches 60 % of the lower inflammability level. The requirements of **9.4.4** shall be met.

9.12 DESIGN OF DF ENGINE AND GF ENGINE

9.12.1 General Design principles.

9.12.1.1 The manufacturer is to declare the allowable gas composition limits for the engine and the minimum and (if applicable) maximum methane number.

9.12.1.2 Components containing or likely to contain gas shall be designed to:

minimize the risk of fire and explosion so as to demonstrate an appropriate level of safety commensurate with that of an oil-fueled engine;

mitigate the consequences of a possible explosion to a level providing a tolerable degree of residual risk, due to the strength of the component(s) or the fitting of suitable pressure relief devices of an approved type.

Discharge from pressure relief devices shall prevent the passage of flame to the machinery space and be arranged such that the discharge does not endanger personnel or damage other engine components or systems. Relief devices shall be fitted with a flame arrester.

Also refer to the IGF Code **10.2** and **10.3**.

9.12.2 Requirements for design and gas piping as an engine component.

9.12.2.1 The piping shall be designed in accordance with the criteria for gas piping (design pressure, wall thickness, materials, piping fabrication and joining details etc.) as given in the IGF Code chapter **7**.

For engines of gas carriers, IGC Code chapter **5.1** to **5.9** and **16** applies..

9.12.2.2 Pipes and equipment containing fuel gas are defined as hazardous area Zone 0 (refer to IGF Code **12.5.1**).

The space between the gas fuel piping and the wall of the outer pipe or duct is defined as hazardous area Zone 1 (refer to IGF Code **12.5.2.6**),

9.12.2.3 The "double wall" gas piping system on the engine shall be arranged according to the principles and requirements of the IGF Code **9.6**.

For engines of gas carriers, IGC Code **16.4.3** applies.

9.12.2.4 The design criteria for the double pipe or duct are given in the IGF Code **7.4.1.4** and **9.8**.

In case of a ventilated double wall, the ventilation inlet shall be located in accordance with the provisions of IGF Code, regulation **13.8.3**. For gas carriers, IGC Code **16.4.3.2** applies.

The pipe or duct shall be tested in accordance with **21.2.1**, Part VIII "Systems and Piping" to ensure gas tight integrity and to show that it can withstand the expected maximum pressure at gas pipe rupture.

9.12.2.5 Alternative arrangement. Single walled gas piping is only acceptable:

for engines installed in ESD protected machinery spaces, as defined in IGF Code **5.4.1.2** and in compliance with other relevant parts of the IGF Code (e.g. **5.6**);

in the case gas is supplied into the air inlet directly on each individual cylinder during air intake to the cylinder on a low pressure engine, such that a single failure will not lead to release of fuel gas into the machinery space.

For engines of gas carriers, the IGC Code applies.

In case of gas leakage in an ESD-protected machinery space, which result in the shutdown of the engine(s) in that space, a sufficient propulsion and manoeuvring capability including essential and safety systems shall be maintained (refer to **2.1.16**, Part VII "Machinery installations").

9.12.2.6 The safety concept of the engine is to indicate application of the "double wall" or "alternative" arrangement.

9.12.2.7 Charge air system on the engine.

The charge air system on the engine shall be designed in accordance with **9.12.1.2**.

In case of a single engine installation, the engine shall be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event. Sufficient power for propulsion capability shall be maintained.

Load reduction shall be considered on a case by case basis, depending on engine configuration (single or multiple) and relief mechanism (self-closing valve or bursting disk).

9.12.2.8 Exhaust system on the engine.

The exhaust gas system on the engine shall be designed in accordance with **9.12.1.2**.

In case of a single engine installation, the engine shall be capable of operating at sufficient load to maintain power to essential consumers after opening of the pressure relief devices caused by an explosion event.Sufficient power for propulsion capability shall be maintained.

Continuous relief of exhaust gas (through open rupture disc) into the engine room or other enclosed spaces is not acceptable.

9.12.2.9 Engine crankcase.

9.12.2.9.1 Crankcase explosion relief valves shall be installed in accordance with **2.3.5** (refer also to IGF Code **10.3.1.2**).

9.12.2.9.2 Inerting.

For maintenance purposes, a connection, or other means, shall be provided for crankcase inerting and ventilating and gas concentration measuring.

9.12.2.10 Gas ignition in the cylinder.

Requirements of IGF Code **10.3** apply.

For engines of gas carriers, IGC Code **16.7** applies.

9.12.2.11 Control, monitoring, alarm and safety systems.

The engine control system shall be independent and separate from the safety system.

The gas supply valves shall be controlled by the engine control system or by the engine gas demand.

Combustion shall be monitored on an individual cylinder basis. In the event that poor combustion is detected on an individual cylinder, gas operation may be allowed in the conditions specified in IGF Code **10.3.1.6**.

If monitoring of combustion for each individual cylinder is not practicable due to engine size and design, common combustion monitoring may be accepted.

Unless the risk analysis required by **9.3** proves otherwise, the monitoring and safety system functions for DF or GF engines shall be provided in accordance with Table 9.12.2.11.

9.12.2.12 Gas admission valves.

Gas admission valves shall be certified safe by a competent body as follows:

the inside of the valve contains gas and shall therefore be certified for Zone 0;

when the valve is located within a pipe or duct in accordance with **9.12.2.3** and **9.12.2.4**, the outside of the valve shall be certified for Zone 1;

when the valve is arranged without enclosure in accordance with the ESD-protected machinery space (taking in account **9.12.2.5** and **9.12.2.6**) concept, no certification is required for the outside of the valve, provided that the valve is de-energized upon gas detection in the space.

However, if they are not rated for the zone they are intended for, it shall be documented that they are suitable for that zone.

Documentation and analysis shall be based on IEC 60079-10-1:2013 or IEC 60092-502:1999.

Table 9.12.2.11 **Monitoring and Safety System Functions for DF (applies only to the gas mode) and GF Engines**

Parameter	Alarm	Automatic activation of the double block and bleed valves[7]	Automatic activation of the double block and bleed valves[1]	Engine shutdown
1	2	3	4	5
Abnormal pressures in the gas fuel supply line	X	X	X	X[5]
Gas fuel supply systems – malfunction	X	X	X	X[5]
Pilot fuel injection or spark ignition systems – malfunction	X	X[2]	X	X[2, 5]
Exhaust gas temperature after each cylinder – high	X	X[2]	X	X[2, 5]
Exhaust gas temperature after each cylinder, deviation from average – low[3]	X	X[2]	X	X[2, 5]
Cylinder pressure or ignition – failure, including misfiring, knocking and unstable combustion	X	X[2, 4]	X[4]	X[2, 4, 5]
Oil mist concentration in crankcase or bearing temperature[6] – high	X	X		X
Pressure in the crankcase – high[4]	X	X	X	
Engine stops – any cause	X	X		
Failure of the control-actuating medium of the block and bleed valves[7]	X	X	X	

[1] DF engine only, when running in gas mode.

[2] For GF engines, the double block and bleed valves and the engine shutdown may not be activated in case of specific failures affecting only one cylinder, provided that the concerned cylinder can be individually shutoff and the safe operation of the engine in such conditions is demonstrated by the risk analysis.

[3] Required only if necessary for the detection of misfiring.

[4]) In the case where the failure can be corrected by an automatic mitigation action, only the alarm may be activated. If the failure persists after a given time, the safety actions shall be activated.

[5] GF engine only.

[6] Where required in compliance with **2.3**

[7] DBBV – the double block and bleed valves

9.13 SPECIFIC DESIGN REQUIREMENTS

9.13.1 DF engines.

9.13.1.1 General.

The maximum continuous power that a DF engine can develop in gas mode may be lower than MCR of the engine (i.e. in oil fuel mode), depending in particular on the gas quality.

This maximum power available in gas mode and the corresponding conditions shall be stated in the technical documentation and demonstrated during the type test taking into account the requirements of Section **5**, Part IV "Technical Supervision during manufacture of products" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

9.13.1.2 Starting, changeover DF engines and stopping.

DF engines shall be arranged to use either oil fuel or gas fuel for the main fuel charge and with pilot oil fuel for ignition.

The engines shall be arranged for rapid changeover from gas use to fuel oil use. In the case of changeover to either fuel supply, the engines shall be capable of continuous operation using the alternative fuel supply without interruption to the power supply.

Changeover to gas fuel operation shall be only possible at a power level and under conditions where it can be done with acceptable reliability and safety as demonstrated through testing.

Changeover from gas fuel operation mode to oil fuel operation mode shall be possible at all situations and power levels.

The changeover process itself from and to gas operation shall be automatic but manual interruption shall be possible in all cases. In case of shut-off of the gas supply, the engines shall be capable of continuous operation by oil fuel only.

9.13.1.3 Pilot injection.

Gas supply to the combustion chamber shall not be possible without operation of the pilot oil injection. Pilot injection shall be monitored by fuel oil pressure and combustion parameters or otherwise.

9.13.2 GF engines.

9.13.2.1 Spark ignition system.

In case of failure of the spark ignition, the engine is to be shut down except if this failure is limited to one cylinder, subject to immediate shut off of the cylinder gas supply and provided that the safe operation of the engine is substantiated by the risk analysis and by tests.

9.13.3 Pre-mixed engines.

9.13.3.1 Charge air system. Inlet manifold, turbo-charger, charge air cooler, etc. are to be regarded as parts of the fuel gas supply system.

Failures of those components likely to result in a gas leakage shall be considered in the risk analysis (refer to **9.3**).

Flame arresters shall be installed before each cylinder head, unless otherwise justified in the risk analysis, considering design parameters of the engine such as the gas concentration in the charge air system, the path length of the gas-air mixture in the charge air system, etc.

9.14 ADDITIONAL REQUIREMENTS FOR INTERNAL COMBUSTION GAS ENGINES INTENDED FOR INSTALLATION ON SHIPS WITH A GFS SIGN IN THE SHIP'S CLASS NOTATION

9.14.1 General requirements for internal combustion engines.

9.14.1.1 The exhaust gas system shall be equipped with explosion relief ventilation sufficiently dimensioned to prevent excessive explosion pressures in the event of ignition failure of one cylinder followed by ignition of the unburned gas in the system.

Note: Since 01.01.2024 refer to **9.14.1.1-1**.

9.14.1.1-1.[10] The exhaust system shall be equipped with explosion relief systems unless designed to accommodate the worst case overpressure due to ignited gas leaks or justified by the safety concept of the engine.

A detailed evaluation of the potential for unburnt gas in the exhaust system is to be undertaken covering the complete system from the cylinders up to the open end.

This detailed evaluation shall be reflected in the safety concept of the engine.

9.14.1.2 For engines where the space below the piston is in direct communication with the crankcase, a detailed evaluation regarding the hazard potential of fuel gas accumulation in the crankcase shall be carried out and reflected in the safety concept of the engine.

9.14.1.3 Each engine other than two-stroke cross-head type diesel engines shall be fitted with vent systems independent of other engines for crankcases and sumps.

[10] Refer to IMO MSC.458(101).

9.14.1.4 Where gas can leak directly into the working media of auxiliary system (lubricating oil, cooling water), appropriate means shall be fitted after the engine outlet to extract gas in order to prevent gas dispersion.

The gas extracted from the working media of auxiliary systems shall be vented to a safe location in the atmosphere.

9.14.1.5 For engines fitted with ignition systems, prior to admission of gas fuel, correct operation of the ignition system on each unit shall be verified.

9.14.1.6 A means shall be provided to monitor and detect poor combustion or misfiring. In the event that it is detected, gas operation may be allowed provided that the gas fuel supply to the concerned cylinder is shut off and provided that the operation of the engine with one cylinder cut-off is acceptable with respect to torsional vibrations.

9.14.1.7 For engines starting on fuels in accordance with **9.1.1**, if combustion has not been detected by the engine monitoring system within an engine specific time after the opening of the fuel supply valve, the fuel supply valve shall be automatically shut off.

Means to ensure that any unburnt fuel mixture is purged away from the exhaust system shall be provided.

9.14.1.8 Premixed engines using fuel gas mixed with air before turbocharger shall be located in ESD protected machinery spaces.

9.14.2 Requirements for dual fuel internal combustion engines.

9.14.2.1 In case of shutoff of the gas fuel supply, the engines shall be capable of continuous operation by oil fuel only, without interruption.

9.14.2.2 An automatic system shall be fitted to change over from gas fuel operation to oil fuel operation and vice versa with minimum deviations of the engine power from the mean value. Acceptable reliability shall be demonstrated through testing.

In case of unstable operation on engines when gas firing, the engine shall automatically change to oil fuel mode. Manual activation of gas system shutdown shall always be possible.

9.14.2.3 In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

9.14.3 Requirements for gas-only engines.

9.14.3.1 In case of a normal stop or an emergency shutdown, the gas fuel supply shall be shut off not later than the ignition source. It shall not be possible to shut off the ignition source without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

9.14.4 Requirements for multi-fuel engines.

9.14.4.1 In case of shutoff of one fuel supply, the engines shall be capable of continuous operation by an alternative fuel with minimum deviations of the engine power.

9.14.4.2 An automatic system shall be fitted to change over from one fuel operation to an alternative fuel operation with minimum deviations of the engine power from the mean value.

Acceptable reliability shall be demonstrated through testing. In the case of unstable operation on an engine when using a particular fuel, the engine shall automatically change to an alternative fuel mode. Manual activation shall always be possible.

General requirements for multi fuel engines are given in Table 9.14.4.2.

Table 9.14.4.2 **Characteristics of multi fuel engines**

Engine parameters	Fuel			
	Gas only		Dual fuel	Multi fuel
Ignition medium	Spark	Pilot fuel	Pilot fuel	N/A
Main fuel	Gas	Gas	Gas and/or oil fuel	Gas and/or oil fuel

PART X. BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of the present Part of the Rules apply to boilers, heat exchangers and pressure vessels, excluding:

.1 water heating boilers (not mentioned in **1.3.2.1** and **1.3.2.3**);

.2 manned submersibles and diving systems as re-gards the construction and strength of their pressure hulls;

.3 non-stationary standard liquefied gas cylinders (refer to **1.3.2.4**);

.4 assemblies and components of units that are not self-contained pressure vessels;

.5 units comprising pressure pipe systems and instal-led outside boilers, heat exchangers or pressure vessels;

.6 air coolers designed to operate at a working pressure less than 0,1 MPa in the air space;

.7 heat exchangers and vessels subjected exclusively to liquid pressure (not mentioned in **1.3.2.1** and **1.3.2.3**).

1.1.2 The requirements of the present Part also apply to oil burner units of boilers.

1.2 DEFINITIONS AND EXPLANATIONS

1 The definitions and explanations relating to general terminology of the Rules are given in General regulations on classification and other activities and in Part I "Classification" of the Rules for the classification and construction of ships.

For the purpose of the present Part the following definitions have been adopted.

Automatic boiler oil burner unit is a device for combustion of fuel oil, the operation of which is controlled automatically, without any direct attendance of the operating personnel.

Auxiliary boilers for essential services are boilers, which supply steam to the auxiliary machinery, systems and equipment providing propulsion of the ship, safety of navigation and proper carriage of goods, if no other sources of power being available on board the ship for operating the said machinery, equipment and systems in case the boilers fail to operate.

Water heating boiler is a ship's boiler heating water or water-base liquid systems (e.g.ethylene glycol solution in water) of appropriate temperature.

Steam boiler is a ship's boiler generating steam of appropriate steam conditions.

Working pressure is the maximum permissible pressure under normal conditions on continuous running, excluding permissible short-time pressure rises, such as may be occasioned by the operation of a safety valve or other protective devices.

Design boiler capacity is the maximum amount of steam that can be generated by the boiler at design parameters during 1 h on continuous running.

Design wall temperature is the average wall thickness temperature used in calculation of allowable stresses in dependence upon the temperature of the medium and the heating conditions.

Design pressure is the pressure used in strength calculations.

Walls of boilers, heat exchangers and pressure vessels are the walls of steam and water (gas and liquid) spaces as well as the walls of branch pipes up to the stop valves and the walls of stop valve bodies.

1.3 SCOPE OF SURVEYS

1.3.1 The general provisions relating to procedure of classification, survey during construction and in service are given in the General Regulations for the Classification and Other Activity and in Part I "Classification".

1.3.1.2 Boilers, heat exchangers and pressure vessels are classified in accordance with Table 1.3.1.2 depending on the parameters and design features.

1.3.1.3 Boilers and heat exchangers of Class I and II shall be produced by manufacturers having the Recognition Certificate of the Register.

Table 1.3.1.2

Item	Class		
	I	II	III
Boilers including waste-heat boilers and water heating boilers designed for water temperature above 115°C, steam superheaters and steam headers	$p > 0{,}35$	$p \le 0{,}35$	–
Thermal liquid boilers	Any parameter	–	–
Refrigerants	Group II[1] Any parameter	Group I[1] Any parameter	–
Pressure vessels and heat exchangers with toxic, inflammable[2] or explosive working medium	Any parameter	–	–
Pressure vessels and steam heat exchangers[3]	$p > 1{,}6$ or $t > 350$	$0{,}7 < p \le 1{,}6$ or $350 < t \le 170$	$p \le 0{,}7$ and $t \le 170$
Pressure vessels and thermal liquid heat exchangers[3]	$p > 1{,}6$ or $t > 300$	$0{,}7 < p \le 1{,}6$ or $300 < t \le 150$	$p \le 0{,}7$ and $t \le 150$
Pressure vessels and fuel heat exchangers[3]	$p > 1{,}6$ or $t > 150$	$0{,}7 < p \le 1{,}6$ or $60 < t \le 150$	$p \le 0{,}7$ and $t \le 60$
Pressure vessels and heat exchangers for lubricating oil and fuel oil of hydraulic systems[3]	$p > 1{,}6$ or $t > 300$	$0{,}7 < p \le 1{,}6$ or $90 < t \le 300$	$p \le 0{,}7$ and $t \le 90$
Pressure vessels and heat exchangers for non-combustible media[3, 4]	$p > 4$ or $t > 350$ and $s > 35$	$1{,}6 < p \le 4$ or $200 < t \le 350$ and $16 < s \le 35$	$p \le 1{,}6$ and $t \le 200$ and $s \le 16$

[1] According to **2.2.1**, Part XII "Refrigerating Plants".
[2] For the purpose of the Table flammable medium is any liquid or gas with a flash point less than 60°C.
[3] For heat exchangers, the parameters of the two working media participating in the heat exchange shall be taken into account, the vessel class being selected according to the largest parameter for each medium.
[4] Applicable to heat exchangers and pressure vessels specified in **1.3.2.1.3**.

Symbols:
p – design pressure, in MPa;
t – design wall temperature, in °C;
s – wall thickness, in mm.

1.3.2 Scope of surveys.

1.3.2.1 Subject to survey by the Register in the process of construction are:

.1 steam boilers (including waste-heat boilers), steam superheaters and economizers operating at working pressure of 0,07 MPa and upwards;

.2 thermal liquid boilers (with organic working medium), including waste-heat boilers;

.3 heat exchangers and vessels, which under operating conditions are filled fully or partially with gas or vapour at working pressure of 0,07 MPa and over, and which have a capacity of 0,025 m^3 and over, or with the product of pressure, in MPa, by capacity, in m^3, being 0,03 MPa/m^3 and upwards;

.4 desalinating plants;

.5 condensers of main and auxiliary machinery;

.6 oil burning equipment;

.7 water heating boilers designed for water temperatures above 115°C;

.8 coolers, heaters and filters of fuel and lubricating oil and water for main and auxiliary engines;

.9 automatic devices for control of salinity of boiler feed water;

.10 incinerator boilers.

1.3.2.2 Exempt from the survey by the Register in the process of construction are the heat exchangers and pressure vessels indicated in **1.1.1.2** and **1.1.1.6**.

1.3.2.3 Water heating boilers designed for water temperatures above 115°C shall comply, as regards the materials used and scantlings of elements, with the requirements for steam boilers specified in the present Part.

Note. Filters and coolers of main and auxiliary machinery shall comply, as regards the materials used and scantlings of elements, with the requirements for heat exchangers and pressure vessels specified in the present Part.

1.3.2.4 Cylinders designed for storage of compressed gases and used in various sytems and units for the purposes of ship's operation may be manufactured to the current standards under the supervision of a competent technical supervision body.

1.3.2.5 The scope of survey of the heat exchangers and pressure vessels incorporated into refrigerating plants is specified in **1.1.3**, **1.3.2** and **1.3.3**, Part XII "Refrigerating Plants"..

1.3.3 Components subject to survey.

1.3.3.1 The components specified in Table 1.3.3 are subject to survey by the Register during manufacture according to the technical documentation approved by the Register, the list of which is given in **1.3.4**.

Table 1.3.3

№	Components of boilers, heat exchangers and pressure vessels	Material	Chapter of Part XIII "Materials"
1	**Boilers, steam superheaters, economizers and steam-heated steam generators**		
1.1	Shells, end plates, tube plates, drums, headers and chambers	Rolled steel	3.3
1.2	Heated and non-heated tubes	Rolled steel	3.4
1.3	Furnaces and elements of combustion chambers	Rolled steel	3.3
1.4	Girders, long and short stays	Forged steel Rolled steel	3.7 3.3
1.5	Bodies of valves for pressure of 0,7 MPa and over	Forged steel Cast steel Cast iron Copper alloys	3.7 3.8 3.9 4.1
2	**Heat exchangers and pressure vessels**		
2.1	Shells, distributors, end plates, headers and covers	Forged steel Rolled steel Cast steel Copper alloys Cast iron	3.7 3.3 3.8 4.1 3.9
2.2	Tube plates	Rolled steel Copper alloys	3.3 4.1
2.3	Tubes	Rolled steel Copper alloys	3.4 4.1
2.4	Reinforcing elements, long and short stays	Forged steel Rolled steel	3.7 3.3
2.5	Bodies of valves for pressure of 0,7 MPa and over, 50 mm in diameter and over	Forged steel Cast steel Copper alloys Cast iron	3.7 3.8 4.1 3.9
Note. The material shall be selected according to 1.4.			

1.3.4 Technical documentation.

1.3.4.1 The following technical documentation shall be submitted to the Register before manufacture of boilers, heat exchangers and pressure vessels is commenced:

.1 construction drawings with sections and descriptions, giving all necessary data for checking the calculations and structures (scantlings, materials, electrodes, location and dimensions of weld seams, fastenings, heat treatment methods to be used, etc.);

.2 construction drawings for the components listed in Table 1.3.3, unless all necessary data are shown in the drawings mentioned in **1.3.4.1.1**;

.3 valve replacement with technical data;

.4 strength calculations made in accordance with the present Part of the Rules for components subject to pressure other than valves, flanges and fastenings if the latter comply with the standards approved by the Register;

.5 calculation of cross-sectional area of safety valves;

.6 welding process;

.7 drawings of oil burning equipment, chambers and arrangements for combustion of oil residues and garbage (for incinerator boilers);

.8 for thermal liquid boilers: circuit scheme of the system with description and indication of working parameters, drawings of expansion, drainage tanks and storage tank;

.9 bench test programme.

1.3.4.2 Documentation on automatic control system, protective devices and alarms, as well as on automatic oil burning installations shall be submitted in accordance with the requirements of **4.2**, Part I "Classification" and **1.4**, Part XV "Automation".

1.4 MATERIALS

1.4.1 Materials intended for manufacture of components of boilers, heat exchangers and pressure vessels shall satisfy the requirements of the relevant chapters of Part XIII "Materials" specified in column 4 of Table 1.3.3.

Materials for components of boilers, heat exchangers and pressure vessels of Class I and Class II (except for the components specified in items **1.5** and **2.5**) are subject to survey by the Register during manufacture. Materials for components of boilers, heat exchangers and pressure vessels of Class II and III, listed in Table. 1.3.3, can be supplied with certificates according to form 3.1 of EN 10204 (in Ukraine ДСТУ EN 10204:2017), if the confirmed test results comply with the requirements of the Register Rules. When checking the documents by the Register Surveyor and when the reasonable doubts about the quality of the material used arise, the Register reserves the right to require additional checks on the compliance of the material with the declared properties.

Materials for components of boilers, heat exchangers and pressure vessels of Class III as well as the components specified in items **1.5** and **2.5** of Table 1.3.3 for any Classes may also be selected in accordance with the international and national standards valid at the time of consideration of technical documentation and be supplied with documents of the manufacturer. In this case, the use of materials is subject to agreement with the Register during review of the technical documentation.

1.4.2 Carbon and carbon-manganese steels are permitted for manufacture of components of boilers, heat exchangers and pressure vessels at design temperatures up to 400°C, and low-alloy steel, at design medium temperatures up to 500°C.

The use of these steels for media with temperatures above the specified values may be permitted on condition that their mechanical properties and average stress to produce rupture in 100000 h satisfy the current standards and are guaranteed by the manufacturer at the specified elevated temperature.

For media with temperatures above 500°C the components, valves of boilers and heat exchangers shall generally be made of alloy steel.

1.4.3 For heat exchangers and pressure vessels with design medium temperatures below 250°C, on agreement with the Register, hull structural steel may be used according to the requirements of **3.2**, Part XIII "Materials".

For some components of heat exchangers and pressure vessels with working pressures below 0,7 MPa and design medium temperatures below 120°C semi-killed steel may be used on agreement with the Register.

1.4.4 When the yield stress at the elevated temperature is taken as the design characteristic of the material (refer to **2.1.4.1**), tensile tests of the material shall be carried out at the design wall temperature; when the design characteristic is the average stress to produce rupture in 100 000 h, the data on the average stress at the design wall temperature shall be submitted to the Register.

1.4.5 During the use of alloy steel for boilers, heat exchangers and pressure vessels it is necessary to submit to the Register data on mechanical properties, average stress at the design wall temperature for steel and welded joints, technological characteristics, welding technique and heat treatment.

The use of cast iron and copper alloys for valves of thermal fluid boilers is not permitted.

1.4.6 Boiler valves of nominal diameter from 50 up to 200 mm designed for working pressure up to 1 MPa and temperatures up to 350°C may be manufactured from spheroidal or nodular graphite cast iron of entirely ferritic structure meeting the requirements of Table 3.9.3.1, Part XIII "Materials".

For the same valves with nominal diameter d below 50 mm, the product $p \times d$ shall not exceed 250 MPa×mm.

1.4.7 Components and valves of heat exchangers and pressure vessels with diameters up to 1000 mm and working pressures up to 1 MPa may be manufactured from spheroidal or nodular graphite cast iron of entirely ferritic structure meeting the requirements of Table 3.9.3.1, Part XIII "Materials".

1.4.8 The use of copper alloys for components of boilers, heat exchangers and pressure vessels as well as for their valves is allowed at design medium temperatures up to 250°C and working pressures up to 1,6 MPa.

1.4.9 For components specified under items **1.2** and **2.3** of Table **1.3.3**, on agreement with the Register, electric welded tubes with longitudinal seams may be used if it is demonstrated that they are equivalent to seamless tubes (refer also to **3.2.14**).

1.4.10 Composite materials (structures made of laminated fibrous composite materials and metals, having cylindrical or spherical configuration) may be used in pressure vessels for the design temperatures not higher than 60°C.

The manufacturer or designer shall submit to the Register full details of the materials used (structure and density of reinforcement, moduli of elasticity and shear, yield point, tensile strength, ultimate strains, impact toughness, low cycle fatigue resistance, etc).

Moreover, details of product structure, method of manufacture (residual stresses after liner moulding, heat treatment, etc), working environment and service loads shall be submitted as well.

1.5 WELDING

1.5.1 Welding and non-destructive testing of welded joints shall comply with the requirements specified in Part XIV "Welding".

1.5.2 Typical examples of allowable welded joints are given in the Appendix.

Strength of the structures using fillet joints or joints affected by bending stresses shall be checked by the strength and fatigue calculations.

1.6 HEAT TREATMENT

1.6.1 Components, in which the material structure may undergo changes after welding or plastic working, shall be subjected to appropriate heat treatment.

When performing heat treatment of a welded structure, the requirements of **2.4.4**, Part XIV "Welding" shall be duly observed.

1.6.2 Heat treatment is required for:

.1 plate-steel elements of boilers, vessels and heat exchangers, which are subjected during manufacture to cold stamping, bending and flanging resulting in plastic deformation of surface fibres exceeding 5 %;

.2 tube plates welded of several components (heat treatment, in this case, may be performed before drilling for tube holes);

.3 welded end plates manufactured by cold stamping;

.4 elements subjected to hot forming, with the temperature at the end of this process being lower than that of forging;

.5 welded structures manufactured from steels with a carbon content higher than 0,25 per cent.

1.7 TESTS

1.7.1 On completion of manufacture or assembly all the components of boilers, heat exchangers and pressure vessels shall be subjected to hydraulic tests in accordance with the requirements of Table 1.7.1.

1.7.2 Hydraulic tests shall be carried out on completion of all welding operations and prior to application of insulation and protective coatings.

1.7.3 Where an all-round inspection of the surfaces to be tested is difficult or impossible after assembling the individual components and units, they shall be tested prior to assembling.

1.7.4 The dimensions of components to be tested under test pressure $p_{\omega} + 0{,}1$MPa and also of components to be tested under test pressure above the value given in Table 1.7.1 shall be checked by calculation to this pressure. The stresses involved shall not exceed 0,9 times the yield stress of the material.

1.7.5 After installation on board the ship the steam boilers shall be steam tested under working pressure.

1.7.6 After installation on board the ship the air receivers shall be air tested under working pressure, with all valves complete.

Table 1.7.1

№	Boilers, heat exchangers, pressure vessels and components	Test pressure p_h, MPa	
		after manufacture or joining of strength shell elements without valves	after assembly, with valves installed
1	**2**	**3**	**4**
1	Boilers, steam superheaters, economizers and their components operating at temperatures below 350°C	$1{,}5p_\omega$, but not less than p_ω+0,1MPa	$1{,}25p_\omega$, but not less than p_ω + 0,1 MPa
2	Thermal liquid boilers	$1{,}5p_\omega$, but not less than p_ω+0,1 MPa	$1{,}5p_\omega$, but not less than p_ω + 0,1 MPa
3	Steam superheaters and their components operating at temperatures of 350°C and above	$1{,}5 p_\omega \frac{R_{eL/350}}{R_{eL/t}}$	$1{,}25p_\omega$
4	Heat exchangers, pressure vessels and their components operating at temperatures below 350°C and pressure[1,2] up to 15 MPa above 15 MPa	 $1{,}5p_\omega$, but not less than p_ω+ 0,1 MPa $1{,}35p_\omega$	 – –
5	Heat exchangers and their components operating at temperature 350°C and above and pressure[2] up to 15 MPa above 15 MPa	 $1{,}5 p_\omega \frac{R_{eL/350}}{R_{eL/t}}$ $1{,}35 p_\omega \frac{R_{eL/350}}{R_{eL/t}}$	 – –
6	Oil burning equipment components subject to fuel oil pressure	–	$1{,}5p_\omega$, but not less than 1 MPa
7	Gas spaces of waste-heat boilers	–	To be tested by air pressure at 0,01 MPa
8	Boiler valves	As per **1.3** of Part IX "Machinery", but not less than $2p_\omega$	To be tested for tightness of closure at $1{,}25p_\omega$
9	Feed valves of boilers and shut-off valves of thermal liquid boilers	$2{,}5p_\omega$	Ditto
10	Арматура теплообмінних апаратів і посудин під тис Valves of heat exchangers and pressure vessels ком	As per **1.3** of Part IX "Machinery"	Ditto

[1] For testing ICE coolers, refer to Table 1.3.3, Part IX "Machinery".
[2] With p_ω=15 – 16,6MPa; $p_h \geq$ 22,5MPa.

Symbols:
p_h – test pressure, MPa;
p_ω – working pressure, MPa, but not less than 0,1MPa;
$R_{eL/350}$ – lower yield stress of material at 350°C, MPa;
$R_{eL/t}$ – lower yield stress at operating temperature, MPa.

1.7.7 Heat exchangers and vessels incorporated in refrigerating plants shall be tested as specified in **12.1**, Part XII "Refrigerating Plants".

1.8 BOILER ROOMS

1.8.1 The boiler rooms shall satisfy the requirements of **4.2** to **4.5**, Part VII "Machinery Installations".

2. STRENGTH CALCULATIONS

2.1 GENERAL

2.1.1 Application.

2.1.1.1 The wall thicknesses obtained by calculation are the lowest permissible values under normal operating conditions.

The standards and methods of strength calculation do not take into account the manufacture tolerances for thicknesses, which shall be added as special allowances to the design thickness values.

Additional stresses due to external loads (axial forces, bending moments and torques) acting upon the element under calculation (in particular, loads due to its own mass, the mass of attached elements, etc.) shall be specially taken into account as required by the Register.

2.1.1.2 The dimensions of structural elements of boilers, heat exchangers and pressure vessels, for which no strength calculation methods are given in the present Rules, shall be determined on the basis of experimental data and proved theoretical strength calculations under common and agreed with the Register standards.

2.1.2 Design pressure.

2.1.2.1 The design pressure to be used for strength calculations of the elements of boilers, heat exchangers and pressure vessels shall generally be taken equal to the working pressure of the medium.

The hydrostatic pressure shall be taken into account in the design pressure calculations when it exceeds 0,05 MPa.

2.1.2.2 For uniflow and forced-circulation boilers the design pressure shall be determined with due consideration for the hydrodynamic resistances in boiler elements at the design steaming capacity.

2.1.2.3 For flat walls subject to pressure on both sides, the design pressure shall be taken as equal to the maximum pressure acting on the walls.

The walls with curved surfaces subject to pressure on both sides shall be designed both for the internal and external pressures.

Where the pressure on one side of the wall with flat or curved surface is below the atmospheric pressure, the design pressure shall be taken as equal to the maximum pressure acting on the other side of the wall plus 0,1 MPa.

2.1.2.4 For economizers the design pressure shall be taken as equal to the sum total of the working pressure in the boiler steam drum and the hydrodynamic resistances in the economizer, piping and valves at boiler design steaming capacity.

2.1.2.5 For heat exchangers and pressure vessels incorporated in refrigerating plants the design pressure shall be taken as specified in **2.2.2**, Part XII "Refrigerating Plants".

2.1.3 Design temperature.

2.1.3.1 For the purpose of determining the allowable stresses depending on the temperature of the medium and heating conditions, the design wall temperature shall be taken as not lower than that indicated in Table 2.1.3.1.

2.1.3.2 The design wall temperature t of steam superheater elements with maximum temperature of superheated steam $t_н$ > 400°C shall be determined for several steam superheater cross-sections with regard to possible operational increase in temperature of separate elements and parts within the range of any possible operational steaming capacity.

The maximum temperature obtained from calculation for the most stressed cross-sections of the steam superheater shall be taken as a design temperature.

The rated design temperature of steam superheater tube walls at $t_н$ > 400°C (refer to 2.5 of Table 2.1.3.1) is obtained from the formula

$$t = t_a + \Delta t_q + \Delta t, \qquad (2.1.3.2\text{-}1)$$

where:

t_a – mean temperature of steam in the tube cross-section under consideration, °C. t_a is determined from the analysis of thermal conditions of the steam superheater operation and its layouts and also from the results of thermal calculations for the boiler;

Δt_q – mean difference between the design temperature of the tube wall and steam temperature in the tube crosssection under consideration, °C. To determine this difference, it is necessary to calculate or obtain from the boiler thermal calculations the following values:

α_1 – coefficient of heat transfer from flue gases to the tube wall taken as a mean value around the circumference of the tube,W/(m^2 · K);

α_2 – coefficient of heat transfer from the tube wall to steam, W/(m^2 · K);

α_3 – coefficient of heat transfer by radiator, W/(m^2 · K);

t_k – temperature of flue gases in front of the row of tubes under consideration, °C.

Δt_q is determined from Fig. 2.1.3.2-1.

For determination of Δt_q an auxiliary value A_0 is derived from the formula

$$A_0 = k_0 \frac{1{,}6\alpha_1 + \alpha_3}{\alpha_2}, \qquad (2.1.3.2\text{-}2)$$

where: k_0 – coefficient obtained from Fig. 2.1.3.2-2.

For heated tubes of steam superheaters Δt is dependent upon the coefficient k of uneven heat absorption over the width of the superheater gas flue and upon the steam temperature increment Δt_v at the portion measured from the point of steam entry into the tube to the cross-section under consideration, the value t being obtained from Fig. 2.1.3.2-3.

Coefficient k is taken to be equal to:

1,3 - for vertical water-tube boilers of conventional type with loop or coil superheater;

1,2 - for U-type top-fired boilers with coil superheaters.

Note. In calculation of non-heated headers and tubes of superheaters with $t_н$ > 400°C, the value Δt_v represents the full temperature increment in the superheater step or section under consideration.

Table 2.1.3.1

№	Boiler, heat exchanger, pressure vessel elements and operating conditions thereof	Design wall temperature, °C
1	**2**	3
1	**Elements exposed to radiant heat**	
1.1	Boiler tubes	$t_м + 50$
1.2	Steam superheater tubes	$t + 50$
1.3	Corrugated furnaces	$t_м + 75$
1.4	Plain furnaces, headers, combustion and other chambers	$t_м + 90$
2	**Elements heated by hot gases but protected against radiant heat effect**[1]	
2.1	Shells, end plates, headers, chambers, tube plates and boiler tubes	$t_м + 30$
2.2	Headers and steam superheater tubes at steam temperatures up to 400°C	$t_м + 35$
2.3	Headers and steam superheater tubes at steam temperatures above 400°C	$t_м + x\Delta t + 25$
2.4	Waste-heat boilers operating without flame cleaning of heating surfaces	$t_м + 30$
2.5	Waste-heat boilers operating with flame cleaning of heating surfaces	t_v
3	Elements heated by steam or fluids	t_v
4	Non-heated elements[2]	$t_м$

[1] Refer to **2.1.3.4**.

[2] Refer to **2.1.3.3.**

Symbols:

$t_м$ – maximum temperature of heated medium in the element under consideration, °C;

t_v – maximum temperature of heating fluid, °C;

t – rated design temperature of the tube wall determined from **2.1.3.2**, °C;

Δt – steam temperature increase in the most heat-stressed tube as against the mean temperature t_α (refer to **2.1.3.2**), °C;

x – = factor characterizing steam mixing in the steam superheater header;

x = 0 at the concentrated steam supply to the header sides and ends;

x = 0,5 at the uniform dispersed steam supply to the header.

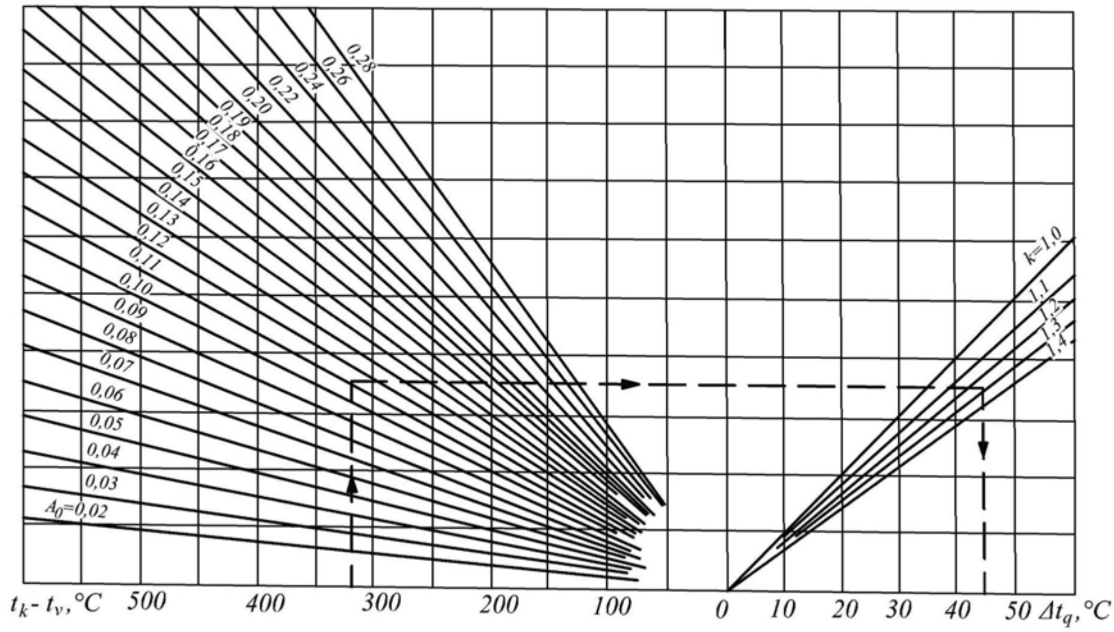


Fig.2.1.3.2-1

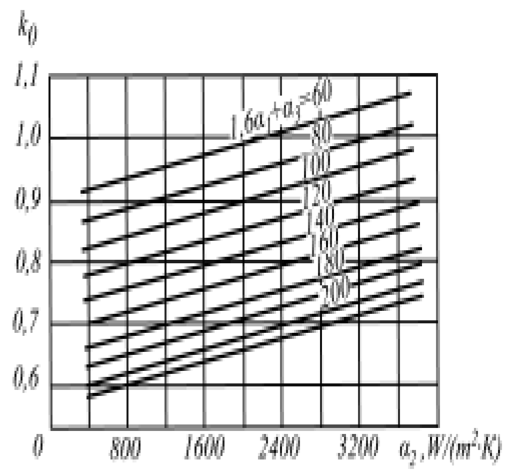


Fig.2.1.3.2-2

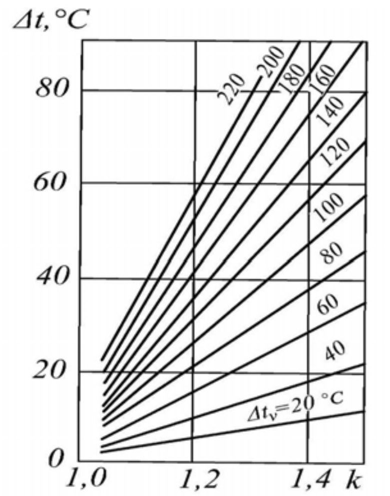


Fig.2.1.3.2-3

2.1.3.3 The walls are considered to be non-heated in the following cases:

.1 the walls are separated from the combustion space or uptake by fire-resistant insulation, the distance between walls and insulation being 300 mm and over; or

.2 the walls are protected with fire-resistant insulation not exposed to radiant heat.

2.1.3.4 The walls are considered to be protected from radiant heat effect in the following cases:

.1 the walls are protected with fire-resistant insulation; or

.2 the walls are protected by a closely spaced row of tubes (with a maximum clearance between the tubes in the row up to 3 mm); or

.3 the walls are protected by two staggered rows of tubes with a longitudinal pitch equal to a maximum of two outside tube diameters or by three or more staggered rows of tubes with a longitudinal pitch equal to a maximum of two and a half outside tube diameters.

2.1.3.5 The design temperature for heated walls of the boiler and non-heated walls of the steamconducting boiler elements shall not be less than 250°C.

2.1.3.6 The design temperature for heated walls of the boiler and non-heated walls of the steamconducting boiler elements shall not be less than 800°C.

If, with wall thicknesses measuring less than 20 mm and flue gas temperatures running higher than 800°8C, there are areas extending over 8 tube diameters and unprotected by insulation or by tube rows, the design wall temperature shall be determined by thermal stress analysis.

The requirements concerning the wall protection from radiant heat effect are given in.

2.1.3.7 The design wall temperature for heat exchangers and pressure vessels operating under coolant pressure shall be taken as equal to 20°C if occurrence of higher temperature is not possible.

2.1.4 Strength characteristics of materials and allowable stresses.

2.1.4.1 When determining the allowable stresses in carbon and alloy steels with the ratio of the upper yield stress R_{eH} to tensile strength R_m not exceeding 0,6, the lower yield stress $R_{eL/t}$ t or proof stress $R_{p0,2/t}$ and the average stress to produce rupture in 100 000 h $R_{m/t100000}$ at design temperatures shall be adopted as design characteristics.

For steels having the ratio of the upper yield stress to tensile strength above 0,6, the tensile strength $R_{m/t}$ at design temperature shall be adopted additionally. For steels, the service conditions of which are characterized by creep (at temperatures above 450°C), irrespective of the value of the ratio R_{eH}/R_m, the creep strength $R_{1\%(10\,^\circ)/t}$ at design temperature shall be added to the above characteristics.

Minimum values of$R_{eL/t}$, $R_{p0,2/t}$ and $R_{m/t}$ as stipulated by the steel specifications shall be adopted, while of $R_{m/t}$ i $R_{1\%(10\,^\circ)/t}$ average values shall be adopted.

2.1.4.2 For materials having no clearly defined yield stress point, the minimum tensile strength value $R_{m/t}$ at the design temperature shall be taken as the design characteristic.

2.1.4.3 For spheroidal or nodal graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure and with elongation less than 5 per cent, the minimum tensile strength valueR_v at 20°C shall be taken as the design strength characteristic.

For cast irons with ferritic structure and elongation more than 5 per cent, the lesser of two values given below shall be taken as the design strength characteristic:

R_v - minimum ultimate strength of material at 20°C or

$R_{0,2}$ - proof stress at 20°C, at which the permanent elongation is 0,2 per cent.

2.1.4.4 When non-ferrous metals and their alloys are used, it shall be taken into account that the heating during working or welding tends to relieve them of the strengthening effects realized under cold conditions.

Therefore, the strength characteristics to be used for strength calculations of components and assemblies manufactured from such materials shall be those applied to their heattreated condition.

2.1.4.5 The recommended values of the design characteristics of steel at higher temperatures are given in Tables 7.1 and 7.2.

For the materials omitted from these tables, strength characteristics are taken according to the standards agreed with the Register.

2.1.4.6 The allowable stress σ, in MPa, used for determining the scantlings shall be adopted equal to the smallest of the following values (bearing the requirements of **2.1.4.1** to **2.1.4.5** in mind):

$$\sigma = R_{m/t}/n_t,\ \sigma = R_{1\%(10\,^\circ)/t}/n_{cs},\ \sigma = R_{eL/t}/n_y - (\text{або } \sigma = R_{p0,2/t}/n_y),\ \sigma = R_{m/t100000}/n_{av}, \quad (2.1.4.6)$$

where:

n_t – tensile strength safety factor;

n_{cs} – creep strength safety factor;

n_y – yield stress safety factor;

n_{av} – safety factor for the average stress to produce rupture in (100 000h.);

$R_{m/t}$ – tensile strength;

$R_{1\%(10\,^\circ)/t}$ – creep strength;

$R_{p0,2/t}$ – proof stress;

$R_{m/t100000}$ – average stress to produce rupture in 100 000 h;

$R_{eL/t}$ – lower yield stress.

The factors are chosen in accordance with**2.1.5**.

2.1.5 Safety factors.

2.1.5.1 For items manufactured of steel forgings and rolled steel, which are under internal pressure, the safety factors shall be chosen of at least:

$$n_y = n_{av} = 1{,}6;\ n_t = 2{,}7 \text{ and } n_{cr} = 1{,}0.$$

For items under external pressure, the safety factors n_y, n_{av} and n_t shall be increased by 20 per cent.

2.1.5.2 For components of boilers, heat exchangers and pressure vessels of Class II and Class III, which are made of steels having the ratio $R_{eH}/R_m \le 0{,}6$, the safety factors may be adopted as follows:

$$n_y = n_{av} = 1{,}5 \text{ and } n_t = 2{,}6.$$

2.1.5.3 For components of boilers, heat exchangers and pressure vessels, which are made of cast steel and are under internal pressure in service, the safety factors shall be chosen of at least:

$$n_y = n_{av} = 2{,}2,\ n_t = 3{,}0,\ n_{cr} = 1{,}0.$$

For items that are under external pressure in service, the safety factors shall be increased by 20 % (except for n_{cr}, which shall remain equal to 1).

2.1.5.4 For essential boiler components being under thermal stress, the safety factors n_y and n_{av} shall be adopted equal to:

3,0 for corrugated furnaces;

2,5 for plain furnaces, combustion chambers, stay tubes, long and short stays;

2,2 for gas uptake pipes subjected to pressure or other similar gas heated walls и.

2.1.5.5 When determining scantlings for the items made of grey cast iron, spheroidal or nodular graphite cast iron and ductile cast iron with ferritic-perlitic and perlitic structure having elongation less than 5 per cent, the tensile strength safety factor n_t shall be adopted equal to 4,8 after annealing and to 7,0 without annealing both for the case of internal and external pressure.

For the items made of cast iron with ferritic structure having elongation more than 5 per cent, the tensile strength safety factor n_t shall be adopted equal to 4,0 for the case of internal pressure and 4,8 for the case of external pressure and the proof strength safety factor n_p shall be taken equal to 2,8.

2.1.6 Efficiency factors.

2.1.6.1 Efficiency factor of welded joints shall be selected from Table 2.1.6.1-1 depending on the type of joint and welding method used; efficiency factor of welded joints depending on the class of boilers, heat exchangers and pressure vessels (refer to **1.3.1.2**) shall not be below the values given in Table 2.1.6.1-2.

Table 2.1.6.1-1

Welding	Welded joint	Weld seam	φ
Automatic welding	Butt joint	Double-sided	1,0
		Single-sided on backing strip	0,9
		Single-sided without backing strip	0,8
	Overlap joint	Double-sided	0,8
		Single-sided	0,7
Machine welding and manual welding	Butt joint	Double-sided	0,9
		Single-sided on backing strip	0,8
		Single-sided without backing strip	0,7
	Overlap joint	Double-sided	0,7
		Single-sided	0,6
Notes: 1. In any case, full root penetration shall be provided. 2. For electroslag welding the efficiency factor of welded joints is taken as φ = 1,0.			

Table ***2.1.6.1-2***

Equipment	Efficiency factor of welded joints φ depending on class of boilers		
	I	II	III
Boilers and steam accumulators	0,90	0,80	–
Steam-heated steam generators	0,90	0,80	–
Heat exchangers and pressure vessels	0,90	0,70	0,60

2.1.6.2 The ligament efficiency factor of cylindrical walls weakened by holes of the same diameter shall be taken as equal to the lowest of the following three values:

.1 the ligament efficiency factor of cylindrical walls weakened by a longitudinal row or a field of unstaggered, equally-pitched holes (refer to Fig. 2.1.6.2.1), as determined by the following formula:

$$\varphi = (a - d)/a; \qquad (2.1.6.2.1)$$

.2 the ligament efficiency factor, reduced to the longitudinal direction, of cylindrical walls weakened by a transverse row or a field of equally-pitched holes (refer to Fig. 2.1.6.2.1), as determined by the following formula

$$\varphi = 2(a_1 - d)/a_1; \qquad (2.1.6.2.2)$$

.3 the ligament efficiency factor, reduced to the longitudinal direction, of cylindrical walls weakened by a field of staggered and equally-spaced holes (refer to Fig. 2.1.6.2.3), as determined by the following formula

$$\varphi = k\,(a_2 - d)/a_2\,, \qquad (2.1.6.2.3)$$

where

d – diameter of the hole for expanded tubes or inside diameter of welded-on tubes and upset nozzles, mm;

a – pitch between two adjacent hole centres in the longitudinal direction, mm;

a_1 – pitch between two adjacent hole centres in the transverse (circumferential) direction (taken as a mean circumference arc), mm;

a_2 – pitch between two adjacent hole centres in the diagonal direction, in mm, as determined by the following formula

$$a_2 = \sqrt{l^2 + l_1^2}\;;$$

l – centre-to-centre distance between two adjacent holes in the longitudinal direction (refer to Fig. 2.1.6.2.3), mm;

l_1 – centre-to-centre distance between two adjacent holes in the transverse (circumferential) direction (refer to Fig. 2.1.6.2.3), mm;

k – factor selected from Table 2.1.6.2.3 in dependence upon the ratio of l_1/l.

Table 2.1.6.2.3

l_1/l	5,0	4,5	4,0	3,5	3,0	2,5	2,0	1,5	1,0	0,5
k	1,76	1,73	1,70	1,65	1,60	1,51	1,41	1,27	1,13	1,00
Note . Intermediate values of k are determined by interpolation.										

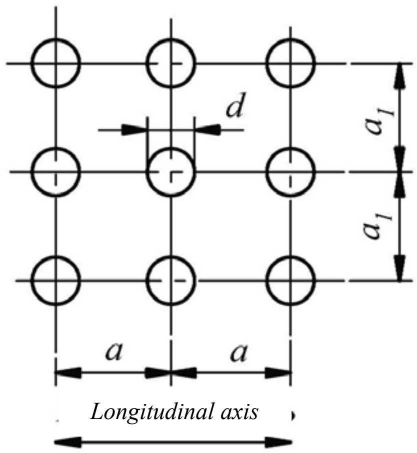


Fig.2.1.6.2.1

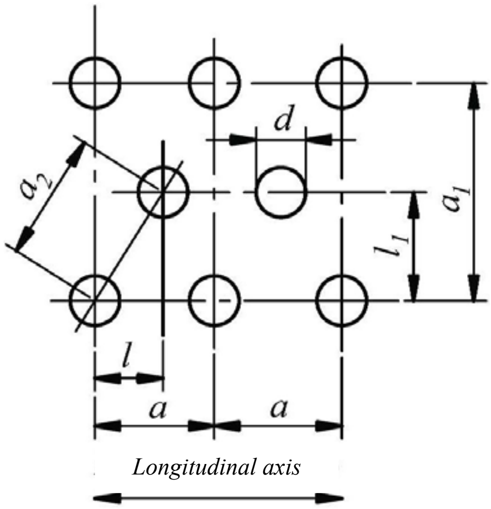


Fig.2.1.6.2.3

2.1.6.3 Where rows or fields of equally-pitched holes contain holes of alternate diameters, in Formulae (2.1.6.2.1), (2.1.6.2.2) and (2.1.6.2.3) for ligament efficiency factor determination value d shall be replaced by a value equal to the arithmetic mean of two largest adjacent hole diameters. In the case of unequal pitch between holes of equal diameter, the formulae for ligament efficiency factor determination shall be used with the lowest values of a, a_1 and a_2.

2.1.6.4 Where a welded joint has a hole or where the distance between the edge of a hole nearest to the welded joint centre is less than 50 mm or less than one-half the width of the mostly local opening affected zone, Q, in mm, determined by Formula (2.1.6.4), the efficiency factor shall be taken as equal to the product of the efficiency factor of welded joint by the ligament efficiency factor of the wall weakened by holes.

In cases where the hole edge is at a distance more than 0,5Q and more than 50 mm from the welded joint centre the lowest of the values determined for the ligament efficiency factors of the wall weakened by holes and the efficiency factor of welded joint shall be taken as the efficiency factor.

The width of the mostly local opening affected zone, Q, in mm, is calculated by the formula.

$$Q = \sqrt{D_m(s-c)}, \qquad (2.1.6.4)$$

where:

s – wall thickness, in mm;

c – corrosion allowance, in mm, taken according to **2.1.7**;

D_m – mean diameter of the weakened wall, in mm;

For cylindrical walls and dished ends

$D_m = D + s$, або $D_m = D_a - s$.

For conical walls

$D_m = (D_a/\cos\alpha) - s$, або $D_m = (D/\cos\alpha) - s$, where D_a – outside diameter;

D – = inside diameter.

For conical walls D and D_a are measured across a section, which passes through the centre of the weakening hole;

α – angle between conical wall and central axis (refer to Fig. 2.3.1-1).

2.1.6.5 For seamless cylindrical walls not weakened by welds or rows/fields of holes, the ligament efficiency factor shall be taken equal to 1.

In no case shall the factor be taken higher than 1.

2.1.6.6 The ligament efficiency factor of walls weakened by holes for expanded tubes shall be taken as not less than 0,3 as determined by Formulae (2.1.6.2.1), (2.1.6.2.2) and (2.1.6.2.3). 2.1.6.7 Where cylindrical walls are manufactured from plates of various thickness, jointed together by longitudinal welds, wall thickness calculation shall be made for each plate separately, taking into account the weakenings. 2.1.6.8 For longitudinally welded tubes the efficiency factor of welded joints shall be chosen in accordance with 2.1.6.1. 2.1.6.9 The ligament efficiency factors for cylindrical and conical walls and dished ends weakened by isolated openings shall be determined by the formulae:

for single non-reinforced openings:

$$\varphi_{in} = \frac{2}{d/Q + 1{,}75}, \qquad (2.1.6.9\text{-}1)$$

for single reinforced openings:

$$\varphi_{ir} = \varphi_{in}\left(1 + \frac{\Sigma f}{2(s-c)Q}\right), \qquad (2.1.6.9\text{-}2)$$

where:

Σf – the sum of compensating reinforcement areas, in mm^2 , determined according to **2.9**;

d – opening diameter, in mm;

s – wall thickness, in mm;

c – corrosion allowance, in mm, taken according to *2.1.7*;

Q – determined according to **2.1.6.4**.

2.1.6.10 When determining the permissible thicknesses of cylindrical, spherical, conical elements and dished ends, the lowerst of the values determined for a row or a field of non-reinforced openings in accordance with **2.1.6.2** to **2.1.6.7** and for single reinforced and non-reinforced openings determined according to **2.1.6.9** shall be taken as the design efficency factor.

2.1.6.11 The ligament efficiency factor of flat tube plates shall be determined for tangential and radial pitches by Formula (2.1.6.2.1). The lower of the values thus obtained shall be used for calculating the tube plate thickness.

2.1.7 Design thickness allowances.

2.1.7.1 In all cases where the design wall thickness allowance c is not expressly specified, it shall be taken as equal to at least 1 mm.

For steel walls over 30 mm in thickness, walls manufactured from corrosion-resistant or having protective coating non-ferrous or high alloy materials, design wall thickness allowance may be reduced to zero on agreement with the Register.

2.1.7.2 For heat exchangers and pressure vessels, which are inaccessible for internal inspection, or the walls of which are heavily affected by corrosion or wear, the allowance c may be increased if required by the Register.

2.2 CYLINDRICAL AND SPHERICAL ELEMENTS AND TUBES

2.2.1 Elements subject to internal pressure.

2.2.1.1 The requirements given below cover the following conditions:

at $D_a/D \le 1{,}6$ – for cylindrical walls;

at $D_a/D \le 1{,}7$ – for tubes;

at $D_z/D \le 1{,}2$ – for spherical walls.

Cylindrical walls with $D_a \le 200$ mm are regarded as tubes.

2.2.1.2 The thickness s, in mm, of cylindrical walls and tubes shall not be less than:

$$s = \frac{D_a p}{2\sigma\varphi + p} + c, \quad (2.2.1.2\text{-}1) \quad \text{або} \quad s = \frac{Dp}{2\sigma\varphi - p} + c, \quad (2.2.1.2\text{-}2)$$

where:

p – design pressure (refer to **2.1.2**), MPa;

D_a – outside diameter, mm;

D – = inside diameter, mm;

φ – efficiency factor (refer to **2.1.6**);

σ – allowable stress (refer to **2.1.4.6**), MPa;

c – allowance (refer to **2.1.7**), mm.

2.2.1.3 Spherical wall thickness shall not be less than:

$$s = \frac{D_a p}{4\sigma\varphi + p} + c, \quad (2.2.1.3\text{-}1) \text{ або } \quad s = \frac{Dp}{4\sigma\varphi - p} + c. \quad (2.2.1.3\text{-}2)$$

The symbols used are the same as in **2.2.1.2**.

2.2.1.4 Irrespective of the values obtained from Formulae (2.2.1.2-1), (2.2.1.2-2), (2.2.1.3-1) and (2.2.1.3-2), the thicknesses of spherical and cylindrical walls and tubes shall not be less than:

.1 5 mm for seamless and welded elements;

.2 12 mm for tube plates with radial hole arrangement for expanded tubes;

.3 6 mm for tube plates with welded-on or soldered tubes;

.4 values given in Table 2.2.1.4, for tubes.

The thickness of tube walls heated by gases with temperatures exceeding 800°C shall not be more than 6 mm.

Table 2.2.1.4

D_a, мм	< 20	>20≤ 30	>30≤ 38	>38≤ 51	>51≤ 70	>70≤ 95	>95≤ 102	>102≤ 121	>121≤ 152	>152≤ 191	>191
s, мм	1,75	2,0	2,2	2,4	2,6	3,0	3,25	3,5	4,0	5,0	5,4
Note. Reduction in wall thickness due to bending or expansion shall be compensated by allowances.											

2.2.1.5 On agreement with the Register, the minimum thicknesses of the walls of tubes of nonferrous alloys and stainless steels may be taken less than those specified in **2.2.1.4**, but not less than determined by Formulae (2.2.1.2-1), (2.2.1.2-2), (2.2.1.3-1) and (2.2.1.3-2).

2.2.2 Elements subject to external pressure.

2.2.2.1 The requirements specified below refer to cylindrical walls at $D_a/D \le 1{,}2$.

The thickness of tubes with $D_a \le 200$ mm shall be determined from **2.2.1.2**.

2.2.2.2 Plain cylindrical walls with or without stiffening members, including plain furnaces of boilers, shall have a thickness s, in mm, not less than

$$s = \frac{50(B + \sqrt{B^2 + 0{,}04AC})}{A} + c; \quad (2.2.2.2\text{-}1)$$

where:

$$A = 200\frac{\sigma}{D_m}\left(1 + \frac{D_m}{10l}\right)\left(1 + \frac{5D_m}{l}\right); \quad (2.2.2.2\text{-}2)$$

$$B = p\left(1 + \frac{5D_m}{l}\right); \quad (2.2.2.2\text{-}3)$$

$$C = 0{,}045pD_m, \qquad (2.2.2.2\text{-}4)$$

p – design pressure (refer to **2.1.2**), MPa;
D_m – mean diameter, mm;
σ – allowable stress (refer to **2.1.4.6** and **2.1.5.3**), MPa;
c – allowance (refer to **2.1.7**), mm;
l – design length of cylindrical portion between stiffening members, mm.

Assumed as stiffening members may be end plates, furnace connections to end plates and combustion chamber as well as reinforcing rings shown in Fig. 2.2.2.2, or similar structures.

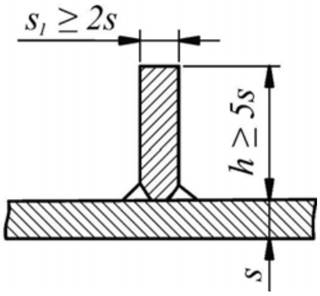


Fig. 2.2.2.2

2.2.2.3 Corrugated furnaces shall have a wall thickness s, in mm, not less than

$$s = \frac{pD}{2\sigma} + c, \qquad (2.2.2.3)$$

where:
p – design pressure (refer to **2.1.2**), MPa;
D –minimum inside diameter of the furnace over the corrugated portion, mm;
σ –allowable stress (refer to **2.1.4.6** and **2.1.5.3**), MPa;
c –allowance (refer to **2.1.7**), mm.

2.2.2.4 Where the length of the straight portion of a corrugated furnace from the front end wall to the commencement of the first corrugation exceeds the corrugation length, the wall thickness over this portion shall be obtained from Formula (2.2.2.2-1).

2.2.2.5 The thickness of plain furnaces shall not be less than 7 mm nor more than 20 mm.

The thickness of corrugated furnaces shall not be less than 10 mm nor more than 20 mm.

2.2.2.6 Plain furnaces up to 1400 mm in length need not generally be fitted with reinforcing rings.

Where a boiler has two or more furnaces, the reinforcing rings of adjacent furnaces shall be arranged in alternate planes.

2.2.2.7 Holes and openings in cylindrical and spherical walls shall be compensated for as per **2.9**.

2.2.2.8 The thickness s_1, in mm, of the ogee rings (refer to Fig. 2.2.2.8) connecting furnace bottoms of the vertical boilers to the shell and bearing vertical loads shall not be less than that determined by the following formula

$$s_1 \geq \frac{3{,}7}{\sigma}\sqrt{pD_1(D_1 - D_0)} + 1, \quad (2.2.2.8)$$

where:
σ – allowable stress (refer to **2.1.4.6**), MPa.
p – design pressure (refer to **2.1.2**), MPa;
D_1 – inside diameter of the boiler wall, mm;
D_0 – outside diameter of combustion chamber where it joins the ogee ring.

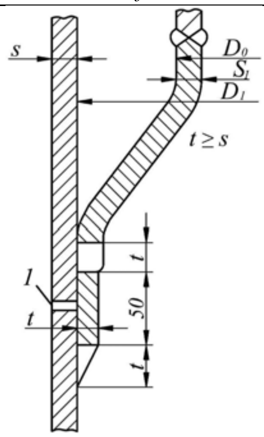


Fig. 2.2.2.8
1 – at least 4 openings 10 mm in diameter equispaced over the shell

2.3 CONICAL ELEMENTS

2.3.1 The wall thickness *s*, in mm, of conical elements subject to internal pressure shall not be less than:

.1 at $\alpha \le 70°$

$$s = \frac{D_a p y}{4\sigma\varphi} + c \qquad (2.3.1.1\text{-}1) \qquad \text{and } s = \frac{D_c p}{2\sigma\varphi - p}\frac{1}{\cos\alpha} + c\,; \qquad (2.3.1.1\text{-}2)$$

.2 at $\alpha > 70°$

$$s = 0{,}3\left[D_a - (r + s)\right]\sqrt{\frac{p}{\sigma\varphi}\frac{\alpha}{90°}} + c, \quad (2.3.1.2)$$

where:

D_c – design diameter (Figs. 2.3.1-1 to 2.3.1-4), mm;

D_a – outside diameter (Figs. 2.3.1-1 to 2.3.1-4), mm;

p – design pressure (refer to **2.1.2**), MPa;

y – shape factor (refer to Table 2.3.1);

α, α_1, α_2, α_3 – angles (refer to Figs. 2.3.1-1 to 2.3.1-4), deg.;

σ – allowable stress (refer to **2.1.4.6**), MPa;

φ – efficiency factor (refer to **2.1.6**);

in Formulae (2.3.1.1-1) and (2.3.1.2) the efficiency factor of a circumferential welded joint shall be used, and in Formula (2.3.1.1-2) that of a longitudinal welded joint;

for seamless shells, as well as in situations where circumferential weld is removed from the edge to a distance exceeding $0{,}5\sqrt{D_a s / \cos\alpha}$, the efficiency factor of the welded joint shall be taken equal to 1;

c – allowance (refer to **2.1.7**), mm;

r – radius of edge curvature (refer to Figs. 2.3.1-1, 2.3.1-2 and 2.3.1-4), mm.

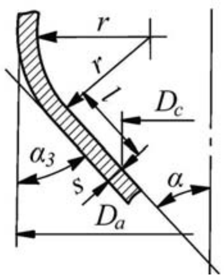


Fig. 2.3.1-1

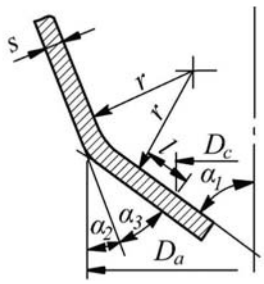


Fig. 2.3.1-2

In Figs. 2.3.1-1, 2.3.1-2 and 2.3.1-4, *l* is the distance, in mm, from the edge of the wide end of the conical shell, parallel to the generatrix of the conical shell assumed equal to 10 thicknesses, but not larger than half the length of the conical shell generatrix.

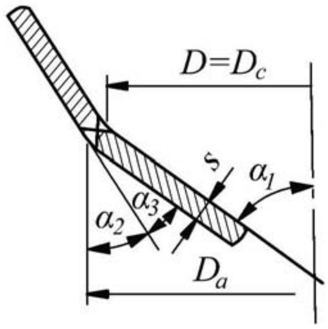


Fig. 2.3.1-3

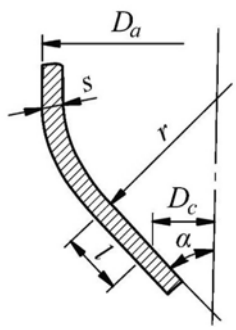


Fig. 2.3.1-4

Table 2.3.1

α, deg.	Shape factor y at r/D_a, equal to:											
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1.1	1,1	1,1	1,1	1,1
20	2,0	1,8	1,7	1,6	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1
30	2,7	2,4	2,2	2,0	1,8	1,7	1,6	1.4	1,3	1,1	1,1	1,1
45	4,1	3,7	3,3	3,0	2,6	2,4	2,2	1,9	1,8	1,4	1,1	1,1
60	6,4	5,7	5,1	4,7	4,0	3,5	3,2	2,8	2,5	2,0	1,4	1,1
75	13,6	11,7	10,7	9,5	7,7	7,0	6,3	5,4	4,8	3,1	2,0	1,1
Note . For fillet joints, the shape factor y is determined at r/D_a = 0,01.												

2.3.2 The wall thickness s, in mm, of conical elements subject to external pressure shall be determined from **2.3.1** having regard to the following conditions:

.1 efficiency factor of welded joints φ shall be taken equal to 1;

.2 allowance c shall be taken equal to 2 mm;

.3 design diameter D_c is determined by the following formula

$$D_c = \frac{d_1 + d_2}{2} \frac{1}{\cos\alpha}, \quad (2.3.2.3)$$

where: d_1 and d_2 – cone maximum and minimum diameters, mm;

.4 at α < 45° it shall be demonstrated that no elastic concave deformation of the walls occurs. The pressure p_1, in MPa, at which the elastic concave deformation of the walls occurs, shall be determined by the following formula

$$p_1 = 26E\cdot 10^{-6} \frac{D_c}{l_1} [\frac{100(s-c)}{D_c}]^2 \sqrt{\frac{100(s-c)}{D_c}}, \quad (2.3.2.4)$$

where:

E – modulus of elasticity, MPa;

l_1 – cone maximum length or distance between reinforcements, mm.

The condition for absence of elastic concave deformation is $p_1 > p$, where p – design pressure, MPa.

2.3.3 Fillet welded joints (refer to Fig. 2.3.1-3) are allowed only at $\alpha_3 \leq 30°$ and $s \leq$ mm. The joint shall be welded on both sides. For conical shells with $\alpha \geq 70°$, fillet joints may be welded without edge preparation if the requirements of **2.3.2** are met. It is recommended that fillet joints shall not be used on boilers.

2.3.4 Holes and openings in conical walls shall be reinforced according to **2.9**.

2.4 FLAT WALLS, END PLATES AND COVERS

2.4.1 Flat end plates and covers.

2.4.1.1 The thickness s, in mm, of flat end plates unsupported by stays, as well as that of covers (Figs. 2.4.1.1-1 to 2.4.1.1-8 and **1.2** of the Appendix) shall not be less than

$$s = kD_c\sqrt{\frac{p}{\sigma}} + c, \quad (2.4.1.1\text{-}1)$$

where:

k – design factor according to Figs. 2.4.1.1-1 to 2.4.1.1-8 and **1.1** to **1.6** of the Appendix;

D_c – design diameter (refer to Figs. 2.4.1.1-2 to 2.4.1.1-7 and **1.6** of the Appendix), mm, determined as follows:

for end plates shown in Figs. 2.4.1.1-1 and **1.1** of the Appendix the design diameter shall be

$$D_c = D - r; \quad (2.4.1.1\text{-}2)$$

for rectangular or oval covers (refer to Fig. 2.4.1.1-8) the design diameter shall be

$$D_c = m\sqrt{\frac{2}{1+(m/n)^2}}; \quad (2.4.1.1\text{-}3)$$

D – inside diameter, mm;

r – inside conjugation radius of the end plate, mm; n and m – major and minor sides or axis of the openings, measured to the centre of the gasket (refer to Fig. 2.4.1.1-8), mm;

p – design pressure (refer to **2.1.2**), MPa;

σ – allowable stress (refer to **2.1.4.6**), MPa;

c – allowance (refer to **2.1.7**), mm;

D_b – circle diameter of fastening bolts (refer to Fig. 2.4.1.1-6), mm.

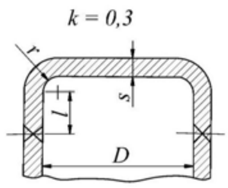


Fig. 2.4.1.1-1

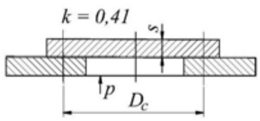


Fig. 2.4.1.1-2

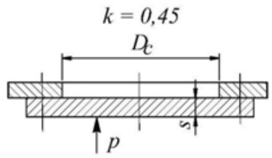


Fig. 2.4.1.1-3

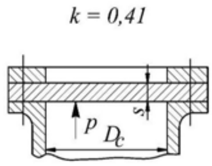


Fig. 2.4.1.1-4

In Figs. 2.4.1.1-1 and **1.1** of the Appendix, l is the length, mm, of cylindrical portion of end plate.

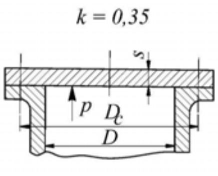


Fig. 2.4.1.1-5

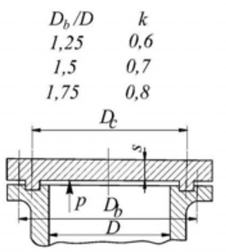


Fig. 2.4.1.1-6

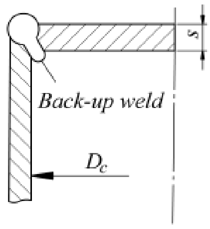


Fig. 2.4.1.1-7

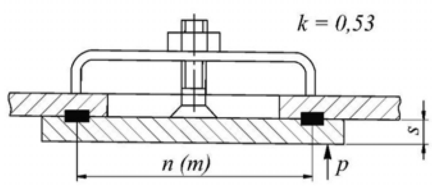


Fig. 2.4.1.1-8

2.4.1.2 The thickness s, in mm, of the end plates shown in Fig. **1.2** of the Appendix shall not be less than that determined by Formula (2.4.1.1-1).

Additionally, the following conditions shall be satisfied:

.1 for circular end plates

$$0{,}77 s_1 \geq s_2 \geq \frac{1{,}3p}{\sigma}\left(\frac{D_c}{2} - r\right); \quad (2.4.1.2.1)$$

.2 for rectangular end plates

$$0{,}55 s_1 \geq s_2 \geq \frac{1{,}3p}{\sigma}\frac{mn}{m+n}, \quad (2.4.1.2.2)$$

where:

s_1 – thickness of the shell, mm;

s_2 – thickness of the end plate in the relieving groove area, mm.

Other symbols used are the same as in 2.4.1.1.

In no case shall the value s_2 be less than 5 mm.

The above conditions are applicable to end plates not more than 200 mm in diameter or side length.

2.4.2 Walls reinforced by stays.

2.4.2.1 Flat walls (Figs. 2.4.2.1-2 and 2.4.2.1-3) reinforced by long and short stays, corner stays, stay tubes or other similar structures shall have a thickness s, in mm, not less than

$$s = kD_c\sqrt{\frac{p}{\sigma}} + c, \quad (2.4.2.1\text{-}1)$$

where:

k – design factor (refer to Figs. 2.4.2.1-1, 2.4.2.1-2 and 2.4.2.1-3 and also Figs. 5.1, 5.2 and 5.3 of the Appendix).

If the wall area in question is reinforced by stays having different factor k values, Formula (2.4.2.1-1) is used with the arithmetic mean of these factor values**;**

D_c – design assumed diameter (Figs. 2.4.2.1-2 and 2.4.2.1-3), mm, determined as follows in case of uniform distribution of stays

$$D_c = \sqrt{a_1^2 + a_2^2}, \quad (2.4.2.1\text{-}2)$$

in case of non-uniform distribution of stays

$$D_c = (a_3 + a_4)/2. \quad (2.4.2.1\text{-}3)$$

in all other cases, the value D_c shall be taken equal to the diameter of the largest circle, which can be drawn through the centres of three stays or through the centres of stays and the commencement of the curvature of flanging if the radius of the latter is as specified in **2.4.3**. The flanging, in this case, is regarded as a point of support. A manhole flanging shall not be regarded as a point of support;

a_1, a_2, a_3, a_4 – pitch or stay-to-stay distance (Fig. 2.4.2.1-1), mm.

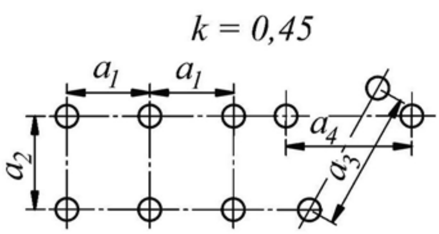


Fig. 2.4.2.1-1

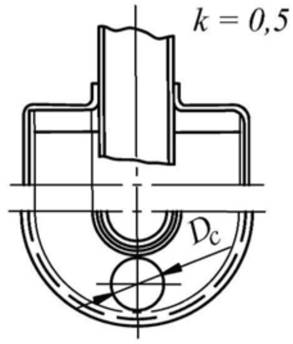


Fig. 2.4.2.1-2

Other symbols used are the same as in **2.4.1.1**.

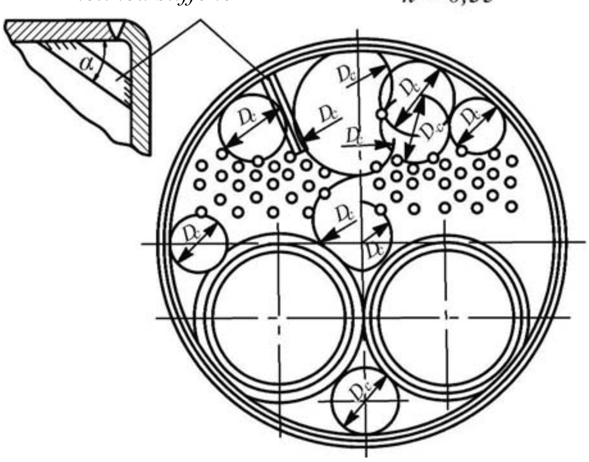


Fig. 2.4.2.1-3

2.4.3 Flanging of flat walls.

2.4.3.1 In flat wall and end plate calculations, the flanging is only taken into account when the flanging radii are not less than those given in Table 2.4.3.1.

The minimum flanging radius shall not be less than 1,3 times the wall thickness.

***Table** 2.4.3.1*

Radius of flanging, mm	25	30	35	40	45	50
Outside diameter of end plate, mm	До 350	351–500	501–950	951–1400	1401–1900	Понад 1900

2.4.3.2 The cylindrical portion of a flanged flat end plate shall have a length l not less than $0{,}5\sqrt{Ds}$ (refer to Fig. 2.4.1.1-1).

2.4.3.3 End plates with a relieving groove shall have a groove curvature radius r according to 1.2 of the Appendix.

2.4.4 Reinforcement of openings.

2.4.4.1 Openings in flat walls, end plates and covers measuring over four thicknesses in diameter shall be reinforced by means of welded-on nozzles, branch pieces and pads, or by increasing the design wall thickness.

Openings shall be arranged at a distance of not less than 1/8 of the size of the opening from the design diameter outline.

2.4.4.2 If the actual wall thickness is larger than that required by Formulae (2.4.1.1-1) and (2.4.2.1-1), the maximum diameter d, in mm, of a non-reinforced opening shall be determined by the following formula

$$d = 8s_f\left(1{,}5\frac{s_f^2}{s^2} - 1\right), \qquad (2.4.4.2)$$

where:
s_f – actual wall thickness, mm;
s – design wall thickness obtained from Formulae (2.4.1.1-1) and (2.4.2.1-1), mm.

2.4.4.3 Edge reinforcement shall be provided for openings of larger dimensions than those indicated in **2.4.4.1** and **2.4.4.2**.

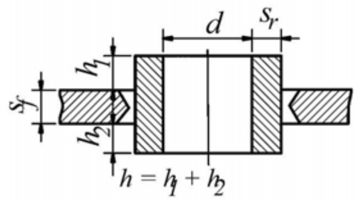


Рис. 2.4.4.3

The dimensions of reinforcing elements (nozzles and branches), in mm, shall satisfy the expression

$$s_r(h^2 / s_f^2 - 0{,}65) \geq 0{,}65d - 1{,}4s_f, \quad (2.4.4.3)$$

where: s_r – width of reinforcing element (Fig. 2.4.4.3), mm;

h – height of reinforcing element (Fig. 2.4.4.3), mm.

Other symbols used are the same as in **2.4.4.2**.

2.4.4.4 The design heights h_1 and h_2, in mm, of reinforcing elements (nozzles and branches) (refer to Fig. 2.4.4.3) shall be determined by the following formula

$$h_1(h_2) \leq \sqrt{(d + s_r)s_r}\,. \quad (2.4.4.4)$$

The symbols used are the same as in **2.4.4.2** and **2.4.4.3**.

2.5 TUBE PLATES

2.5.1 The thickness s_1, in mm, of flat tube plates of heat exchangers shall not be less than

$$s_1 = 0{,}9kD_{\text{в}}\sqrt{\frac{p}{\sigma\varphi}} + c, \qquad (2.5.1)$$

where:
p – = design pressure (refer to **2.1.2**), MPa;

σ – allowable stress (refer to **2.1.4.6**), MPa.

For heat exchangers of rigid construction the allowable stress may be reduced by 10 per cent when the materials of the shell and tubes have different linear expansion coefficients;

c – allowance (refer to 2.1.7), mm;

k – factor depending on the ratio of the shell thickness s to the tube plate thickness s_1 (s/s_1).

For tube plates welded to the shell along the perimeter the factor k is determined from Fig. 2.5.1. The preset value of the thickness s_1 shall be used. When the difference between the preset value of the thickness s_1 and that obtained from Formula (2.5.1) is more than 5 per cent, the recalculation shall be made. For tube plates fastened between the flanges of the shell and cover by bolts and studs, k is equal to 0,5;

$D_в$ – inside diameter of the shell, mm

φ – ligament efficiency factor of the tube plate weakened by holes (refer to **2.5.2**).

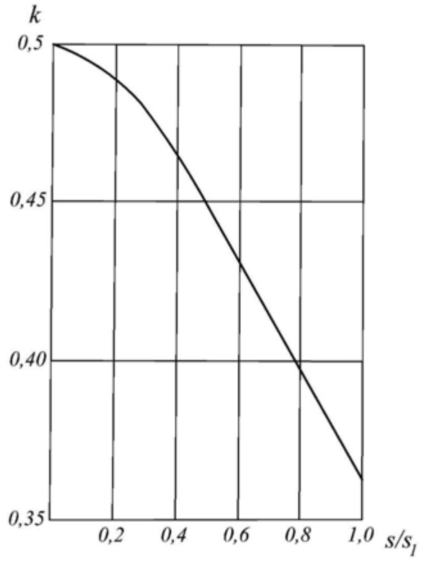


Fig. 2.5.1

2.5.2 The ligament efficiency factor of the tube plate at 0,75 > d/a > 0,4 and $D_a/s_1 \geq 40$ shall be determined by the following formulae:

for spacing of holes on an equilateral triangle

$$\varphi = 0{,}935 - 0{,}65 d/a; \qquad (2.5.2\text{-}1)$$

for unstaggered and staggered spacing of holes

$$\varphi = 0{,}975 - 0{,}68 d/a_2, \qquad (2.5.2\text{-}2)$$

where:

d – diameter of the hole in the tube plate, mm;

a – pitch between hole centres for spacing of holes on an equilateral tringle, mm;

a_2 – the lesser pitch for unstaggered or staggered spacing of holes (including concentric rows of holes), mm.

2.5.3 Ratio of dimensions of the tube plates d/a and D_B/s_1 shall be within the range specified in 2.5.2.

The ratio d/a = 0,75 ÷ 0,80, may be admitted, but in this case the thickness of the tube plates, calculated by Formula (2.5.1), shall also satisfy the following condition:

$$f_{min} \geq 5d, \qquad (2.5.3)$$

where: f_{min} – minimum permissible cross-sectional area of the tube plate portion between holes, mm^2.

2.5.4 The thickness of tube plates with expanded tubes, apart from Formula (2.5.1), shall satisfy the following condition

$$s_1 = 10 + 0{,}125d. \qquad (2.5.4)$$

The expansion joints of tube plates shall also satisfy the requirements of **2.10.2.2**, **2.10.2.3** and **2.10.2.4**.

2.5.5 If the tube plates are reinforced by means of welded-on or expanded tubes in such a way that the requirements of **2.10** are satisfied, the calculations for such tube plates may be made according to **2.4**.

2.6 DISHED ENDS

2.6.1 Dished ends, unpierced or pierced, subject to internal or external pressure (Fig. 2.6.1) shall have a thickness s, in mm, not less than

$$s = \frac{D_a py}{4\sigma\varphi} + c\,, \qquad (2.6.1)$$

where:

p – design pressure (refer to **2.1.2**), MPa;

D_a – outside diameter of the end, mm;

φ – efficiency factor (refer to **2.1.6**);

σ – allowable stress (refer to **2.1.4.6**), MPa;

y – shape factor selected from Table 2.6.1 depending on the ratio of the height to the outside diameter and on the nature of weakening of the end.

For elliptical and torispherical ends $R_в$ is the maximum radius of curvature. For intermediate values of h_a/D_a and $d/\sqrt{D_a s}$ the shape factor y is determined by interpolation.

The flanged area of the end is assumed to commence at a distance of not less than $0{,}1D_a$ from the outside outline of the cylindrical portion (refer to Fig. 2.6.1).

To choose y using Table 2.6.1 the value s shall be selected from a number of standard thicknesses. The finally accepted value s shall not be less than that determined by Formula (2.6.1);

c – allowance to be taken equal to: 2 mm at internal pressure and 3 mm at external pressure.

At wall thickness exceeding 30 mm the above allowance values may be reduced by 1 mm;

d – the larger dimension of the non-reinforced opening, mm.

The symbols for dished end elements are shown in Fig. 2.6.1.

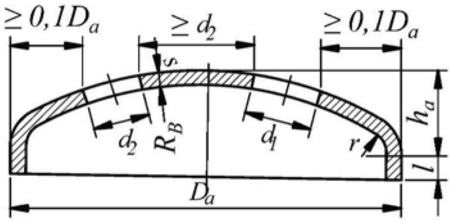


Fig. 2.6.1.

Table 2.6.1

Dished end shape	$\frac{h_a}{D_a}$	Коефіцієнт форми y							
		y – for flanged area of end and for unpierced ends	y - for dished part of end with non-reinforced openings, for which $\frac{d}{\sqrt{D_a s}}$ is equal to:						y_o – for dished part of end with reinforced openings
			0,5	1,0	2,0	3,0	4,0	5,0	
Elliptical or torispherical, with $R_в = D_a$	0,20	2,9	2,9	2,9	3,7	4,6	5,5	6,5	2,4
Elliptical or torispherical, with $R_в = 0{,}8D_a$	0,25	2,0	2,0	2,3	3,2	4,1	5,0	5,9	1,8
Hemispherical, with $R_в = 0{,}5D_a$	0,50	1,1	1,2	1,6	2,2	3,0	3,7	4,35	1,1

2.6.2 Formula (2.6.1) is valid where the following relations are observed:

$$h_a / D_a \geq 0{,}18;$$

$$(s - c)/ D_a \geq 0{,}0025;$$

$$R_в \leq D_a; \quad r \geq 0{,}1D_a\,;$$

$$l \leq 150\text{mm};$$

$$l \geq 25\text{mm at } s \leq 10\text{mm};$$

$$l \geq 15 + s \text{ at } 10 < s \leq 20\text{mm};$$

$$l \geq 25 + 0{,}5s \text{ at } s > 20\text{mm}.$$

2.6.3 By unpierced end is meant an end, which has no openings or one with openings located at a distance of not less than $0{,}2D_a$ from the outside outline of the cylindrical portion and measuring not more than 4s in diameter and never more than 100 mm.

In the flanged area of the end, non-reinforced openings are allowed, with diameters less than the wall thickness but not more than 25 mm.

2.6.4 The wall thickness of dished ends in combustion chambers of vertical boilers may be calculated as for unpierced ends, also where the flue-gas outlet branch passes through the end.

2.6.5 Dished ends subject to external pressure, except for those of cast iron, shall be checked for stability by calculation based on the following relation

$$\frac{36{,}6E_t}{R_B^2}\frac{(s-c)^2}{100p} > 3{,}3, \qquad (2.6.5)$$

where:
E_t – modulus of elasticity at design temperature, MPa;
for modulus of elasticity for steel, refer to Table 2.6.5;
for non-ferrous alloys, values of E_t shall be agreed with the Register;
R_B – maximum inside radius of curvature, mm.

Other symbols used are the same as in **2.6.1**.

Table 2.6.5

Design temperature t, °C	20	250	300	400	500
Modulus of elasticity for steel E_t, MPa	$2{,}06 \cdot 10^5$	$1{,}86 \cdot 10^5$	$1{,}81 \cdot 10^5$	$1{,}72 \cdot 10^5$	$1{,}62 \cdot 10^5$

2.6.6 The minimum wall thickness of steel dished ends shall not be less than 5 mm. For ends manufactured from non-ferrous alloys and stainless steels, the minimum wall thickness may be reduced.

2.6.7 Where the results of a calculation made according to **2.9.2** call for the reinforcement of openings in dished ends, the reinforcement shall be made in compliance with the requirements of **2.9.3**.

2.7 FLANGED END PLATES

2.7.1 Unpierced flanged end plates (refer to Fig. 2.7.1) subject to internal pressure shall have a thickness s, in mm, not less than

$$s = (3pD)/\sigma + c, \qquad (2.7.1)$$

where:
p – design pressure (refer to **2.1.2**), MPa;
D – inside diameter of the end plate flange to be equal to the inside diameter of the shell, mm;
σ – allowable stress (refer to **2.1.4.6**), MPa;
c – allowance (refer to **2.1.7**), mm.

In Fig. 2.7.1, l is the distance, in mm, from the inside diameter edge to the centre line of holding bolts.

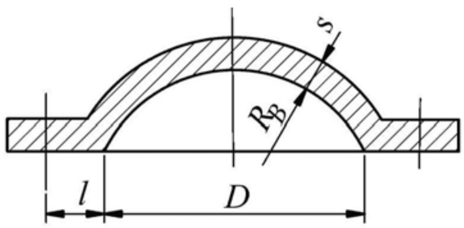


Fig.2.7.1

2.7.2 Flanged end plates are allowed within the range of diameters up to 500 mm and for working pressures not more than 1,5 MPa.

The radius of curvature R_B of the end plate shall not be more than $1{,}2D$, and the distance l not more than $2s$.

2.8 HEADERS OF RECTANGULAR SECTION

2.8.1 The wall thickness s, in mm, of rectangular headers (Fig. 2.8.1-1) subject to internal pressure shall not be less than that determined by the following formula

$$s = \frac{pn}{2{,}52\sigma\varphi_1} + \sqrt{\frac{4{,}5kp}{1{,}26\sigma\varphi_2}}, \quad (2.8.1\text{-}1)$$

where:

p – design pressure (refer to **2.1.2**), MPa;

n – half the width in the clear of the header side normal to that being calculated, mm;

σ – allowable stress (refer to **2.1.4.6**), MPa;

φ_1 and φ_2 – efficiency factors of headers, weakened by holes determined as follows:

φ_1 – by Formula (2.1.6.2.1);

φ_2 – by Formula (2.1.6.2.1) at $d < 0{,}6m$, at $d \geq 0{,}6m$ – by the following formula

$$\varphi_2 = 1 - 0{,}6\, m/a, \quad (2.8.1\text{-}2)$$

where m – alf the width in the clear of the header side being calculated, mm;

where the holes are arranged in a staggered pattern, a_2 (Fig. 2.8.1-2) shall be substituted for a in Formula (2.8.1-2); where the rectangular headers have longitudinal welded joints (refer to Fig. 2.8.1-1), the efficiency factors φ_1 i φ_2 are assumed to be equal, respectively, to the efficiency factor of welded joints selected as per **2.1.6**.

Longitudinal welded joints shall be arranged, as far as possible, within the area l_1 for which k=0;

where the header wall is weakened in several different ways, the calculations shall be based on the lowest efficiency factor value:

k – design factor for bending moment at the centre of the side wall or at the centre line of the row of holes, mm2 , determined by the formulae:

for the centre line of the header wall

$$k = \frac{1}{3}\frac{m^3 + n^3}{m + n} - \frac{m^2}{2}; \quad (2.8.1\text{-}3)$$

for rows of holes or longitudinal welded joints

$$k = \frac{1}{3}\frac{m^3 + n^3}{m + n} - \frac{m^2 - l_1^2}{2}. \quad (2.8.1\text{-}4)$$

If the above formulae yield negative values, the absolute numerical values shall be used; where the holes are arranged in a staggered pattern, factor k shall be multiplied by cos α;

α – angle of the diagonal pitch to the longitudinal axis, deg.;

l_1 – distance between the row of holes under consideration and the centre line of header wall (refer to Fig. 2.8.1-2), mm;

d – diameter of the hole, mm.

For oval holes, d shall be taken as equal to the size of the holes on the longitudinal axis, but in Formulae (2.1.6.2.1) and (2.8.1-2) the size on the axis normal to the header centre line shall be taken as d for oval holes.

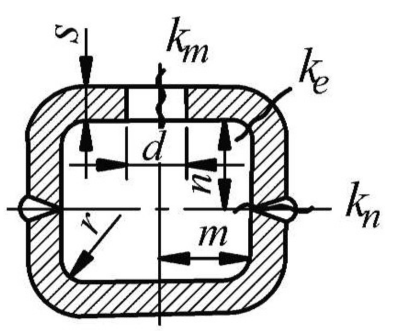


Fig. 2.8.1-1

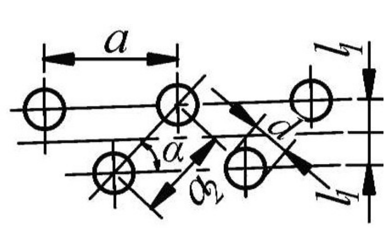


Fig. 2.8.1-2

2.8.2 Where fillet welded joints are allowed in headers the wall thickness of such headers shall not be less than

$$s = \frac{p\sqrt{m^2 + n^2}}{2{,}52\sigma\varphi_1} + \sqrt{\frac{4{,}5k_e p}{1{,}26\sigma\varphi_2}}, \quad (2.8.2\text{-}1)$$

where: k_e – design factor for bending moment at the edges, mm^2, determined by the following formula

$$k = \frac{1}{3}\frac{m^3 + n^3}{m + n}. \qquad (2.8.2\text{-}2)$$

Other symbols used are the same as in **2.8.1**.

2.8.3 The radius of curvature of rectangular header side shall not be less than 1/3 of the wall thickness and never less than 8 mm.

The minimum thickness of header walls designed to accommodate expanded tubes shall not be less than 14 mm.

The width of ligaments between holes shall not be less than 0,25 times the pitch between hole centres. The wall thickness in the area of curvature shall not be less than that determined by Formulae (2.8.1-1) and (2.8.2-1).

2.9 REINFORCEMENT OF OPENINGS IN CYLINDRICAL, SPHERICAL, CONICAL WALLS AND IN DISHED ENDS

2.9.1 General.

2.9.1.1 For the purpose of the present Rules openings are subdivided into the following types:

.1 openings reinforced by means of welded-on disc-shaped reinforcing plates (refer to Fig. 2.9.1.1.1);

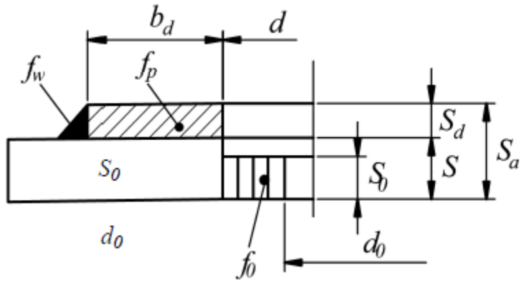


Fig. 2.9.1.1.1

.2 openings reinforced by means of welded-on tubuler elements such as nozzles, sleeves, branch pieces, flanging, etc (refer to Figs. 2.9.1.1.2-1 to 2.9.1.1.2-3);

.3 openings reinforced by combinations of reinforcing elements listed above (refer to Fig. 2.9.1.1.3);

.4 openings having no reinforcing elements (nozzles, sleeves, branch pieces, flanging and weldedon disc-shaped reinforcing plates), i.e. non-reinforced openings.

The dimensions of non-reinforced openings shall not exceed those given in **2.9.2**.

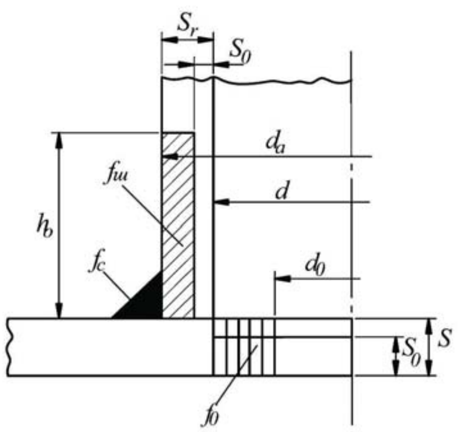


Fig. 2.9.1.1.2-1

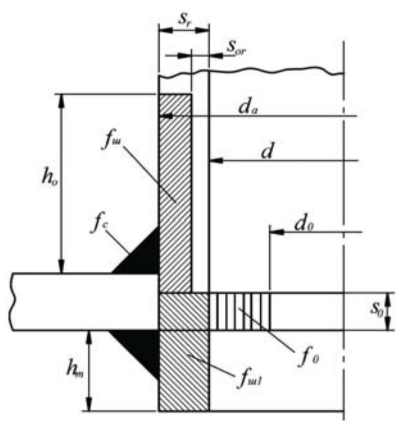


Fig. 2.9.1.1.2-2

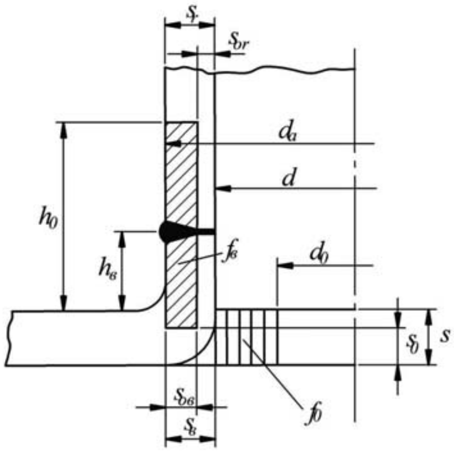


Fig. 2.9.1.1.2-3

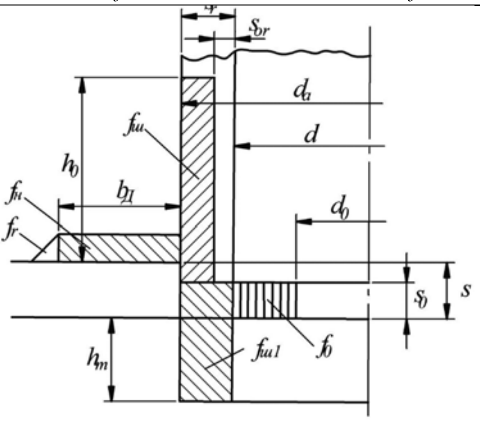


Fig. 2.9.1.1.3

2.9.1.2 The materials used for the wall to be reinforced and for reinforcing elements shall have identical strength characteristics as far as possible.

Where reinforcing materials with inferior strength characteristics compared to those of the wall to be reinforced are used, the area of reinforcing sections shall be increased proportionally to the ratio of permissible material stress of the wall to be reinforced to that of the reinforcing material.

The higher strength of the reinforcing element shall be neglected.

2.9.1.3 As a rule, openings in walls shall be located at the distance of at least 3*s* (where *s* is the thickness of the wall to be reinforced), but not less than 50 mm away from welded joints.

If the distance of the arrangement of openings away from welded joints is less than specified above, the efficiency factor shall be taken in accordance with **2.1.6.4**.

2.9.1.4 The minimum thickness of reinforcing tubular elements (branch pieces, sleeves, nozzles) attached by welding to the walls of boilers, heat exchangers or pressure vessels shall be generally taken not less than 5 mm.

2.9.1.5 The maximum thickness of a tubular element or reinforcing plate taken in the reinforcement calculation shall not generally exceed the thickness of the wall to be reinforced.

The use of reinforcing elements with a thickness up to two thicknesses of the wall to be reinforced may be accepted if required by technological process, but such an increased thickness is disregarded in the reinforcement calculation.

2.9.2 The maximum permissible diameter of a non-reinforced opening.

A single opening is an opening, the edge of which is at a distance of at least 2*Q* from the edge of the nearest opening (where *Q* is the width of the mostly local opening affected zone, determined by Formula (2.1.6.4)).

The maximum permissible diameter of a single non-reinforced opening in cylindrical, spherical and conical walls and dished ends is determined by the formula

$$d_0 = (2/[\varphi_{in}] - 1,75)Q, \quad (2.9.2\text{-}1)$$

where:

Q – = the width of the mostly local opening affected zone determined by Formula (2.1.6.4);

$[\varphi_{in}]$ – minimal permissible efficiency factor value of a component weakened by opening, equal to:

for cylindrical wall

$$[\varphi_{in}] = \frac{P(D_a - s + c)}{2(s - c)\sigma}, \quad (2.9.2\text{-}2)$$

for ellipsoidal, torospherical and semi-spherical ends

$$[\varphi_{in}] = \frac{P(D^2/2h_a + s - c)}{4(s - c)\sigma}, \quad (2.9.2\text{-}3)$$

for conical walls

$$[\varphi_{in}] = \frac{P(D_c + s - c)}{2(s - c)\sigma\cos\alpha}, \quad (2.9.2\text{-}4)$$

where:

D_a, D – outside and inside diameter of the wall to be reinforced, in mm, respectively;

D_c – inside diameter of large base of the conical wall, in mm;

σ – permissible stress, in MPa;

h_a – height of the dished part of end, in mm;

α – = cone angle equal to half the angle at the conical wall vertex, in deg.;

s – wall thickness, in mm;

c – corrosion allowance, in mm, taken according to **2.1.7**.

2.9.3 Reinforcement of openings.

2.9.3.1 When reinforcing single openings in cylindrical, conical walls and dished ends, the sum of compensating areas of reinforcements Σf shall exceed the required area of reinforcement f_0:

$$\Sigma f = f_t + f_{t1} + f_p + f_w + f_c > f_0, \quad (2.9.3.1\text{-}1)$$

where:

f_t and f_{t1} – compensating areas of exterior and interior parts of a tubular reinforcing element (refer to Figs. 2.9.1.1.2-1, 2.9.1.1.2-2, 2.9.1.1.2-3, 2.9.1.1.3), determined according to **2.9.3.2**;

f_p – compensating area of disc-shaped reinforcing plate (refer to Figs. 2.9.1.1.1, 2.9.1.1.3), determined according to **2.9.3.3**;

f_w – total compensating area of welded joints equal to the sum of deposited areas without regard weld reinforcement, mm^2;

f_c – compensating area of flanged collar metal (refer to Fig. 2.9.1.1.2-3), determined according to **2.9.3.4**;

f_0 – minimum required area of reinforcement, determined according to **2.9.3.5**.

2.9.3.2 Compensating areas of tubular elements (nozzles) are determined by the following formulae:

for exterior part of a tubular reinforcing element

$$f_{ш} = 2h_0(s_r - s_{or} - c), \text{ mm}^2, \quad (2.9.3.2\text{-}1)$$

for interior part of a tubular reinforcing element

$$f_{ш1} = 2h_m(s_r - c), \text{ mm}^2, \quad (2.9.3.2\text{-}2)$$

where:

s_r – wall thickness of a tubular element, in mm, taken according to the drawing with consideration for recommendations of **2.9.1.5** and **2.9.1.6**;

s_{or} – minimum design wall thickness of a tubular element determined according to 2.2.1.2 at φ = 1,0 and c = 0, mm;

c – corrosion allowance, in mm (refer to **2.1.7**);

h_0 – height of the exterior part of a tubular element, mm which shall be taken according to the drawing in case it does not exceed the value determined by the formula

$$h_0 = 1{,}25\sqrt{(d_a - s_r)(s_r - c)}, \quad (2.9.3.2\text{-}3)$$

d_a – outside diameter of a tubular element, in mm;

h_m – =height of the interior part of a tubular element, which shall be taken according to the drawing in case it does not exceed the value determined by the formula

$$h_m = 0{,}5\sqrt{(d_a - s_r)(s_r - c)}. \quad (2.9.3.2\text{-}4)$$

2.9.3.3 Compensating areas of a disc-shaped reinforcing plate are determined by the formula

$$F_p = 2b_d s_d, \quad (2.9.3.3)$$

where:

s_d – = thickness of disc-shaped plate taken according to the drawing and with consideration for the requirements of **2.9.1.6**;

b_d – of 2.9.1.6; bd = a reinforcing plate width (refer to Figs. 2.9.1.1.1 and 2.9.1.1.3), which shall be taken according to the drawing but shall not exceed the width of the mostly opening affected area, Q, determined according to **2.1.6.4**.

2.9.3.4 The compensating area of the flanged collar metal (refer to Fig. 2.9.1.1.2-3) is determined by the formula

$$f_c = 2h_{c1}(s_c - s_{oc} - c) + 2(h_0 - h_c)(s_r - s_{or} - c) \quad (2.9.3.4\text{-}1)$$

wheree: h_{c1} – height of collar taken equal to the dimension according to the drawing but not more than

$$h_c \leqslant 0{,}5\sqrt{(d - s_c)(s_c - c)}, \quad (2.9.3.4\text{-}2)$$

where:

s_c – thickness of the extended throat or flanged collar taken according to the drawing but not more than wall thickness s, in mm;

s_{oc} – the minimal design wall thickness of a collar or expanded throat, in mm, determined by the formula

$$s_{oc} = \frac{P(d+0{,}25r)}{2\sigma - P}, \qquad (2.9.3.4\text{-}3)$$

where:

r – curvature radius of a collar or throat, which shall be taken according to the drawing but shall not be less than 5 mm;

d – diameter of an opening to be reinforced, in mm.

2.9.3.5 The minimum required area of a reinforcement f_0 is determined by the formula

$$f_0 = (d - d_0)\, s_0, \qquad (2.9.3.5)$$

where:

s_0 – the minimum required design wall thickness at $\varphi = 1$ and $c = 0$, determined according to **2.2.1.2**, **2.2.1.3**, **2.3.1** and **2.6.1**.

In calculation of wall thickness s_0 by Formula (2.6.1), the valuey_a, obtained from Table 2.6.1 shall be substitued for y;

d_0 – the maximum permissible diameter of an isolated non-reinforced opening, in mm (refer to **2.9.2-1**);

d – diameter of an opening to be reinforced, in mm.

2.9.3.6 In case where combined reinforcing elements are used (refer to Fig. 2.9.1.1.3) the condition of strength according to Formula (2.9.3.1-1) shall be satisfied and the dimensions of reinforcing elements shall meet the requirements of **2.9.1.6 – 2.9.1.7**.

2.9.4 Interdependence of openings.

2.9.4.1 The interdependence of openings shall be taken into account if the distance between the edges of adjacent openings determined according to the drawing (refer to Fig. 2.9.4.1) is smaller than two Q, that is the following condition shall be satisfied

$$l + s_{r1} + s_{r2} \geq 2Q, \qquad (2.9.4.1\text{-}1)$$

where:

$l + s_{r1} + s_{r2}$ – the distance between the edges of adjacent openings (Fig. 2.9.4.1-1 and 2.9.4.1-2), mm;

Q – width of the mostly local opening affected zone determined by Formula (2.1.6.4).

If the above condition (2.9.4.1-1) is not satisfied, it is necessary to check the stress occurring in the section between the openings due to design pressure. The stress involved shall not exceed, both longitudinally and transversely, the allowable values according to the relation

$$F/f_c \leq \sigma, \qquad (2.9.4.1\text{-}2)$$

where:

σ – allowable stress (refer to **2.1.4.6**), in MPa;

F – load caused by the design pressure upon the section between the openings (refer to **2.9.4.2**), in N;

f_c – design sectional area between the openings (refer to **2.9.4.3**), in mm^2.

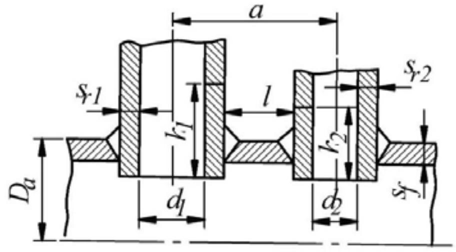


Fig. 2.9.4.1-1

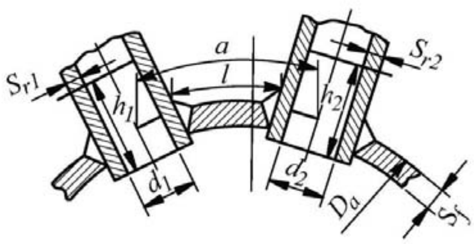


Fig. 2.9.4.1-2

2.9.4.2 The load caused by the design pressure, in N, affecting the section between two openings shall be determined as follows:

.1 for openings arranged longitudinally along a cylindrical wall

$$F_a = Dpa/2; \qquad (2.9.4.2.1)$$

.2 for openings arranged circumferentially in cylindrical or conical walls as well as for openings in spherical walls

$$F_b = Dpa/4; \qquad (2.9.4.2.2)$$

.3 for openings in dished ends

$$F_b = Dpya/4, \qquad (2.9.4.2.3\text{-}1)$$

where:
a – pitch between two adjacent openings on the circumference (determined on the outside of the wall as shown in Fig. 2.9.4.1-2), mm;
D – inside diameter (for conical walls measured at the centre of the opening), mm;
p – design pressure (refer to **2.1.2**), MPa;
y – shape factor (refer to **2.6.1**).

Where openings are arranged in cylindrical walls at a diagonal pitch, the load involved is determined by Formula (2.9.4.2.2), the results being multiplied by a factor

$$k = 1 + \cos^2 \alpha , \qquad (2.9.4.2.3\text{-}2)$$

where: α – angle of inclination of the line through the opening centres to the longitudinal axis, deg.

2.9.4.3 The design sectional area f_c, in mm^2, between two adjacent openings with tubular reinforcements shall be determined by the following formula

$$f_c = l(s - c) + 0{,}5[h_1(s_{r1} - c) + h_2(s_{r2} - c)], \quad (2.9.4.3)$$

where:
h_1 and h_2 – = heights of the reinforcement, mm, determined by the following formulae:
$h_1(h_2) = h_o + s$ – for non-through reinforcements;
$h_1(h_2) = h_o + s + h_m$ – for through reinforcements;
l – of the ligament between two adjacent rein-forcements (refer to Figs. 2.9.4.1-1 and 2.9.4.1-2), mm;
s – thickness of the wall to be reinforced, mm;
s_{r1} and s_{r2} – thicknesses of the tubular reinforcements (refer to Figs. 2.9.4.1-1 and 2.9.4.1-2), mm;
c – allowance (refer to **2.1.7**), mm;
h_o – design height of the tubular reinforcement (refer to Formula (2.9.3.2-3));
h_m – height of inward projecting portion of the tubular reinforcement (refer to Formula (2.9.3.2-4)), mm.

For openings to be reinforced by other methods (combined or disc-shaped reinforcements, etc.) the design sectional area f_c shall be determined in a similar manner.

2.10 STAYS

2.10.1 Scantlings of stays.
2.10.1.1 The cross-sectional area f, in mm^2, of long and short stays, corner stays and stay tubes subject to tensile or compressive stresses shall not be less than

$$f = pf_s/(\sigma \cos \alpha), \qquad (2.10.1.1)$$

where:
p – design pressure (refer to **2.1.2**), MPa;
σ – allowable stress (refer to **2.1.4.6**), MPa;
α – angle between the corner stay and the wall, to which the stay is attached (refer to Fig. 2.4.2.1-3), deg.;
f_s – maximum surface area per stay of the wall to be reinforced, bounded by lines passing at right angles through the centres of the lines joining the centre of the stay with the adjacent points of support (stays), mm^2.
The cross-sectional area of the stays and tubes within this area may be deducted from the surface area per stay.

2.10.1.2 For stays subject to longitudinal bending, the allowable bending stresses shall be taken with a safety factor not less than 2,25.
2.10.1.3 For end plates with a separate reinforcing stay (Fig. 2.10.1.3), the latter shall be so designed that it may take up at least half the load upon the end plate. An end plate of this type shall have a thickness in compliance with the requirements of **2.4.2.1**.

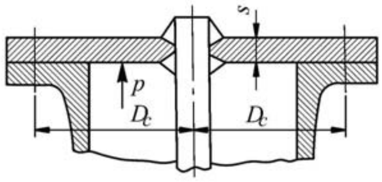


Fig.2.10.1.3

2.10.1.4 Stay and ordinary fire tubes shall have a thickness not lower than that indicated in Table 2.10.1.4.

The thickness of stay tubes with diameters over 70 mm shall not be less than:

6 mm for peripheral tubes;

5 mm for tubes arranged inside the tube nest.

Table 2.10.1.4

Outer diameter of the tude, in mm	Design pressure *p,* MPa, at wall thickness, in mm			
	3,0	3,5	4,0	4,5
50	1,1	1,85	–	–
57	1,0	1,65	–	–
63,5	0,9	1,5	2,1	–
70	0,8	1,35	1,9	–
76	0,75	1,25	1,75	2,25
83	–	1,15	1,6	2,1
89	–	1,05	1,5	1,9

2.10.2 Attachment of stays.

2.10.2.1 The cross-sectional area of welded joints of welded-on stays shall be such as to satisfy the following condition

$$\pi\, d_a e/f \geq 1{,}25, \qquad (2.10.2.1)$$

where:

d_a – stay diameter (for tubes – outside diameter), mm;

e – weld thickness (Figs. 5.1 to 5.3 of the Appendix), mm;

f – cross-sectional area of the stay (refer to **2.10.1.1**), mm^2.

2.10.2.2 For expanded tubes the length of the expansion joint in the tube plate shall not be less than 12 mm. Expansion joints for working pressures above 1,6 MPa shall be made with sealing grooves.

2.10.2.3 Expansion joints shall be checked for secure seating of the tubes in the tube plates by axial testing loads. The tubes may be considered securely seated, if the inequality is effected

$$pf_s/20sl \leq A, \qquad (2.10.2.3)$$

where:

A is equal to:

15 for joints of plain tubes;

30 for joints with sealing grooves;

40 for joints with flanging of tubes.

s – thickness of the tube wall, mm; p and f_s – , refer to **2.10.1.1**;

l – length of the expansion belt, mm. l shall be taken as not more than 40 mm.

2.10.2.4 The expansion of the plain tubes shall ensure secure seating of the tubes $q \geq 250$N/mm according to the formula

$$q = F/l, \qquad (2.10.2.4\text{-}1)$$

where:

q – secure seating of the tube in the opening per 1 mm of the expansion belt length, N/mm; in case of automatic expansion, this value shall be taken as 250 N/mm; in other cases, it shall be obtained experimentally. Where lower values are obtained, the thickness of the tube plate shall be proportionally increased;

F – tension necessary for rupture of the expansion joint, N;

l – expansion belt length, in mm, which shall not be less than that determined by the formula

$$l = p\, f_s\, k_r/q, \qquad (2.10.2.4\text{-}2)$$

where: k_r – safety factor for the expansion joint, which shall be taken as 5,0.

Other symbols used are the same as in **2.10.1.1**.

2.11 TOP GIRDERS

2.11.1 The section modulus W, in mm^3, of top girders of rectangular section shall not be less than

$$W = 1000M / (1{,}3\sigma z), \quad (2.11.1\text{-}1)$$

where:
σ – allowable stress (refer to **2.1.4.6**), MPa;
z – coefficient of rigidity of the wall to be reinforced;
for the structure shown in Fig. 2.11.1, z =1,33;
M – bending moment of the girder, N·m:
for a rectangular section:

$$M = pal^2/8000; \quad (2.11.1\text{-}2)$$

s_1 – width of the girder, mm;
h – height of the girder, which shall not be more than $8s_1$, mm;
l – design length of the girder, mm;
p – design pressure (refer to **2.1.2**), MPa;
a – spacing of girders, mm.

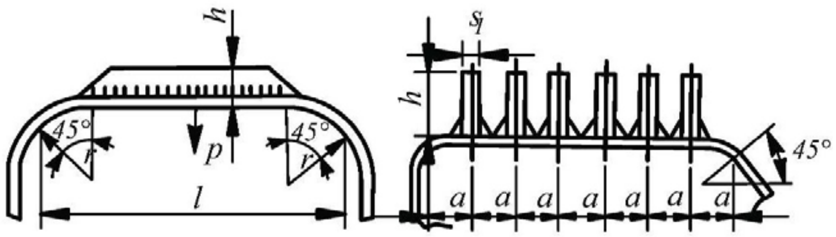


Fig. 2.11.1

3. BOILERS

3.1 GENERAL

3.1.1 The general provisions concerning surveys, technical documentation, manufacture, materials and general requirements for boilers and also strength calculation standards for boiler elements are set forth in Sections **1** and **2**.

3.1.2 The boilers shall remain operative under the environmental conditions specified in **2.3**, Part VII "Machinery Installations".

3.1.3 Where the failure of an auxiliary boiler for essential services involves the stop of main engine or ship deenergizing or results in the deviation from the specified requirements for proper carriage of goods, two boilers may be required by the Register, the capacity of each being sufficient to ensure normal ship operation.

3.1.4 The manufacturer shall provide operating instructions for each economizer which shall include reference to:

.1 feed water treatment and sampling arrangements;

.2 operating parameters: pressure, exhaust gas and feed water temperatures;

.3 inspection and cleaning procedures, records of maintenance and inspection;

.4 the need to maintain adequate water flow through the economizer under all operating conditions;

.5 periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly;

.6 procedures for using the exhaust gas economizer in the dry condition;

.7 procedures for maintenance and overhaul of safety valves.

3.1.5 If the ship according to 13, Part VII "Machinery Installations" is fitted with the Boiler Monitoring System which allows to carry out internal examination of steam boilers without participation of the surveyor of the Register, the design of a boiler shall allow to carry out examination by the crew.

(BMS) mark shall be assigned to liquid fuel auxiliary steam boilers and recycling boilers with an operating pressure of not more than 2.0 MPa.

3.2 CONSTRUCTION REQUIREMENTS

3.2.1 The thickness of tube walls thinned in the process of bending shall not be less than the design values.

3.2.2 The use of long and short stays shall be avoided, and also that of stay tubes exposed to bending or shearing stresses. Stays, strength walls, reinforcements, etc. shall have no abrupt changes in cross-sections.

Control drilled holes shall be provided for at short-stay ends as shown in Fig. 5.3 of the Appendix.

3.2.3 For walls reinforced by short stays and exposed to flame and high-temperature gases, the distance between stay centres shall not be larger than 200 mm.

3.2.4 Corner stays of gas-tube boilers shall be arranged at a distance of not less than 200 mm from the furnaces flues.

Where flat walls are reinforced with welded-on girders, this shall be done so that the load involved is transferred as far as possible to the boiler shell or the most rigid parts.

3.2.5 The distance between furnaces flues and boiler shell shall not be less than 100 mm.

The distance between any two furnaces shall not be less than 120 mm.

3.2.6 Branches and nozzles shall be of rigid construction and minimum length sufficient for fixing and dismantling boiler valves without removing the insulation.

Branch pieces shall not be subjected to excessive bending stresses and shall be reinforced by stiffening ribs if so required.

3.2.7 Pads intended for installation of valves and pipes as well as branches, sleeves and nozzles passing through the entire thickness of the boiler wall shall generally be attached by welding from both sides.

Branches and nozzles may also be fillet welded, with single-edge preparation, using removable backing strip, or by some other method that ensures penetration throughout the thickness of the part being attached.

3.2.8 Boiler drums and headers having a wall thickness greater than 20 mm and also superheater headers shall be protected from direct heat radiation as indicated in **2.1.3.4**.

The heating surface components of boilers and oil burner unit tuyeres subject to direct heat radiation shall have no projecting portions or edges on the fire side.

3.2.9 Where use is made of non-metal sealing gaskets, manhole and handhole closures shall be so designed as to prevent the possibility of the gasket being forced out.

3.2.10 Manholes, sight holes and other openings in boiler walls shall be reinforced as specified in **2.4.4** and **2.9**.

3.2.11 Structural measures shall be taken to prevent steam generation in economizers of boilers.

3.2.12 A nameplate indicating all principal technical data of boilers shall be provided in a conspicuous place.

3.2.13 The fastening elements of the boiler, apart from those which are not stressed, shall not be attached by welding directly to the boiler walls (shell, ends, headers, drums, etc.) but shall be attached by means of welded-on plates.

3.2.14 The tubes securely seated in the headers and tube plates by expansion of their ends shall be seamless.

3.2.15 Water-tube finned-tube boilers and all waste-heat boilers with forced circulation shall be equipped with an effective fire-resistant soot-cleaning system and their heating surfaces shall have access for inspection and cleaning as well as for sediments removal.

3.2.16 Waste-heat boilers with forced circulation connected to exhaust gas systems of two stroke diesels with inlet gas temperature of 270°C and lower shall meet the following requirements:

.1 hydraulic resistance of the boiler gas duct shall be such that during operation the gas flow velocity at the pipes of heating surfaces is not less than 10 m/s;

.2 for disconnection of the boiler heating when the engine is operated at partial loads the automated or remotely controlled arrangement providing full gas transfer shall be provided;

.3 the boilers shall be equipped with the system of washing and sediments removal. At the same time measures shall be taken to exclude washing products entering in the engine gas duct.

It is advisable to use special additive-injection arrangements to facilitate removal of sediments from the heating surfaces.

3.2.17 The design of waste-heat boilers with forced circulation shall provide for the fixed fireextinguishing systems to be connected, as stipulated in item **11** of Table 3.1.2.1, Part VI "Fire Protection".

3.2.18 Tube plate connections to the economizer shell shall be made with full penetration of the welded joints.

After welding the connections shall be subjected to heat treatment and to 100 per cent radiographic and ultrasonic examination.

Every shell type economizer shall be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

The removable elements shall ensure measurements at least at 4 points located at mutually perpendicular midship lines.

The requirements to economizer safety valves, means of steam pressure monitoring and quality of feed water are specified in **3.3.6**, **3.3.6.12** of the present Part and in **17.2.5**, Part VIII "Systems and Piping", respectively.

3.3 VALVES AND GAUGES

3.3.1 General.

3.3.1.1 All boiler valves shall be fitted on special welded-on branches, nozzles and pads, and shall generally be secured thereto by studs or bolts.

The studs shall have a full thread holding in the pad for a length of at least one external diameter.

The bore of threaded nozzle fitted mountings is allowed to be not greater than 15 mm, special pads being used for attaching them to the boiler.

The construction of pads, branches and nozzles shall comply with the requirements of **2.9**.

3.3.1.2 The valve covers shall be secured to valve cases by studs or bolts.

Valves with bore diameters of 32 mm and less may have screwed covers provided that they are fitted with reliable stops.

3.3.1.3 The valves and cocks shall be fitted with open and shut position indicators.

Position indicators are not required where the design allows to see without difficulty whether the valves are open or shut.

All valves shall be arranged to be shut with a clockwise motion of the wheels.

3.3.2 Feed valves.

3.3.2.1 Each main boiler and each auxiliary boiler for essential services shall be equipped with at least two feed valves.

Auxiliary boilers for other services, and also waste-heat boilers may have one feed valve each.

3.3.2.2 The feed valves shall be of a non-return type (check valves).

A shut-off valve shall be installed between the check valve and the boiler.

The check and shut-off valves may be housed in one casing.

The shut-off valve shall be fitted directly on the boiler.

3.3.2.3 The requirements concerning the feed water system are given in Section **17**, Part VIII "Systems and Piping".

3.3.3 Water level indicators.

3.3.3.1 Each boiler with free water evaporating surface shall be provided with at least two independent water level indicators with transparent faces (refer to **3.3.3.3**).

In agreement with the Register one of these indicators need not be installed when provision is made on the boiler for the lowest water level protective devices, as well as the lowest and highest water level alarms (the transducers of protective and signalling systems shall be independent and shall have different measuring points), or for lowered or remote water level indicator of an approved type with separate measuring points.

Boilers with a steaming capacity of 750 kg/h and less as well as all steam-heated steam generators, waste-heat boilers with free water evaporating surface and steam headers of waste-heat boilers may be provided with one water level indicator having a transparent face.

3.3.3.2 Forced circulation boilers shall be provided, instead of water level indicators, with two independent alarms to signal a shortage of water supply to the boiler.

When the boiler is serviced by an automatic oil burner unit, complying with the requirement of **5.3.3.4**, a second alarm is not required.

This requirement is not applicable to waste-heat boilers.

3.3.3.3 Flat prismatic glass shall be used in water level indicators for boilers having a working pressure of less than 3,2 MPa.

For boilers having a working pressure of 3,2 MPa and upwards, sets of mica sheets shall be used instead of glass, or else plain glass with a mica layer to protect the glass from water and steam effects, or other materials resistant to destructive action of the boiler water.

3.3.3.4 The water level indicators shall be fitted on the front of the boiler, at an equal height and, as far as possible, at an equal distance from the vertical centre line of the drum/boiler shell.

3.3.3.5 All water level indicators shall be provided with shut-off devices both on the water and steam sides.

Shut-off devices shall have safe drives for disconnection of the devices in case of glass breakage.

3.3.3.6 Water level indicators shall have the possibility of separately blowing off the water and steam spaces.

Blow-down ducts shall have an inside diameter of not less than 6 mm.

The design of water level indicators shall prevent the gasket materials from being forced into the ducts, and allow of cleaning the blow-down ducts, as well as of replacing the glasses while the boiler is in operation.

3.3.3.7 Water level indicators shall be so installed that the lower edge of the gauge slot is positioned below the lowest water level in the boiler by not less than 50 mm, however, the lowest water level shall not be above the centre line of the visible portion of the water level indicator.

3.3.3.8 Water level indicators shall be connected to the boiler by means of independent branch pieces.

No tubes leading to these branches are allowed inside the boiler.

The branches shall be protected from exposure to hot gases, radiant heat and intense cooling.

If the gauge glasses are fitted on the additional small vessels, the space inside such vessels shall be divided by partitions.

Water gauges and connecting pipes between them shall not be allowed to carry nozzles or branch pieces to be used for other purposes.

3.3.3.9 The branch pieces for attachment of water level indicators to boilers shall have an inside diameter not less than:

32 mm for bent branches of main boilers;

20 mm for straight branches of main boilers and for bent branches of auxiliary boilers;

10 mm for straight branches of auxiliary boilers.

3.3.3.10 The design, dimensions, number, location and lighting of water level indicators shall provide for adequate visibility and reliable control of the boiler water level.

Where water level visibility is inadequate, irrespective of the height of water level indicator location, or where the boilers are remotely controlled, provision shall be made for highly reliable remote water level indicators (placed at a lower position) or other types of water gauges approved by the Register and installed in the boiler control stations.

This requirement is not applicable to waste-heat boilers and their steam accumulators (steam separators).

3.3.3.11 Remote water level indicators for boilers may have a tolerance not exceeding ±20 mm as compared to water level indications of gauge glasses fitted on the boiler while the relevant delays in level indications at the highest possible rate of change shall not exceed 10 per cent of difference between the upper and lower levels.

3.3.4 Lowest water level and highest heating-surface point.

3.3.4.1 Each natural circulation boiler with free water evaporating surface shall have its lowest water level marked on the boiler water level indicator with a reference line drawn on the gauge frame or body.

Additionally, the lowest water level shall be marked on a plate with a reference line and an inscription "lowest level".

The plate shall be attached to the boiler shell close to the water level indicators.

The reference line and the plate shall not be covered over with boiler insulation.

3.3.4.2 In all cases the lowest water level in the boiler shall not be less than 150 mm above the highest heating-surface point.

This distance shall also be maintained when the ship is listed up to 5 degress either side and under all possible service trim conditions. In the case of boilers with design steaming capacity less than 750 kg/h, the said minimum distance between the lowest water level and the highest heating-surface point may be reduced down to 125 mm.

3.3.4.3 The position of the upper ends of the uppermost downcomers is assumed to be the highest point of the heating surface of water-tube boilers.

3.3.4.4 Gas-tube boilers shall be fitted with a position indicator for the highest heatingsurface point, which shall be securely attached to the boiler wall, close to the lowest water-level plate, and to have an inscription "highest heating-surface point".

3.3.4.5 The requirements for the position of the highest heating-surface point and the relevant position indicator do not apply to waste-heat boilers, forced circulation boilers, economizers and steam superheaters..

3.3.5 Pressure gauges and thermometers.

3.3.5.1 Each boiler shall have at least two pressure gauges connected with the steam space by separate pipes fitted with stop valves or stop cocks.

Three-way valves or cocks shall be provided between the pressure gauge and the pipe to make it possible to shut off the pressure gauge from the boiler, connect it to the atmosphere, blow off the connecting pipe and install the control pressure gauge.

3.3.5.2 One of the pressure gauges shall be installed on the front of the boiler, the other at the main engine control station.

3.3.5.3 Boilers with design steaming capacity below 750 kg/h and waste-heat boilers are allowed to have one pressure gauge.

3.3.5.4 A pressure gauge shall be provided at the water outlet from the economizer.

3.3.5.5 Pressure gauges shall have a scale sufficient to allow of boiler hydraulic testing.

The pressure gauge scale shall have a red line to mark the working pressure in the boiler.

3.3.5.6 Pressure gauges fitted on boilers shall be protected from the heat emitted by the hot boiler surfaces.

3.3.5.7 The pressure gauges shall be calibrated by a competent body.

3.3.5.8 Steam superheaters and economizers shall be equipped with thermometers.

Remote temperature control does not obviate the need for providing local thermometers.

3.3.5.9 A means of indicating the internal pressure of economizers shall be located so that the pressure can be easily read from any position from which the pressure can be controlled.

3.3.6 Safety valves.

3.3.6.1 Each boiler shall have not less than two spring-loaded safety valves of identical construction and equal size, to be installed on the drum, as a rule, on a common branch piece and one valve to be fitted on the superheater outlet header.

The superheater safety valve shall be so adjusted as to open before the safety valve installed on the drum.

Safety valves of the impulsive action type are recommended for steam boilers having a working pressure of 4 MPa and more.

For steam boilers with design steaming capacity below 750 kg/h, steam headers and unfired steam generators only one safety valve may be permitted if the adequate protection against overpressure is confirmed by carrying out a risk assessment approved by the Register.

3.3.6.2 The aggregate cross-sectional area f, in mm^2, of safety valves shall not be less than:

for saturated steam

$$f = k\,\frac{G}{10{,}2p_{\omega}+1}; \qquad (3.3.6.2\text{-}1)$$

for superheated steam

$$f = k\,\frac{G}{10{,}2p_{\omega}+1}\sqrt{\frac{V_H}{V_s}}\,, \qquad (3.3.6.2\text{-}2)$$

where:

G – design steaming capacity, kg/h;

p_{ω} – working pressure, MPa;

V_H – specific volume of superheated steam at the appropriate working pressure and temperature, m^3/kg;

V_s – specific volume of saturated steam at the appropriate pressure, m^3/kg;

k – coefficient of hydraulic resistance is assumed to be equal to:

d/h at $h/d < 0{,}25$,

1,25 at $h/d > 0{,}25$;

d – minimum valve diameter, mm;

h – height of valve lifting, mm.

Spring safety valves shall not be less than 32 mm and not more than 100 mm in diameter.

If specially approved by the Register, the use of valves with smaller cross-sectional areas than required by Formulae (3.3.6.2-1) and (3.3.6.2-2) may be allowed, provided it is proved experimentally that each of these valves has a discharge capacity not lower than the design steaming capacity of the boiler.

3.3.6.3 The cross-sectional area of the safety valve installed on the non-disconnectable superheater may be included in the aggregate cross-sectional area of the valves to be determined from Formulae (3.3.6.2-1) and (3.3.6.2-2).

This area shall not amount to more than 25 per cent of the aggregate area of the valves.

3.3.6.4 In all cases the safety valve shall be so adjusted that at fully open position the pressure shall not exceed $1{,}1P_w$.

The safety valves of main and auxiliary boilers for essential services shall fully interrupt the outgoing steam flow in case of the pressure drop in the boiler not below 0,85 of the working pressure.

3.3.6.5 Economizers shall be provided with spring-loaded safety valves not less than 15 mm in diameter.

3.3.6.6 Where safety valves are fitted on a common branch, the cross-sectional area of the branch shall not be less than 1,1 times the aggregate cross-sectional area of the valves installed.

3.3.6.7 The cross-sectional area of the waste-steam branch of the safety valve and of the pipe connected thereto, shall not be less than twice the aggregate cross-sectional area of the valves.

3.3.6.8 To remove the water of condensation, a drain pipe without any stopping devices shall be provided for on the valve body or on the waste-steam pipe (if the latter is located below the valve).

3.3.6.9 The safety valves shall be connected directly to the boiler steam space without any stopping devices.

Supply pipes leading to the safety valves are not allowed to be installed inside the boiler.

No provision shall be made on the safety valve bodies or their connections for steam extraction devices for other purposes.

3.3.6.10 The safety valves shall be so arranged that they can be lifted by a manual remote control gear as well as that powered from energy source.

The remote control gear of one of the valves shall be operated from the boiler room, and of the other valve from any other readily accessible position outside the engine room.

The remote control gear for safety valves of steam superheaters, waste-heat boilers and their steam headers (separators) may be operated only from the boiler room.

3.3.6.11 The safety valves shall be so designed that they could be sealed or provided with an equivalent safeguard to prevent the valves from being adjusted without the knowledge of the operating personnel.

The springs of the safety valves shall be protected from direct exposure to steam and shall be manufactured from heat- and corrosion-resistant materials, as also are the sealing surfaces of seats and valves.

3.3.6.12 Safety valves of economizers shall comply with the following requirements:

.1 where a shell type economizer is capable of being isolated from the steam plant system, it shall be provided with at least one safety valve, and when it has a total heating surface of 50 m^2 or more, it shall be provided with at least two safety valves;

.2 to avoid the accumulation of condensate on the outlet side of safety valves, the discharge pipes and/ or safety valve housings shall be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economizer where it shall not pose threats to either personnel or machinery.

No valves or cocks are to be fitted in the drainage arrangements.

3.3.7 Shut-off and stop valves.

3.3.7.1 Each boiler shall be separated from all pipelines leading to it by means of shut-off valves secured directly to the boiler.

3.3.7.2 For continually attended in the engine room non-automated ships, shut-off stop valves shall be provided with remote control gears for the operation from other readily accessible position outside the engine room.

The use of manual remote control gears as well as those powered from energy source is allowed.

For automated ships this requirement is considered to be advisory.

3.3.7.3 Where there is one main boiler or an auxiliary boiler for essential services installed on board the ship complete with a superheater or an economizer, the superheater and economizer shall be so arranged as to be shut off from the boiler.

3.3.7.4 The requirements for steam lines and boiler blow-down pipes are set forth in Section 18, Part VIII "Systems and Piping".

3.3.8 Blow-down valves.

3.3.8.1 Boilers, their steam superheaters, economizers and steam accumulators shall be fitted with blow-down arrangements and, where so required, with drain valves.

Blow-down and drain valves shall be fitted directly to the boiler shell.

At working pressures below 1,6 MPa these valves may be installed on welded-on profiled branch pieces.

3.3.8.2 The inside diameter of blow-down valves and pipes shall not be less than 20 mm and not more than 40 mm.

For boilers with design steaming capacity below 750 kg/h the inside diameter of the valves and pipes may be reduced to 15 mm.

3.3.8.3 In boilers with free water evaporating surface the scum arrangements shall ensure scum and sludge removal from the entire evaporating surface.

3.3.9 Salinometer valves.

Each boiler shall be provided with at least one salinometer valve or cock.

The fitting of such valves or cocks on pipes and branches intended for other purposes is not allowed.

3.3.10 Valves for deaeration.

Boilers, steam superheaters and economizers shall be equipped with sufficient number of valves or cocks for deaeration.

3.3.11 Openings for internal inspection.

3.3.11.1 Boilers shall be provided with manholes for inspection of all internal surfaces. Where the provision of manholes is not possible, arrangements shall be made for hand holes.

3.3.11.2 Manhole openings shall have dimensions in the clear not less than 300x400 mm for oval openings, and 400 mm for round openings.

In separate cases the dimensions of manhole openings may be reduced to 280x380 mm and to 380 mm for oval and round openings, respectively.

The oval manholes in cylindrical shells shall be so positioned that the minor axis of the manhole is arranged longitudinally.

3.3.11.3 Vertical gas-tube boilers shall have at least two hand holes arranged in the shell opposite to each other in the area of the working water level.

3.3.11.4 All boiler parts such as may prevent or hinder free access to, and inspection of, internal surfaces shall be of a removable type.

3.4 INCINERATOR BOILERS

3.4.1 The present requirements apply to ship auxiliary boiler units used for burning garbage, oil residues and sludge having a flush point above 60°C.

3.4.2 The strength calculations and requirements for design, valves, oil burning installations, control and protection are specified in Sections **2** to **5**.

3.4.3 Control and monitoring systems of incinerator boilers designed for unattended operation and their elements shall satisfy the requirements of Part XV "Automation".

3.4.4 In order to burn garbage, oil residues and sludge, provision shall, as a rule, be made for a special chamber complying with the following requirements:

.1 the chamber shall be separated from the boiler furnace and shall be covered with refractory lining, which is not chemically affected by combustion products;

.2 the ducts connecting the furnace and the chamber shall have a sufficient cross-sectional area. In any case, the working pressure in the chamber shall not exceed the pressure in the furnace by more than 10 per cent;

.3 provision shall be made for a safety device set to operate when the working pressure is exceeded by more than 0,02 MPa. The safety device shall be so arranged that no flame ejection is possible into the engine and boiler room;

.4 the aggregate cross-sectional area of the safety device shall be at least 115 cm2 per 1 m3 of the volume and not below 45 cm^2.

Garbage may be burned in chambers located within the fire space of the boiler.

Incinerator boilers shall be provided with a charging facility fitted with covers, which are so interlocked that they cannot be opened simultaneously.

For incinerator boilers having no charging facility, provision shall be made for an interlock between the charging door being opened and the temperature in the combustion chamber so as to exclude the self-ignition of cargo during loading.

In case of any restrictions concerning the materials charged, this shall be indicated on a warning plate.

3.4.5 A specially designed system shall generally be used for burning of oil residues and sludge. The use of the boiler fuel supply system and oil burning installation is only permitted if smokeless combustion is ensured.

3.4.6 The incinerator boilers shall be provided with an effective system of soot removal.

3.5 THERMAL LIQUID BOILERS

3.5.1 The requirements of the present Chapter apply to thermal liquid boilers.

3.5.2 General provisions relating to surveys, technical documentation, construction, strength calculation standards and also general requirements are set forth in Sections **1** and **2** and in **3.2.1**, **3.2.6** to **3.2.10**, **3.2.12**, **3.2.13**.

Along with that, regardless of the working pressure, the minimum design pressure for thermal liquid boilers shall be not less than 1,0 MPa and for the tanks containing the thermal liquid - not less than 0,2 MPa.

3.5.3 Boilers shall generally be installed in separate spaces provided with exhaust ventilation sufficient to give at least 6 air changes per hour. In case of other arrangement, the place where the boilers are installed shall be fenced with welded on coaming of at least 150 mm in height, fitted with a drain pipe to an enclosed tank.

3.5.4 The boiler shall be designed so that no temperature increase of the tube wall on the thermal liquid side above the permissible value is possible in any part of the boiler.

3.5.5 Each boiler shall be equipped with:

.1 shut-off devices at the thermal liquid inlet and outlet.

Valves shall be located in an easily accessible and safe place for maintenance and provided with both local and remote control outside the space in which the boilers are located.

Measures shall be taken to ensure that, in the event of the emergency safety valves opening, sufficient air (for the open system) or inert gas (for the closed system) is supplied to the expansion tank.

Thermal liquid system shall be emptied into the drain tank or the stock tank;

.2 at least one spring-loaded safety valve of encased type.

The total capacity of safety valves fitted shall be at least not less than the increment of the thermal liquid amount at the maximum heating intensity.

Safety valves shall not be less than 25 mm and not more than 130 mm in bore diameter.

The opening pressure of a safety valve shall not exceed the maximum working pressure by more than 10 %;

.3 pressure gauge;

.4 arrangement for complete emptying;

.5 emergency thermal liquid emptying device, which is actuated both from the local control station and remotely from outside the spacein which the boilers are located;

.6 manholes or hand holes for inspection of the furnace;

.7 manholes for inspection of the heating surface of a waste-heat boiler at the gas inlet and outlet;

.8 nameplate provided in a conspicuous place according to **3.2.12**;

.9 furnaces of auxiliary boilers and inlet chambers of waste-heat boilers shall be equipped with draining arrangements and thermal liquid leakage alarm.

3.5.6 Electrically heated boilers are subject to the same requirements as oil-fired boilers.

3.5.7 Each waste-heat boiler and oil-fired boiler shall be provided with an effective system of soot blow down.

3.5.8 Boiler tubes shall be attached to drums and headers by welding.

3.5.9 Boilers shall be equipped with valves having bellow seals.

3.5.10 Boilers shall be equipped with temperature sensors at the outlet of gases, fire alarms and limiting temperature protection at the outlet of thermal liquid.

3.5.11 Thermal liquid temperature on the outlet of the waste-heat boilers shall be controlled irrespective of the engines operation by changing the amount of exhaust gases or by-pass of the thermal liquid to the special cooler.

Use of dampers to control temperature in waste-heat boilers is permitted only for boilers with plain tubes, provided the gas velocity therein is not less than 10 m/s.

A shut-off device shall be provided to stop gas supply to a waste-heat boiler in case of operation of protective devices which shall not interfere with the operation of the engine.

When one or two engines are installed on board the ship, this device may be omitted.

3.5.12 Thermal liquid boilers shall be provided with automatic combustion controls, visual and audible alarms in compliance with **4.3.10**, Part XV "Automation", interlocking specified in **5.3.2** and protective devices according to **5.3.3**.

Moreover, interlocking shall be provided for actuation of the burner units with the circulating pumps out of operation.

For waste-heat boilers, in case when these begin to be heated with the circulating pumps out of operation, alarm shall be provided.

3.5.13 Thermal liquid boilers shall be provided with a fixed fire extinguishing system.

The use of drenching systems employing large quantities of water may be accepted.

Gas duct under the wasteheat boiler shall be equipped with a drainage system used for carrying away such water in order to preclude penetration thereof into the engine.

3.6 REGULATIONS FOR BOILERS, UTILIZING NATURAL GAS AS FUEL

3.6.1 Regulations for main and auxiliary boilers.

3.6.1.1 The boilers shall meet the following functional requirements:

.1 the exhaust systems shall be configured to prevent any accumulation of un-burnt gaseous fuel;

.2 unless designed with the strength to withstand the worst case over pressure due to ignited gas leaks, engine components or systems containing or likely to contain an ignitable gas and air mixture shall be fitted with suitable pressure relief systems.

Dependent on the particular engine design this may include the air inlet manifolds and scavenge spaces;

.3 the explosion venting shall be led away from where personnel may normally be present; and

.4 all gas consumers shall have a separate exhaust system.

3.6.1.2 Each boiler shall have a dedicated forced draught system. A crossover between boiler force draught systems may be fitted for emergency use providing that any relevant safety functions are maintained.

3.6.1.3 Combustion chambers and uptakes of boilers shall be designed to prevent any accumulation of gaseous fuel.

3.6.1.4 Burners shall be designed to maintain stable combustion under all firing conditions.

3.6.1.5 On main/propulsion boilers an automatic system shall be provided to change from gas fuel operation to oil fuel operation without interruption of boiler firing.

3.6.1.6 Gas nozzles and the burner control system shall be configured such that gas fuel can only be ignited by an established oil fuel flame, unless the boiler and combustion equipment is designed and approved by the register and Administration to light on gas fuel.

3.6.1.7 There shall be arrangements to ensure that gas fuel flow to the burner is automatically cut off unless satisfactory ignition has been established and maintained.

3.6.1.8 On the fuel pipe of each gas burner a manually operated shutoff valve shall be fitted.

3.6.1.9 Provisions shall be made for automatically purging the gas supply piping to the burners, by means of an inert gas, after the extinguishing of these burners.

3.6.1.10 The automatic fuel changeover system required by **3.6.1.5**, shall be monitored with alarms to ensure continuous availability.

3.6.1.11 Arrangements shall be made that, in case of flame failure of all operating burners, the combustion chambers of the boilers are automatically purged before relighting.

3.6.1.12 Arrangements shall be made to enable the boilers purging sequence to be manually activated.

4. CONTROLS, GOVERNORS, PROTECTIVE DEVICES AND ALARMS FOR BOILERS

4.1 GENERAL

4.1.1 1 The requirements of the present Section apply to continuously attended steam boilers and thermal fluid boilers. Additional requirements for controls, governors, protective devices and alarms for boilers comprising unattended automated boiler plants are specified in **4.3**, Part XV "Automation" and **4.2.3.1**, Part VI "Fire Protection".

4.1.2 Automation systems, their elements and devices shall comply with the requirements of Section **2** and **3**, Part XV "Automation".

4.2 GOVERNORS AND CONTROLS

4.2.1 The oil-fired boilers (main and auxiliary boilers for essential services) shall be equipped with automatic combustion controls. Oil-fired steam boilers shall be also equipped with feed water governors.

For other types of boilers these controls and governors are recommended.

4.2.2 Governors and controls shall be capable of maintaining the prescribed parameters within the predetermined limits over the entire steaming or heating (for thermal liquid boilers) load range.

4.3 PROTECTIVE DEVICES

4.3.1 All the boilers, except for the forced circulation boilers, the design of which allows operation with no water, and the headers of the secondary systems of the double-pressure boilers, shall be equipped with non-disconnectable protective devices for the lowest water level limit in the boiler (refer to **3.3.4**).

4.3.2 Boilers with automatic burner units shall be protected according to the requirements of **5.3**.

4.4 ALARMS

4.4.1 Boilers with automatic feed water governors and automatic burner units shall be equipped with visual and audible alarms at the local boilers control stations in accordance with **4.4.2** and **4.2.3.1** of Part VI "Fire Protection".

4.4.2 Visual and audible alarms shall function in case of:

water level reaching its lowest limit;

water level reaching its highest limit;

failures in the automatic control systems and protective devices, in particular, at power failure;

failure in the burner units (refer to **5.3.3**);

fire in the gas ducts of the boiler.

4.4.3 The lowest level limit alarms shall function prior to the operation of the protective devices.

4.4.4 Provision shall be made for manual disconnection of the audible alarm after its operation.

4.4.5 For boilers with inherent fire risk in the air supply casing and supply ducts and in the flue gas channels and uptake, means to detect at an early stage of the fire and give alarms shall be provided.

Boilers with inherent fire risk in the air supply casing and supply ducts means boilers equipped with rotary heat exchangers having surfaces exposed alternately to air and flue gas.

Boilers with inherent fire risk in the flue gas uptake and ducts means boilers equipped with heat exchangers using flue gases as the heating medium e.g. air/water preheaters or economisers.

5. OIL BURNER UNITS OF BOILERS

5.1 GENERAL

5.1.1 The general provisions concerning the technical supervision, technical documentation, manufacture and general requirements for oil burning installations are set forth in Section **1**.

5.1.2 All the equipment to be used in oil burner units, such as pumps, fans, quick-closing valves, electric drives, shall be of a type approved by the Register and shall be manufactured under supervision of the Register or other competent authorities recognized by the Register. Control, protective, interlocking and signalling devices shall comply with the requirements of Part XV "Automation".

5.1.3 The electrical equipment for oil burner units shall comply with the requirements of Part XI "Electrical Equipment".

5.1.4 Fuel oil used for boilers shall have a flash point in accordance with **1.1.2**, Part VII "Machinery Installations".

5.1.5 Pipes and valves of oil burner units shall comply with the requirements of Part VIII "Systems and Piping".

5.1.6 Sight devices shall be provided for observation of the burning process.

5.1.7 Suitable devices shall be provided for extinguishing of manual igniters.

5.2 BURNERS

5.2.1 The burners shall be so designed as to ensure the possibility of controlling the size and shape of the flame jet.

5.2.2 In case of variable-delivery burners provision shall be made for controlling the combustion air supply.

5.2.3 It is recommended that the inlets of boiler fans be protected against penetration of moisture or solids.

5.2.4 Structural measures shall be provided to prevent the burners from being turned or removed from the working position before oil supply thereto has been stopped.

5.2.5 Where steam or air atomizing burners are used, structural measures shall be provided to prevent air or steam from penetration in the oil and vice versa.

5.2.6 Where boiler oil is heated, structural measures shall be taken to prevent oil overheating in heaters in case steam-generating capacity of the boiler is reduced or burners are shut-off.

5.2.7 Trays shall be provided in places where oil may leak.

5.3 AUTOMATIC BURNER UNITS

5.3.1 The requirements of the present Chapter apply to the burner units of continuously attended steam boilers and thermal liquid boilers.

5.3.2 Burner units shall be interlocked for fuel supply to the boiler furnace to be possible only under the following conditions:

.1 the burner is in the operating position;

.2 all the electrical equipment is connected to sources of electrical power;

.3 pre-ventilation of the boiler furnace is completed;

.4 the pilot burner is alight or electrical ignition is switched on (when the main burner is being set alight);

.5 water level in the boiler is above the lowest limit (for steam boilers); .6 the heat-transfer medium flow through the boiler is within the normal range (for forced-circulation steam boilers and thermal liquid boilers).

5.3.3 Burning installations shall be equipped with non-disconnectable protective devices to operate within 1 s maximum (for pilot burner - not more than 10 s) and to shut off automatically fuel supply to the burner in the cases of:

.1 loss or low head of air flow to the furnace;

.2 flame-jet cut-off at the burner;

.3 water level in the boiler reaching its lowest limit;

.4 heat-transfer medium flow going below the minimum allowable limit (for forced-circulation steam boilers and thermal liquid boilers).

5.3.4 Fuel supply shall be cut off by two self-closing series-connected valves or by a single valve if all the tanks, from which fuel is supplied, are arranged below the burning installation.

5.3.5 Burning installations shall be equipped with a burner flame-jet monitor. Such a monitor shall respond only to the flame jet of the burner under control.

5.3.6 The capacity of the pilot burner shall be such that the burner itself could not maintain the boiler under pressure with the steam consumption completely stopped (for thermal liquid boilers - at the working temperature of the thermal liquid in case where all consumers are cut off).

Where the pilot and main burners are simultaneously in operation and the protection devices are caused to function under conditions specified in **5.3.3**, the pilot burner shall cease operation in the same time as the main burner.

5.3.7 Automatic burning installations of main and auxiliary boilers for essential services shall be capable of being manually controlled. Manual controls shall be provided directly at the boiler. In this case, all interlocking devices required by **5.3.2** and protective devices specified in **5.3.3** shall function.

5.3.8 Provision shall be made for the burning installation to be shut off from two places, one of which shall be situated outside the boiler room.

6. HEAT EXCHANGERS AND PRESSURE VESSELS

6.1 GENERAL

6.1.1 The general provisions concerning the surveys, technical documentation, manufacture, materials and general requirements for pressure vessels and heat exchangers as well as strength calculation standards are set forth in Sections **1** and **2** (except **2.2.1.4**).

6.1.2 The elements of heat exchangers and pressure vessels, which come in contact with sea water or other aggressive media, shall be manufactured from corrosion-resistant materials or provided with protection against corrosion.

6.1.3 The heat exchangers and pressure vessels shall preserve their serviceability under environmental conditions specified in **2.3**, Part VII "Machinery Installations".

6.2 CONSTRUCTION REQUIREMENTS

6.2.1 The requirements of **3.2.1**, **3.2.2**, **3.2.4**, **3.2.6**, **3.2.7**, **3.2.9**, **3.2.10** and, where necessary, **3.2.13** also apply to pressure vessels and heat exchangers.

6.2.2 The construction shall provide, where necessary, for thermal elongation of the shells and various parts of heat exchangers and pressure vessels.

6.2.3 The shells of heat exchangers and pressure vessels shall be provided with suitable lugs for reliable attachment to the foundations.

Overhead attachments shall be provided for, where necessary.

6.2.4 Additional requirements are given in **4.4**, Part VII "Machinery Installations".

6.2.5 Manholes shall be provided to enable inspection of the internal surfaces of heat exchangers and pressure vessels.

Where provision of manholes is not possible, hand holes shall be fitted in suitable places.

Where the length of the heat exchanger or pressure vessel is over 2,5 m, hand holes shall be provided at both ends.

Manholes or hand holes are not required where the equipment is of dismountable construction or where corrosion and contamination of internal surfaces is completely eliminated.

Provision of manholes or hand holes is not necessary in heat exchangers and pressure vessels, which construction excludes the possibility of inspection through such holes. For the dimensions of manhole openings, refer to **3.3.11.2**.

6.3 VALVES AND GAUGES

6.3.1 Each heat exchanger, pressure vessel or their banks in permanent communication shall be fitted with non-disconnectable safety valves.

Where there are several non-communicating spaces, safety valves shall be provided for each space.

Hydrophores shall be fitted with a safety valve to be installed on the water side. In separate cases the variations from the above requirements may be permitted.

6.3.2 Safety valves shall generally be of a spring-loaded type. In fuel and oil heaters it is allowed to use safety diaphragms of a type approved by the Register and installed on the fuel and oil side.

6.3.3 The discharge capacity of safety valves shall be such that under no conditions the working pressure is exceeded by more than 15 per cent.

6.3.4 The safety valves shall be so designed as to allow of their being sealed or fitted with an equivalent safeguard to prevent valve adjustment without the knowledge of the operating personnel.

The materials used for springs and sealing surfaces of valves shall be capable of withstanding the corroding effect of the medium.

6.3.5 Level indicators and sight glasses may only be installed on heat exchangers and pressure vessels where the conditions of control and inspection so require.

Level indicators and sight glasses shall be of a reliable design and shall have an adequate protection.

Flat glass plates shall be used for indicators of water, fuel oil or refrigerant level.

Shut-off devices shall be installed between the level indicators and pressure vessels. In deaerators cylindrical glasses may be used.

6.3.6 Heat exchangers and pressure vessels shall be provided with welded-on pads or short rigid connecting pieces for mounting valves.

Use of threaded connections is permitted for hydrophores.

Fittings shall be mounted taking into consideration the requirements of **3.3.1.1**.

6.3.7 Pressure vessels and heat exchangers shall be equipped with blow-down and drainage devices.

6.3.8 Each heat exchanger, pressure vessel or their groups in permanent connection shall be equipped with pressure gauges or compound gauges.

Where heat exchangers have several spaces, pressure gauges shall be provided for each space.

Pressure gauges shall comply with the requirements set forth in **3.3.5.1**, **3.3.5.5** and **3.3.5.7**.

6.4 SPECIAL REQUIREMENTS FOR HEAT EXCHANGERS AND PRESSURE VESSELS

6.4.1 Air receivers.

6.4.1.1 When lifted, the safety valves on air receivers of main and auxiliary engines and of fire extinguishing systems shall fully stop the air bleeding in case of the pressure drop in the air receiver not below 85 per cent of the working pressure.

6.4.1.2 Where compressors, reduction valves or pipelines intended for air supply to air receivers are provided with safety valves, which are so installed that the air supply to air receivers under pressure exceeding the working pressure is excluded, the installation of safety valves on air receivers is not necessary. In this case, the air receivers shall be equipped with fusible plugs instead of safety valves.

6.4.1.3 The fusible plug shall have a fusion temperature from 100°C to 130°C. The fusion temperature shall be punched out on the fusible plug.

Air receivers having a capacity over 700 l shall be fitted with plugs not less than 10 mm in diameter.

6.4.1.4 Each air receiver shall be equipped with a device for moisture removal. In case of air receivers arranged horizontally, the moisture removal devices shall be provided at both ends of the receiver.

6.4.2 Condensers.

6.4.2.1 The construction of the condenser and its location on board the ship shall be such as to enable tube replacement.

The main condenser shell shall generally be steel welded.

Baffles shall be provided inside the condenser, at excess pressure steam inlets, to protect the tubes from direct steam impact.

The tube attachments shall be so designed as to prevent sagging and hazardous vibration of the tubes.

6.4.2.2 The covers of the condenser water chambers shall be fitted with manholes in number and position as may be required for ensuring access to the tubes in any part of the tube nest for the purpose of expansion, packing replacement, or plugging.

Cathodic protection shall be provided for the water chambers, tube plates and tubes for prevention of electrolytic corrosion.

6.4.2.3 The main condenser shall ensure the operation under damage conditions with any casing of the turbine set being disconnected.

6.4.2.4 The condenser shall be so designed as to enable the instrumentation specified in **19.4**, Part VIII "Systems and Piping" to be connected to it.

6.4.3 Heat exchangers and pressure vessels of refrigerating plants and fire-fighting installations.

6.4.3.1 The heat exchangers and pressure vessels of refrigerating plants and fire-fighting installations shall comply with the requirements of Section **5**, Part XII "Refrigerating Plants" and Section **3**, Part VI "Fire Protection", respectively.

6.4.4 Cylinders.

6.4.4.1 The present requirements apply to seamless cylinders with the capacity of not more than 200 l with the outside diameter not exceeding 420 mm and length not exceeding 2000 mm, which are filled with gas at special stations and are then delivered on board ships for storage and recovery of compressed and liquefied gases.

Cylinders with welded ends shall be calculated for strength in compliance with Section 2 "Strength Calculations".

6.4.4.2 Where the outside diameter and wall thickness of a seamless cylinder are predetermined, the maximum permissible pressure p_D, in MPa, shall not exceed that determined by the following formula:

$$p_D \leq \frac{2\sigma\varphi(s-c)}{D_a-(s-c)}, \qquad (6.4.4.2)$$

where:

σ – permissible stress, MPa (refer to 2.1.4.6 with: n_T = 1,5 and n_B = 2,6;

φ – коефіцієнт міцності (див. **2.1.6**);

s – wall thickness, mm;

D_a – outside diameter, mm;

c – = allowance for corrosion (c = 1 mm for air; c c = 0,3 mm for liquefied gases; c = 0 for high strength steels, as well as without corrosive effect).

Where a cylinder is made of high strength steel with yield stress of not less than 750 MPa and with yield stress to tensile strength ratio of not less than 0,8, the ultimate strength safety factor nB given in **6.4.4.2** may be assumed to be equal to 2,1.

In case the design pressure p for particular gas is above the maximum permissible p_D, it is allowed to reduce pressure p to the value $p < p_D$ at the expense of the reduction of the filling ratio of gas in the cylinder. The design ambient temperature in the space for cylinder storage at the design pressure shall be kept below the critical value for the particular gas and shall be equal to:

50°C – for ships of unrestricted service,

40°C – for ships of restricted area of navigation in temperate zones,

45°C – for liquefied carbon dioxide cylinders regardless of the area of navigation. The design pressure and the filling ratio of carbon dioxide cylinders shall be chosen in compliance with the requirements of **3.8.2.1** or **3.8.3.1**, Part VI "Fire Protection".

6.4.4.3 Each cylinder and its valve head shall be fitted with a non-disconnectable safety device (breaking diaphragm, safety valve or fusible plug) preventing the cylinder from inadmissible temperature increase.

Safety valves and fusible plugs of the cylinders except for the liquefied carbon dioxide cylinders shall satisfy the requirements of 6.3.3, 6.4.1.1, 6.4.1.3.

The opening pressure of breaking diaphragms shall be 1,1p where p is the design pressure.

Safety devices of liquefied carbon dioxide cylinders shall satisfy the requirements of **3.8.2.6.1** or **3.8.3.3**, Part VI "Fire Protection".

6.4.4.4 For cylinders less than 100 l in capacity (except liquefied carbon dioxide cylinders) the safety devices may be omitted provided the following requirements are met:

.1 cylinders shall not be located in the strength hull of the ship below the upper deck;

.2 temperature in spaces where the cylinders are installed shall not be above the value indicated in **6.4.4.2**;

.3 spaces containing the cylinders shall be well removed from accommodation and service spaces and also from places and spaces where the equipment essential for safety of the ship is installed or flammable materials and fuel are stored.

6.4.4.5 Provision shall generally be made for enclosed gas outlet from the safety devices to the atmosphere. In case of free air discharge from the safety valves of air receivers the requirements of **3.1.2.5**, Part VI "Fire Protection" shall be observed.

Gas discharge from safety devices of cylinders of carbon dioxide smothering system shall be provided in accordance with **3.8.2.7**, Part VI "Fire Protection".

6.4.4.6 For cylinders filled without the use of the shipboard equipment (ship's compressors, etc.) installation of pressure gauges is not obligatory.

However, in any case the pressure control in any cylinder shall be possible.

6.4.4.7 The cylinders shall be equipped with blow-down and drainage devices, if required.

6.4.4.8 Spaces for storage of the cylinder containing explosive gases shall have an access from the weather deck.

6.4.4.9 Ends geometry:

.1 the dished spherical end at the transition from the cylindrical part of the cylinder shall have a thickness equal to the wall thickness of the cylindrical part.

In way of the seamless cylinder manhole the thickness of the spherical end wall shall be increased by at least 1,5 times as compared to the cylindrical wall. In this case, the spherical part, being thickened, shall pass gradually into the cylinder manhole;

.2 the minimum thickness of the concave spherical end of the seamless cylinder shall be at least twice the thickness of the cylindrical part of the cylinder.

The thickness of the lower cylindrical wall part of the cylinder shall gradually increase up to 1,7 the thickness of the cylinder wall in its cylindrical part.

The depth of the concave end shall be not less than 0,12 the outside diameter of the cylinder.

6.4.4.10 After manufacture, each cylinder shall be subject to hydraulic tests in compliance with Table 1.7.1. In this case, the maximum design stresses shall not exceed 0,9 the yield stress of the cylinder material.

6.4.4.11 Where individual cylinder specimens are subject to hydraulic fracture tests, the safety factors may be reduced down as against those specified in **6.4.4.2**.

7. STRENGTH CHARACTERISTICS OF BOILER STEEL

7.1 LOWER YIELD STRESS AS A FUNCTION OF DESIGN TEMPERATURE, MPA

Table 7.1

Kind of steel	R_m, MPa	Design temperature, ºC							
		20	100	200	250	300	350	400	450
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Carbon steel:									
Ст10	330	195	186	177	162	147	127	108	78
12К and 15К	350	205	196	181	167	142	118	98	78
Ст3	370	205	196	186	177	157	–	–	–
16К, 20 and 20К	400	235	226	206	186	157	137	118	98
18К	430	255	245	226	206	177	157	137	118
Alloy steel:									
15ХМ	440	225	226	221	216	216	206	196	191
12Х1МФ	440	255	255	250	245	235	226	216	206
16ГС and 09Г2С	450	265	255	235	226	196	177	157	123
High-manganese steel 22ГК	530	335	324	304	284	275	255	245	235

7.2 AVERAGE STRESS AS A FUNCTION OF DESIGN TEMPERATURE, MPA

Table 7.2

Kind of steel	R_m	R_{eH}	Design temperature, ºC							
	MPa		370	380	390	400	410	420	430	440
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Carbon steel:										
10, 12К and 15К	330–350	195–205	186	157	137	118	103	88	74	64
16К, 18К, 20 and 20К	400–430	235–255	216	186	162	142	127	108	98	83
Alloy steel:										
15ХМ	440	225	–	–	–	–	–	–	–	–
12Х1МФ	440	255	–	–	–	–	–	–	–	–
16ГС and 09Г2С	450	265	255	216	186	167	147	127	113	98
High-manganese steel 22ГК	530	335	245	226	206	186	167	157	137	118

Kind of steel	R_m	R_{eH}	Design temperature, ºC								
	MPa		450	460	470	480	490	500	510	520	530
1	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Carbon steel:											
10, 12К and 15К	330–350	195–205	59	–	–	–	–	–	–	–	–
16К, 18К, 20 and 20К	400–430	235–255	69	–	–	–	–	–	–	–	–
Alloy steel:											
15ХМ	440	225	265	245	226	196	157	137	118	103	88
12Х1МФ	440	255	–	–	–	196	186	177	167	152	137
16ГС and 09Г2С	450	265	88	78	69	–	–	–	–	–	–
High-manganese steel 22ГК	530	335	103	93	83	74	69	59	49	34	25

APPENDIX

TYPICAL EXAMPLES OF ALLOWABLE WELDED JOINTS FOR BOILERS, HEAT EXCHANGERS AND PRESSURE VESSELS

Dimensions of structural elements of the prepared edges of welded parts and dimensions of welds shall be taken according to national standards, having regard to the welding method used.

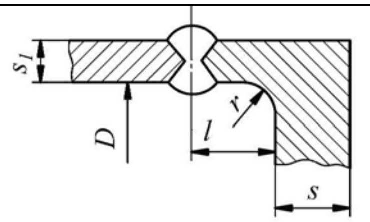
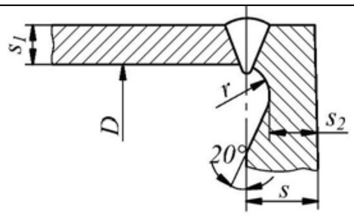
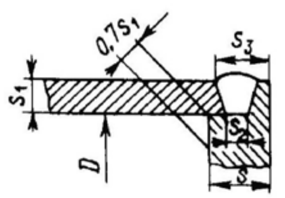
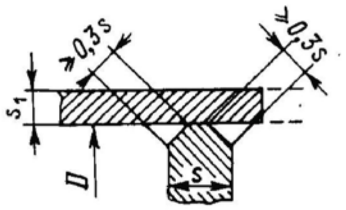
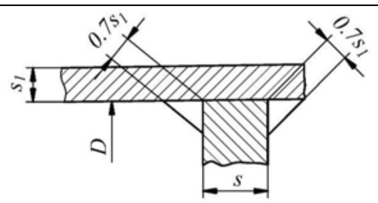
The typical examples of allowable welded joints are given in the present Appendix.

Different types of welded joints shall not be considered as equivalents, and the order in which they are presented is not indicative of their strength characteristics.

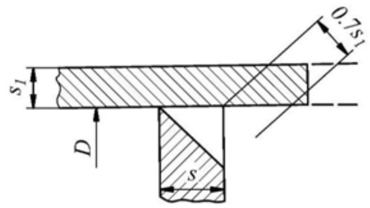
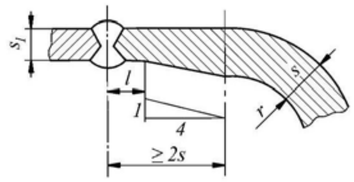
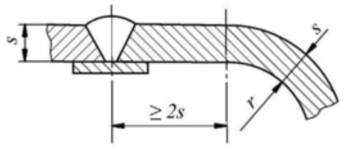
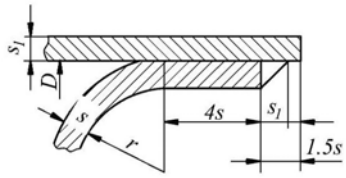
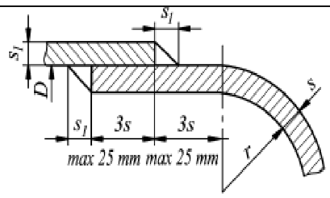
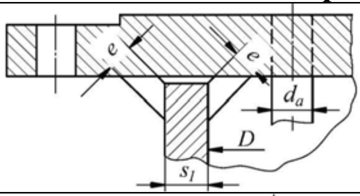
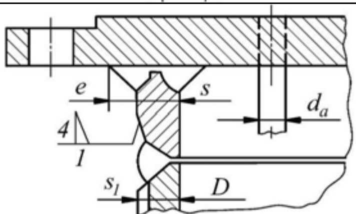
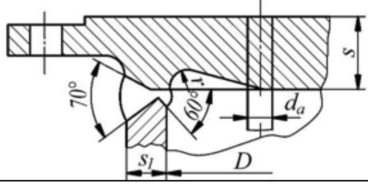
The types of welded joints shown for the elements shall be used on condition that adequate strength of the structure is ensured.

Depending on the caracteristics of the materials used and also on further improvement of the welding procedure, other types of welded joints may also be allowed. In this case and also in case the typical examples of the welded joints cannot be used in whole, the type of the welded joint shall be agreed with the Register.

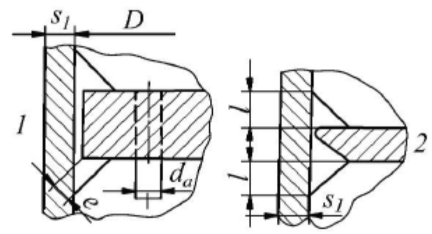
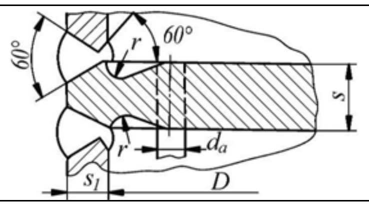
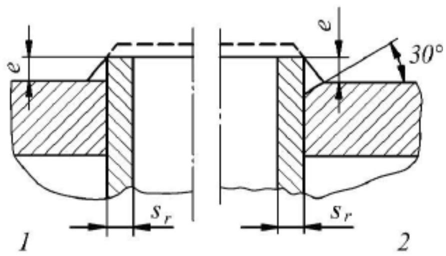
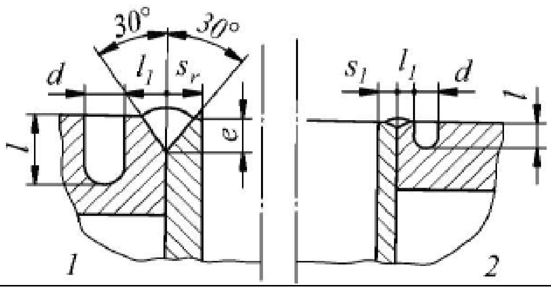
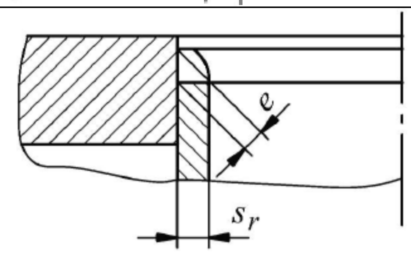
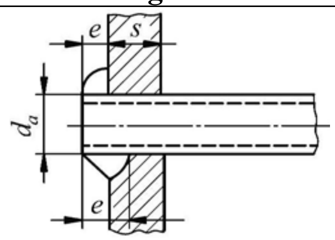
ALLOWABLE WELDED JOINTS

1. Flat end plates and covers		
1	**2**	**3**
1.1		$k = 0{,}38$, $r \geq s/3$, but not less than 8 mm, $l \geq s$.
1.2		$k = 0{,}45$, $r \geq 0{,}2s$, but not less than 5 mm, $s_2 \geq 5$mm. Refer to Note 1.
1.3		$k = 0{,}5$, $s_2 \leq s_1$, but not less than 6,5mm, $s_3 \geq 1{,}25\ s_1$. Refer to Note 1.
1.4		$k = 0{,}45$. Refer to Note 1.
1.5		$k = 0{,}55$. Refer to Note 1.

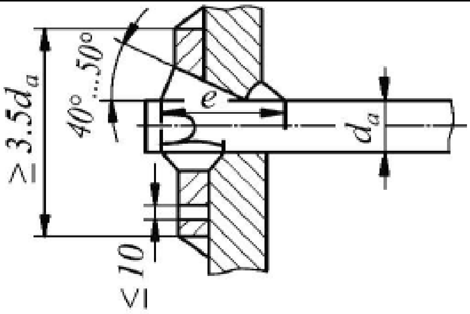
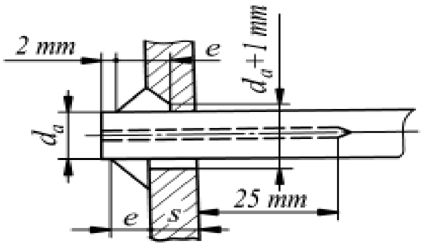
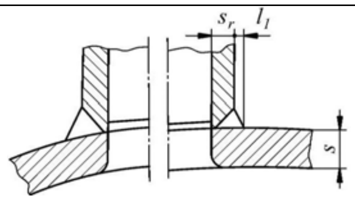
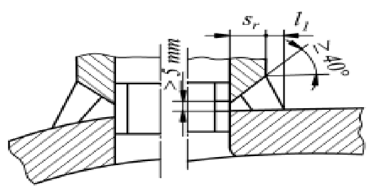
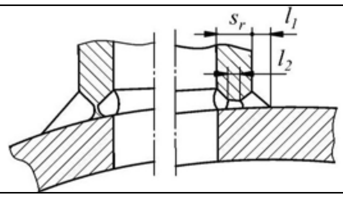
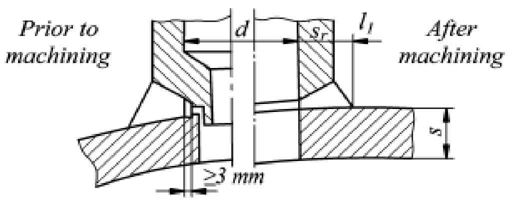
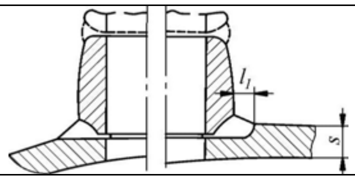
Appendix - continued

1	2	3
1.6		k = 0,57.
	2. Dished ends	
2.1		It is permitted for boilers and pressure vessels of Classes I, II and III. Refer to Notes 2, 17
2.2		It is permitted for boilers and pressure vessels of Classes II and III
2.3		This joint shall be avoided. It is permitted only for pressure vessels of Class III where no danger of corrosion exists. $s_1 \le$ 16mm, $D \le$ 600mm.
2.4		It is permitted only for pressure vessels of Class III. $s_1 \le$ 16mm, $D \le$ 600mm.
	3. Tube plates	
3.1		k = 0,45, $e = 0{,}71\, s_1$, $s_1 \le$ 16mm. Refer to Notes 3, 4.
3.2		k = 0,45, $e = \frac{s_1}{3}$, but not less than 6 mm, s_1 >16 mm. Refer to Notes 5, 6.
3.3		k = 0,45, r ≥ 0,2s, but not less than 5mm

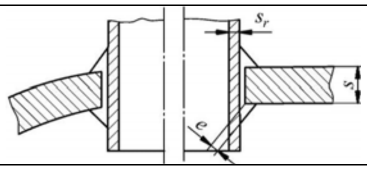
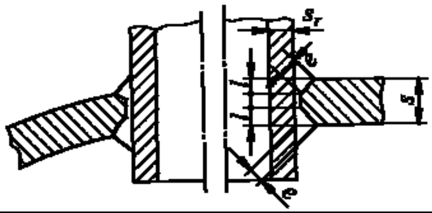
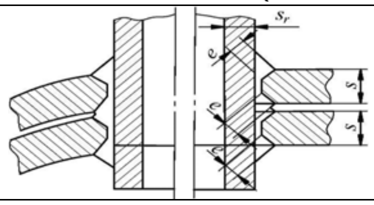
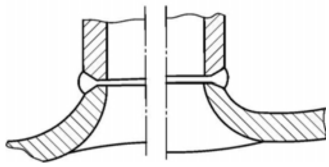
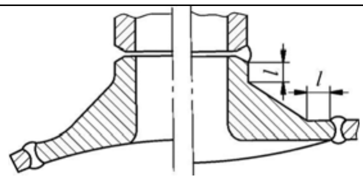
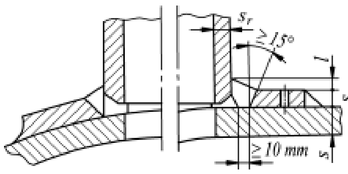
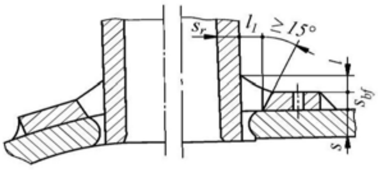
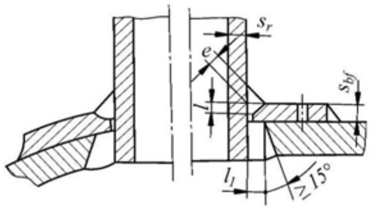
Appendix - continued

1	2	3
3.4		k = 0,45, Type 1: e ≥ 0,71 s_1, but at e > 13 Type 2 is preferable, where *l* = $s_1/3$, but not less than 6mm. Refer to Note 7.
3.5		k = 0,45, r ≥ 0,2s, but not less than 5mm.
	4. Tubes	
4.1		$e = s_r$, $e \geq$ 5mm, $s_r \geq$ 2,5mm. Refer to Notes 8, 9, 10.
4.2		$d = s_r$; $l_1 = s_r$; $1{,}5s_r < l < 2s_r$, Type 1: $s_r \geq$ 5mm; $l = s_r$. Type 2: $s_r <$ 5mm. Refer to Note 11.
4.3		$e = 0{,}7\ s_r$, $s_r \geq$ 3mm. Refer to Note 12.
	5. Long and short stays, stay tubes	
5.1		$k = 0{,}42$.

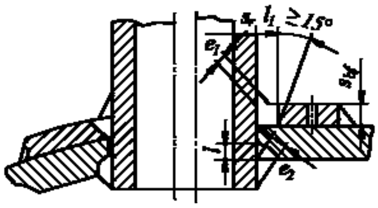
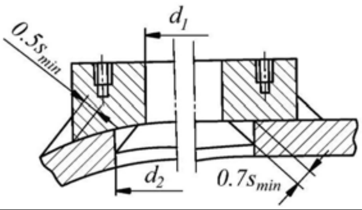
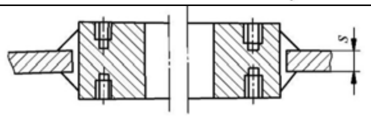
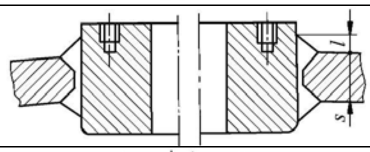
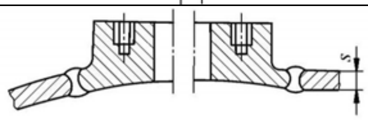
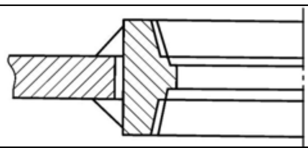
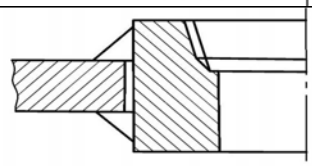
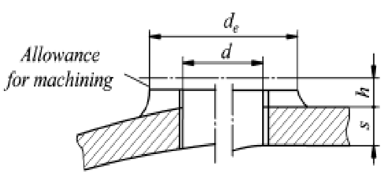
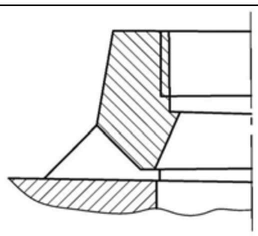
Appendix - continued

1	2	3
5.2		k = 0,34
5.3		k = 0,38. Short stays (Refer to **3.2.2**).
6. Branches, nozzles, pads		
6.1	**Welded-on branches, non-through**	
6.1.1		s_r ≤ 16mm, $l_1 = s_r/3$, but not less than 6mm.
6.1.2		$l_1 = s_r/3$, but not less than 6mm. Refer to Note 13.
6.1.3		l_2 = 1,5...2,5mm, $l_1 \geq s_r/3$, but not less than 6mm. Refer to Note 14.
6.1.4		$l_1 \geq s_r/3$, but not less than 6mm. Refer to Notes 15, 16.
6.1.5		l_1 = 10...13mm. Refer to Note 15

Appendix - continued

1	2	3
6.2	**Welded-on branches, through**	
6.2.1		The joint is mainly used at $s_r < s/2$, $e = s_r$.
6.2.2		The joint is mainly used at $s_r < s/2$, e =6….13mm. $e + l = s_r$
6.2.3		The joint is mainly used at $s_r < s/2$, $e \geq s/10$, but not less than 6mm.
6.3	**Upset nozzles**	
6.3.1		
6.3.2		Refer to Note 17.
6.4	**Branches with disc-shaped reinforcing plates**	
6.4.1		$l \geq s_r/3$, but not less than 6mm.
6.4.2		$l \geq s_r/3$, but not less than 6mm, $l_1 \geq 10$ mm.
6.4.3		$e + l = s_r$ або $e + l = s_{bf}$, whichever is the less; $l_1 \geq 10$mm,

Appendix - continued

1	2	3
6.4.4		$e + l \geq s_r$, $l_1 \geq$ 10mm, $2s_r \leq (e_2 + l)$ + the lesser of the values $(s_{f,b} + e_1)$ or l_1
6.5	**Pads and nozzles for studs**	
6.5.1		$d_2 \leq d_1 + 2s_{\min}$. Refer to Note 18. whichever is the less
6.5.2		$s \leq$ 10mm. Refer to Notes 19, 20.
6.5.3		$l \geq$ 6mm, $s \leq$ 20mm.
6.5.4		$s \geq$ 20mm.
6.6	**Pads and nozzles for threaded joints**	
6.6.1		
6.6.2		
6.6.3		$d \leq s$, $d_e = 2d$, $h \leq$10mm, $h \leq 0{,}5s$. Refer to Note 21.
6.6.4		

Appendix - continued

Notes:

1. The welded joints are applicable to boilers having a shell diameter up to 610 mm. For pressure vessels they may be used without restrictions in case $R_m \leq 460$MPa or $R_{eH} \leq 365$MPa.

2. Reduction in thickness of the shell or flange part of the end may be effected either on the inside or on the outside.

3. This type of the welded joint is used when both sides of the shell are accessible for welding.

4. For shells over 16 mm in thickness the fillet welds are effected with the edge preparation of the shell according to Fig. 3.2.

5. This type of the welded joint is used when the shell is accessible for welding only on the outside.

6. For shells less than 16 mm in thickness the fillet welds may be effected without the edge preparation of the shell. The height of the ring shall not be less than 40 mm.

7. Clearance between inside diameter of the shell and the outside diameter of the tube plate shall be minimized as far as possible.

8. The end of the tube protruding outside the weld seam is removed by milling or grinding.

9. The distance between tubes shall not be less than 2,5 s_r, but never below 8 mm.

10. In case of the manual electric arc welding it is necessary that the thickness shall be $s_r \geq$ 2,5mm.

11. It is recommended when the tube plate deformations resulting from welding shall be minimized.

12. Attachment of tubes is effected by manual electric arc welding.

13. The backing ring shall be tightly fitted and removed after welding.

14. It is used when welding is possible on the inside of the branch.

15. It is used for branches of small sizes as compared to those of pressure vessels.

16. After welding the branch is machined to the final size *d*.

17. The dimensions of cylindrical portions *l* shall be such that the radiographic testing could be carried out, if necessary.

18. The clearance between the pads and the pressure vessel shall not exceed 3 mm.

19. The clearance between the opening and the outside nozzle diameter shall be minimal and in no case shall it exceed 3 mm.

20. The upper holes for studs shall be displaced in relation to the lower ones.

21. The total thickness of the pressure vessel shell and the weld metal shall be sufficient for provision of the required number of threads.

PART XII. REFRIGERATING PLANTS

1. GENERAL

1.1 APPLICATION

1.1.1 The requirements of this Part of the Rules apply to stationary marine refrigerating plants and their equipment in compliance with **5**, Part I "Classification" of the Rules for the Classification and Construction of ships[1].

1.1.2 Classed refrigerating plants shall comply with all the requirements of this Part.

1.1.3 Unclassed refrigerating plants shall comply with the requirements of this Part, set forth in **1.3.2.1**, **1.3.2.2**, **1.3.2.5** (only for heat exchangers and vessels subject to a pressure of a refrigerant), **1.3.2.6** (only for refrigerant systems), **1.3.2.7** (only for the protection system), **1.3.4.2** (only for systems working under a pressure of a refrigerant), **1.3.4.3**, **1.3.4.5**, **1.3.4.7** (only for protection systems), **1.3.4.8**, **2.1.2**, **2.2.1**, **2.2.2**, **2.2.3**, **3.1.1**, **3.1.3 – 3.1.8**, **3.2.1 – 3.2.5**, **3.3.4**, **3.3.8**, **3.3.10**, **3.4**, **3.5**, **4.1.2**, **4.1.5**, **5.1.1**, **5.1.2**, **5.1.4**, **5.1.5**, **5.2.1**, **6.1.1**, **6.1.2**, **6.2.1** (only for refrigerant piping), **6.2.2**, **6.2.3**, **6.2.5 – 6.2.8**, **7.1.2**, **7.2.2**, **7.2.3**, **7.2.4.2**, **7.2.4.3**, **7.2.7**, **8.2.3**, **8.2.4**, **12.1.2** (only for equipment working under a pressure of a refrigerant) **2.5**, **3.3.12**, **13.1.3**, **13.1.6**, **13.2.2**, **13.2.4**, **13.2.6**.

1.2 DEFINITIONS AND EXPLANATIONS

Definitions and explanations relating to general terminology of the Rules are given in General Regulations for Classification and other Activities and in Part I "Classification".

For the purpose of this Part the following definitions and explanations have been adopted.

Refrigerating machinery space is a space containing mechanical and other types of equipment intended for cold production.

Refrigerated spaces are cargo spaces provided with equipment capable of maintaining the reduced temperatures and intended for the carriage of refrigerated and frozen cargoes.

Refrigerant is a working medium of the refrigerating cycle.

Secondary refrigerant is a substance for heat removal from refrigerated objects and heat transfer to a refrigerant.

Note. Brine is an example of a secondary refrigerant.

1.3 SCOPE OF SURVEYS AND TECHNICAL DOCUMENTATION

1.3.1 Provisions concerning the procedure for classification, technical supervision over construction and classification surveys, as well as the requirements for technical documentation submitted to the Register, are given in the General Provisions for Classification and Other Activities and in Part I "Classification".

1.3.1 General provisions and procedure of classification, surveys as well as the amount of technical documents for the refrigerating plant, which shall be submitted to the Register for review and approval are specified in the General Regulations for the Classification and Other Activity, as well as in Section **5**, Part I "Classification" and in Section **13** of this Part.

The technical documents for compressors and pumps to the extent, which shall be submitted to the Register for review, are specified in **1.2.3.2**, Part IX "Machinery" and for heat exchangers and pressure vessels, as determined in **1.3.4.1**, Part X "Boilers, Heat Exchangers and Pressure Vessels".

1.3.2 The following machinery and apparatus shall be surveyed by the Register in the process of manufacture:

.1 refrigerant compressors;

.2 refrigerant pumps;

.3 secondary refrigerant pumps;

.4 cooling water pumps;

.5 heat exchangers and other apparatus and pressure vessels of refrigerant, secondary refrigerant or cooling water;

.6 pipes and valves intended for work at a pressure of 1,0 MPa and over;

.7 devices of control, indication and protection systems as well as instruments for measuring and recording of temperature in the refrigerated spaces.

[1] Hereinafter - Part I «Classification».

1.3.3 The parts of machinery and apparatus mentioned in **1.3.2** are subject to survey by the Register during manufacture to ensure that the provisions of Part XIII "Materials" and Part XIV "Welding" as well as particular requirements of technical documents approved by the Register are complied with.

The parts of machinery under **1.3.2.1** to **1.3.2.4** are listed in Table 1.2.4, Part IX "Machinery" and the parts of apparatus indicated in **1.3.2.5** are given in Table 1.3.3, Part X "Boilers, Heat Exchangers and Pressure Vessels"..

1.3.4 In the process of ship's construction the following shall be subjected to survey by the Register:

.1 manufacture and testing of the relevant items of the refrigerating plant at the workshop;

.2 mounting of machinery, heat exchangers and pressure vessels;

.3 mounting of refrigerant systems;

.4 mounting of secondary refrigerant, cooled air and cooling water systems;

.5 mounting of the main and emergency ventilation systems;

.6 fitting of insulation of the cooling spaces and freezing chambers, apparatus, pressure vessels and refrigerating pipes;

.7 installation of control, indication, alarm and protection systems of the refrigerating plant;

.8 testing of the refrigerating plant.

2. GENERAL TECHNICAL REQUIREMENTS

2.1 GENERAL

2.1.1 The machinery and other units of the refrigerating plant shall remain operative under the environmental conditions specified in **2.3**, Part VII "Machinery Installations".

2.1.2 The machinery and equipment of the refrigerating plant shall be installed and secured on board the ship in accordance with the requirements of **4.4.1**, **4.4.4**, **4.4.6** to **4.4.8**, Part VII "Machinery Installations".

2.2 REFRIGERANTS AND DESIGN PRESSURE

2.2.1 Refrigerants in accordance with Table 2.2.1 are subdivided into two groups as follows:

I - non-flammable and low-toxic refrigerants;

II - flammable, explosive and toxic refrigerants.

Use of refrigerants other than specified in Table 2.2.1 is allowed after submitting to the Register the necessary data on their corrosivity, toxicity, flammability and explosiveness as well as their physical properties and chemical composition, their environmental characteristics (ozone depletion potential (ODP) and global warming potential (HGWP or GWP)).

Table 2.2.1

Refrigerant group	Symbol/name	Chemical formula	Design pressure *p*, MPa
I	R22/ freon 22	$CHClF_2$	2,0
	R134A/ freon 134a	$CF_3\,CH_2F$	1,2
	R744 / carbon dioxide	CO_2	refer to 2.2.3
II	R717/ammonia	NH_3	2,0

2.2.2 In strength calculations of the items operating under the refrigerant pressure, the design pressure shall be taken not less than the excessive pressure of the saturated vapors of the refrigerant at a temperature +50°C refer to Table 2.2.1.

2.2.3 For the refrigerant equipment working under the pressure of refrigerants with low critical temperatures (below +50°C) the design pressure is defined by the results of the refrigerant’s physical properties analysis.

2.2.4 The refrigerating plant components working under pressure shall be calculated for compliance with hydraulic test pressure (refer to **13.1.2**). The stresses involved shall not exceed 0,9 times the yield stress of material.

2.2.5 It is allowed to use hydrocarbons (isobutane R600a or others) as refrigerants in household refrigerators and freezers on board the ships in case the total amount of the refrigerant in household refrigerators and freezers installed in one space does not exceed 150 g**.**

2.3 COMPOSITION AND CAPACITY OF THE REFRIGERATING EQUIPMENT

2.3.1 The refrigerating plant shall provide effective maintenance of the temperatures in refrigerated spaces as may be required for the cargo carried, depending upon its type and conditions of navigation area as well as cold treatment of cargo.

2.3.2 The refrigerating plant shall provide maintenance of required temperatures in the refrigerated cargo spaces with the main equipment at work supplying cold to all consumers under the following environmental conditions:

sea water temperature not below + 32°C;

ambient air temperature not below + 40°C.

For ships intended for navigation in limited geographical areas other temperature values may be defined upon the agreement with the Register.

2.3.3 Capacity of main equipment of the refrigerating plant shall be sufficient to maintain the required temperatures in refrigerated spaces when working 24 h a day and to supply cold to other consumers.

The main equipment shall comprise not less than two similar condensers and, where intermediate secondary refrigerant or cascade and stage cycles are used, two similar evaporators, intercascade heat exchangers and intermediate pressure vessels.

2.3.4 Capacity of the refrigerating plant designed also for cooling of non-precooled cargo with all the machinery at work including the standby unit shall be sufficient to reduce the cargo temperature to the required temperature as quickly as it is necessary for preservation of that cargo.

2.3.5 Standby equipment of compressor refrigerating plant shall comprise one compressor with a drive motor, one condenser, control systems and all valves necessary for independent operation of all components of this equipment.

Capacity of the standby equipment shall be such as to supply cold to all consumers with one of the main compressors or condensers inoperative.

2.3.6 For ships, which, in addition to the refrigerating plants of the cargo spaces, are equipped with other refrigerating facilities (e.g. freezing, cooling and ice making), provision of the standby equipment is optional.

2.3.7 Freezing and cooling facilities shall provide freezing (cooling) of cargo during the time period as required by the conditions of its preservation, handling and proper carriage.

2.3.8 Pipelines between apparatus and machinery shall be joined in such a way as to provide operation of the refrigerating units at various combinations of apparatus, machinery and facilities necessary for their independent operation.

The apparatus shall be fitted with the connections for suction and delivery pipes providing the transfer of the refrigerant and its discharge from the apparatus.

2.3.9 When pumping for liquid refrigerant circulation is used, at least two circulating pumps shall be fitted, one of which shall be a standby pump. If the refrigerant system is so designed that it is capable of properly working without pumps, the standby pump need not be installed, provided the refrigerant system capacity meets the requirements of **2.3.1** and the freezing units capacity is not reduced in excess of 20 %.

2.3.10 The secondary refrigerant system serving a single group of cold consumers shall comprise at least two circulating pumps, one of which being standby. In case of two or more groups of cold consumers with separate secondary refrigerant systems (differing in temperatures), each group shall have at least one circulating pump; a common standby pump may be admitted provided it has adequate capacity and pressure head.

2.3.11 Cooling water supply to the refrigerating plant shall be provided from at least two circulating pumps, one of which shall be used for standby purpose.

Any of sea water pumps with adequate capacity and pressure head may be accepted as standby means.

2.3.12 Cooling water shall be supplied from at least two sea connections.

Where it is intended to use sea connections of general service, proper structural arrangements shall be provided for adequate supply of cooling water from each sea connection under normal service conditions of the ship.

2.4 MATERIALS

2.4.1 Quality and main characteristics of materials used for the manufacture of parts, assemblies and securing items of the refrigerating equipment subject to the dynamic loads, excessive pressure, variable and low temperatures shall comply with the requirements of Part XIII "Materials".

The choice of materials depends on the working temperature and physical and chemical properties of the refrigerant:

.1 materials used for the manufacture of parts of equipment exposed to the refrigerants, lubricating oils and their combinations, cooling and cooled media shall be inert and resistant to their action;

.2 materials used for the manufacture of parts of equipment working at low temperatures shall not be subject to structural irreversible modifications and shall maintain adequate strength at the temperatures concerned;

.3 materials used for the manufacture of parts and assemblies of the refrigerating equipment working at temperatures -50° C shall comply with the requirements of 1.2, Part II "Hull" and 3.5, Part XIII "Materials";

2.4.2 Parts of machinery and apparatus exposed to the action of corrosive agents shall be made of materials with adequate corrosion resistance or be protected by corrosion-resisting coatings.

Assemblies and parts of machinery and apparatus made of materials differing in electrolytic potential shall be protected against contact corrosion.

2.4.3 Steel piping of refrigerant, secondary refrigerant and connecting pieces of these pipes made of steel other than stainless steel shall be galvanized on the outside or treated in some other way ensuring equivalent antirust protection.

Surfaces in contact with refrigerant or secondary refrigerant shall not be galvanized. In manufacturing pipes the requirements of **2.4.1** and **2.4.2** shall be taken into consideration.

2.5 ELECTRICAL EQUIPMENT

2.5.1 Electrical equipment of refrigerating plants and automatic devices as well as the lighting of refrigerating machinery and refrigerated spaces and refrigerant storerooms shall comply with the requirements of Section **20** and other applicable requirements of Part XI "Electrical Equipment".

2.5.2 Driving motors of compressors, pumps and fans shall meet the requirements of Sections **5** and **10**, Part XI "Electrical Equipment".

3. SPACES FOR REFRIGERATING PLANTS AND REFRIGERATED CARGO SPACES

3.1 REFRIGERATING MACHINERY SPACES

3.1.1 The refrigerating machinery spaces shall meet the requirements of **4.5.1**, **4.5.3** and **4.5.4**, Part VII "Machinery Installations" as well as the requirements of this Chapter.

Refrigerating equipment working with Group II refrigerants shall be arranged in isolated gastight compartments.

For fishing vessels of and under 55 m in length and other plants with refrigerant agent not exceeding 25 kg, a refrigerating machine working with Group II refrigerant may be arranged in common machinery space under the following conditions:

the space where refrigerating machines are installed shall be served by a special hood with exhaust ventilation, so as not to permit any leakage of ammonia from dissipating into other areas in the machinery space.

The number of the air changes shall be not less than specified in **3.1.6** and **3.1.7.1**;

water screens shall be provided for the said area;

a fixed ammonia system with alarms inside and outside the compartment shall be fitted;

at least two sets of breathing apparatus and protective clothing shall be available.

Otherwise the installation of a refrigerating machine using a Group II refrigerant in the common machinery space of the ship is permitted after conducting the formal safety assessment of the ship ammonia refrigerating plants according to the procedure set forth by the Register.

Drainage of the refrigerating machinery space with Group II refrigerant shall be provided as required by **7.4.10**, Part VIII "Systems and Piping".

3.1.2 The machinery, apparatus and piping shall be so arranged in the refrigerating machinery space as to permit easy access for maintenance and shall enable the parts to be renewed, if necessary, without dismantling the machinery and apparatus from foundations.

Care shall be taken that the machinery, apparatus and other equipment be placed not less than 100 mm remote from bulkheads and other vertical surfaces.

3.1.3 The refrigerating machinery space shall have two exits located as far apart as practicable, with the doors opening outwards.

Where the refrigerating machinery space is situated above or below the open deck, each escape route shall be fitted with steel ladders as widely separated from each other as possible and leading to the spaces, which give access to the open deck.

A second exit is not required:

.1 for refrigerating machinery spaces, provided the distance between the farthest place where people are likely to be and the exit is 6 m and less;

.2 unattended rooms of automated refrigerating machinery working with Group I refrigerants.

3.1.4 The means of escape from spaces of refrigerating machinery working with Group II refrigerants shall not lead in accommodation, public and service spaces or spaces in communication therewith. One of the means of escape shall lead to the open deck.

Where the escape routes pass through corridors and casings, these shall be fitted with supply and exhaust ventilation, forced air supply being obligatory.

The starting arrangements of the ventilation shall be available both inside and outside the refrigerating machinery space, placed in immediate proximity to the exit.

3.1.5 Exits from spaces housing refrigerating machinery working with Group II refrigerants shall be provided with water-screen arrangements.

The starting means of water screens shall be available from the outside of the space placed in immediate proximity to the exit.

In the machinery space there shall be one fire hydrant with a hose.

3.1.6 In addition to the main ventilation system required by **3.1.6**, each refrigerating machinery space shall be fitted with emergency ventilation system of a capacity sufficient for:

.1 30 air changes per hour for spaces of refrigerating machinery working with Group II refrigerants;

.2 20 air changes per hour for spaces of refrigerating machinery working with Group I refrigerant.

Depending on density of the refrigerant, exhaust ventilation shall be provided from the uppermost or lowest parts of the space.

When calculating the emergency ventilation system, the capacity of the main ventilators may be included, provided these are operable with the emergency ones, shall the switchboard of the refrigerating units be deenergized.

3.1.8 At least two breathing apparatus suitable for the refrigerant used, access to which will not be cut in case of refrigerant leakage, shall be provided at the exits of the refrigerating machinery space.

At least two sets of gastight protective clothings shall be available at the exits of the spaces of refrigerating machinery working with Group II refrigerants.

3.2 REFRIGERANT STOREROOMS

3.2.1 Refrigerant storerooms shall be separated from other spaces.

The spaces intended for storage of the refrigerant shall be gastight. In case of storing small amounts of Group I refrigerant the departure is allowed from the abovementioned requirements on agreement with the Register.

The refrigerant storage cylinders shall comply with the requirements of **6.4.5**, Part X "Boilers, Heat Exchangers and Pressure Vessels".

3.2.2 The refrigerant storage cylinders shall be secured in place in such a way that they will not shift in adverse weather conditions.

Non-metallic pads shall be placed between the steel plating and the storage cylinders as well as between storage cylinders proper.

3.2.3 The refrigerant storerooms shall be provided with an independent ventilation system.

3.2.4 Storage cylinders containing compressed gases other than the refrigerant gas are not permitted to be stowed in spaces of refrigerant storage, nor shall combustible materials be used for the outfit of these spaces.

3.2.5 Storage of refrigerant in fixed receivers is permitted on condition that the receivers and spaces they are arranged to comply with the requirements stated in **3.1.5**, **3.1.7**, **5.1.1**, **5.1.2**, **5.1.4**, **6.2.5** and **6.2.6**. Refrigerant receivers may be located in the refrigerant machinery spaces.

Provision shall be made for sucking off Group II refrigerant from the service piping of each receiver after complete filling of the system or periodical replenishing.

Service piping of receivers designed for refrigerant storage is not to pass through accommodation and service spaces.

3.3 REFRIGERATED CARGO SPACES

3.3.1 Cooling apparatus, grids, mechanisms, devices as well as piping and air ducts arranged in the refrigerated cargo spaces shall be efficiently secured and protected from being damaged by cargo.

3.3.2 Where the air cooling system is used, the air coolers may be located either in separate spaces or in the same spaces as the cargo cooled.

Being arranged in the refrigerated cargo spaces, the air coolers shall be provided with condensate tray.

For the refrigerated spaces with the ambient air temperature being negative, the condensate trays shall be provided with the heating system.

3.3.3 Where the air cooling system is adopted, the air coolers shall be made accessible with the cargo space being entirely loaded with refrigerated cargo.

Alternatively, access to the air coolers shall be provided from adjacent non-cooled spaces.

The access opening of the air cooler space shall be as large as to permit the fan impeller and electric motor to be carried through, if necessary.

3.3.4 In places where air ducts pass through watertight bulkheads, sluice valves shall be fitted.

The sluice valves shall be designed as strong as the bulkhead.

The sluice valves shall be operable from positions above the bulkhead deck.

In passenger ships and special purpose ships, the cargo cooling air ducts may pass through more than one watertight bulkhead if the means of closure at such openings are operated by power and are capable of being closed from the main machinery control room located above the bulkhead deck.

3.3.5 Appropriate ventilation system capable of supplying uncontaminated atmospheric air into the spaces of refrigerated cargoes requiring adequate air exchange during carriage shall be provided.

3.3.6 Each air inlet and outlet shall have airtight closure.

3.3.7 Ventilation ducts passing through refrigerated cargo and other spaces shall be airtight and efficiently insulated.

3.3.8 Where cooling arrangements (batteries or air coolers) under a refrigerant pressure are used in cargo spaces, an independent ventilation system shall be provided for these spaces capable to ensure, relative to the volume of the empty space:

.1 two air changes per hour, where a Group I refrigerant is used;

.2 three air changes per hour, where a Group II refrigerant is used.

The above ventilation system may be combined with the system referred to in **3.3.5** and 10.1.8, if any.

For spaces where cooling arrangements working under Group II refrigerant pressure are used, the requirement of **3.5.4** as regards two exits shall be met.

3.3.9 The refrigerated spaces shall be fitted with telethermometric arrangements.

3.3.10 Drainage of refrigerated spaces shall conform to the requirements stated in **7.4.10** and **7.8**, Part VIII "Systems and Piping".

3.3.11 Piping passing through refrigerated spaces shall comply with **5.4**, Part VIII "Systems and Piping".

3.3.12 Each refrigerated space with an indoor temperature of 0°C and below shall be fitted with a readily identifiable signal push-button located in an accessible position.

The "Man-in-Space" signal actuated by this push-button shall be transmitted to the position where continuous watch is kept.

3.4 FREEZING AND COOLING APPARATUS

3.4.1 The arrangement of air coolers and fans in freezing apparatus shall comply with the requirements of **3.3.1**.

3.4.2 Provision shall be made in the refrigerating machinery space for the devices for monitoring the operation of freezing and cooling apparatus.

3.5 SPACES CONTAINING PROCESS EQUIPMENT

3.5.1 If the arrangement of machinery, apparatus and refrigerant pressure vessels in spaces other than the refrigerating machinery spaces and refrigerated spaces is provided, such spaces shall be considered process equipment spaces.

3.5.2 Spaces containing the process equipment working under pressure of Group II refrigerant shall be provided with a fire hydrant with a hose.

3.5.3 Spaces containing the process equipment working under pressure of a refrigerant shall have an independent ventilation system complying with the requirements of **3.1.6** and **3.1.7**.

3.5.4 In spaces containing the process equipment working under pressure of Group II refrigerants there shall be two exits, as it is specified in **3.1.3** and **3.1.4**.

When using Group II refrigerants, the exits shall be fitted with arrangements capable of producing water screens.

The cut-in device of the screens shall be placed from the outside of the space in immediate proximity to the exit.

4. MACHINERY

4.1 COMPRESSORS

4.1.1 Compressors shall comply with the requirements specified in this Part of the Rules and also with those of **5.1**, Part IX "Machinery".

4.1.2 Parts of compressors exposed to the action of dynamic loads and excessive pressure shall be calculated for strength having in view the design pressures in compliance with **2.2.1**.

4.1.3 The refrigerant suction and delivery sides of the compressor shall have stop valves apart from the automatic valves.

4.1.4 Cavities in compressors reserved for refrigerant, lubricating oil and cooling water shall have drain arrangements, where necessary.

4.1.5 A pressure relief valve or other safety device shall be fitted in the delivery line of the intermediate and final compression stages of compressor between the delivery cavity and the stop valve, the discharge being led to the suction side of the compressor in case of excessive pressure rise.

Discharging capacity of the safety devices shall not be less than the maximum volumetric capacity of the compressor stage protected.

The opening pressure of safety valve shall not exceed 10 % of the working pressure, with the valve being open. No shut-off devices are permitted in the refrigerant gas relief line.

4.1.6 Refrigerant compressor safety devices shall comply with the requirements of **7.2.3**.

4.2 PUMPS

4.2.1 Pumps shall comply with the requirements set out in **5.2**, Part IX "Machinery".

4.3 FANS

4.3.1 Fans shall comply with the requirements set out in **5.3**, Part IX "Machinery".

5. HEAT EXCHANGERS, PRESSURE VESSELS AND COOLING ARRANGEMENTS

5.1 HEAT EXCHANGERS AND PRESSURE VESSELS

5.1.1 Heat exchangers and pressure vessels as regards materials, scantlings of components and provision with valves shall comply with the relevant requirements of Section **6** (except for **6.3.1**, **6.3.3**, **6.4.1**, **6.4.2.3** and **6.4.2.4**), Part X "Boilers, Heat Exchangers and Pressure Vessels" and also with the requirements of this Part.

5.1.2 "Shell and tube" heat exchangers and pressure vessels with the volume of the refrigerant space of 50 dm^3 and over shall be fitted with safety devices having the discharging capacity so designed that the pressure will not rise in excess of 10 % of the design pressure, with the valve being completely open.

The designed discharging capacity G, in kg/s, shall not be less than determined by the following formula

$$G=qS/r\,, \qquad (5.1.2)$$

where:
q – specific intensity of the heat flow from the space during fire, kW/m^2 (assumed to be 10 kW/m^2 in all cases);
S – (assumed to be 10 kW/m2 in all cases^2;
r – specific heat of the refrigerant vaporization under opening pressure of the safety valve, kJ/kg.

The safety devices shall consist of two safety valves and a change-over device so constructed that both or one of these valves will, in any case, communicate with the heat exchanger or pressure vessel involved.

Each of these valves shall provide the full discharging capacity.

The Register may require that the safety valves are also fitted in other apparatus if this is deemed expedient.

No shut-off valves are permitted between the heat exchanger or pressure vessel and the safety device.

5.1.3 Heat exchangers and pressure vessels shall have suitable facilities for removing water, air, lubricating oil and secondary refrigerant.

5.1.4 Pressure vessels with Group II liquid refrigerants with the volume of the refrigerant space of 50 dm^3 and over shall be fitted with suitable facilities for emergency dumping of the latter in compliance with **6.2.6**.

5.1.5 Cooling facilities of refrigerated cargo spaces, freezing and cooling apparatus arranged outside the space for refrigerating machinery working under the pressure of the refrigerant shall be equipped with shut-off valves enabling facilities and apparatus to be disconnected remotely from the refrigerant delivery and return lines.

The disconnection shall be performed from positions arranged outside the spaces where these facilities and apparatus are placed.

5.2 AIR COOLERS, COOLING GRIDS

5.2.1 Air coolers working under pressure of a refrigerant shall be of welded or soldered construction.

Flanged connections between the coil sections and pipes are permitted only when this is proved necessary; all flanged connections shall be arranged in readily accessible places to enable inspection for tightness.

5.2.2 Where only one air cooler is used for cooling cargo spaces, it shall be arranged in not less than two sections, each of which shall be capable of being disconnected, if necessary.

5.2.3 The distribution of cooling grids shall provide the uniform cooling of the space concerned.

Grids shall be combined in not less than two independent sections, with means providing shut-off of each section.

5.2.4 The cooling facilities of refrigerated cargo spaces shall be provided with effective defrosting system or means.

6. VALVES AND PIPING

6.1 VALVES

6.1.1 The refrigerating plants shall be provided with shut-off, regulating and safety valves designed for pressure of not less than 1,25p, where p is the design pressure as given in **2.2.1**.

As a rule, steel valves shall be used. Considering the possibility of using valves made of other materials, chemical compatibility of the material and the refrigerant shall be taken into account.

The integral shut-off valves made of grey cast iron, which are intended for the inlet and outlet cavities of the refrigerant compressors, as well as the valves made of spheroidal graphite cast iron may be permitted when using Group I and Group II refrigerants at ambient temperatures not below -40°C.

6.1.2 The design of safety valves shall ensure the valve blowing up at a pressure exceeding the design pressure as given in **2.2.1** by not more than 10 %.

6.2 PIPING

6.2.1 The piping of refrigerant, secondary refrigerant and cooling water systems as well as air ducts shall comply with the relevant requirements set out in Section **2** and **5.4**, Part VIII "Systems and Piping" and also with the requirements of this Chapter.

In accordance with Table 1.3.2, Part VIII "Systems and Piping", piping conveying Group I refrigerant is Class II piping while piping conveying Group II refrigerant is Class I piping.

6.2.2 The piping of refrigerant shall be made of seamless pipes. The joining of steel pipes carrying the refrigerant shall, as a rule, be made by welding and, where copper pipes are concerned, by welding or brazing.

Where pipes are joined with machinery, heat exchangers and pressure vessels, detachable connections may be admitted.

6.2.3 The refrigerant delivery piping of the compressors and refrigerant pumps shall be fitted with non-return valves. These valves need not be used for compressors working with Group I refrigerant and having no discharge facilities.

6.2.4 Refrigerant driers for moisture absorption shall be fitted on the liquid piping carrying the refrigerant slightly soluble in water. They shall be fitted together with gauze filters to the regulators or structurally connected with them.

6.2.5 The pipes from safety devices of Group II refrigerant shall be led overboard below the waterline corresponding to the minimum draught.

These pipes shall be provided with non-return valves fitted in proximity to the ship's side.

Refrigerant leak detectors shall be installed after each safety device (other than those referred to in **4.1.5**).

Group I refrigerant may be discharged to the atmosphere at a position safe for people.

6.2.6 The pipes for Group II refrigerant dumping from heat exchangers and pressure vessels in emergency shall terminate into a header (refer to **5.1.4**) located outside the refrigerating machinery space, but near the access thereto.

Each dumping pipe shall be fitted with shut-off valves located near the header. These valves shall be protected from opening by unauthorized persons and shall be so constructed as to be convenient for sealing when closed.

No other shut-off valves shall be fitted on the emergency drain pipes between pressure vessels or heat exchangers and shut-off valves near the header.

The common main of the emergency dumping header shall have a non-return valve fitted in accordance with **4.3.2.10**, Part VIII "Systems and Piping" and shall be laid overboard below the waterline corresponding to the minimum draught of the ship.

To permit purging of the common main, steam or compressed air connections shall be provided.

The inner diameters of the refrigerant emergency dumping pipes of separate heat exchangers and pressure vessels shall not be less than the diameter of the relief valve determined as required by **5.1.2**.

The cross-sectional area of the dumping main shall not be less than the total cross-sectional area of three largest dumping pipes communicating with the main.

6.2.7 For pipes laid overboard in a place below the waterline according to **6.2.5** and **6.2.6**, the minimum pipe wall thickness in all cases shall not be less than that specified in column 3 of Table 2.3.8, Part VIII "Systems and Piping".

6.2.8 Group II refrigerant piping shall not pass through accommodation and service spaces specified in

1.5.2 and **1.5.3**, Part VI "Fire Protection".

Group I refrigerant piping shall not pass through accommodation spaces. Their passage is permitted through service spaces and corridors adjacent to or leading into service spaces.

7. INDICATING AND MEASURING INSTRUMENTS. CONTROL, PROTECTION, REGULATION AND ALARM

7.1 INDICATING AND MEASURING INSTRUMENTS

7.1.1 The compressors and apparatus for the refrigerating plants shall be fitted with suitable devices to permit the working parameters being monitored.

Besides, the arrangement shall provide for the possibility of installing additional indicating and measuring instruments required when testing the plant.

7.1.2 Indicating and measuring instruments shall be placed in readily accessible and visible positions.

The instruments shall bear clear marks indicating admissible values of the parameters controlled.

Indicating and measuring instruments shall be checked by competent bodies.

7.2 CONTROL, PROTECTION, REGULATION AND ALARM

7.2.1 Protective, regulation and alarm devices shall comply with the applicable requirements of Part XV "Automation".

The requirements for control, regulation and alarm of refrigerating plants of unattended operation are given in **4.8**, Part XV "Automation".

7.2.2 Provision shall be made for local control and regulation of operating conditions of the refrigerating plant.

7.2.3 The refrigerant compressors shall be provided with protective devices capable of stopping the compressors in case of:

.1 inadmissible drop of suction pressure;

.2 inadmissible rise of discharge pressure;

.3 inadmissible drop of lubricating oil pressure;

.4 inadmissible rise of refrigerant discharge temperature (intended for the refrigerating plants working with Group II refrigerants as well as for the automated refrigerating plants with unattended operation);

.5 inadmissible axial rotor displacement of centrifugal compressor;

.6 inadmissible temperature rise in sliding bearings of centrifugal compressors.

7.2.4 Liquid separators, intermediate vessels and liquid refrigerant receivers (where pumps are used for refrigerant circulation) as well as free-level type evaporators shall be fitted with regulation and protective devices capable of:

.1 maintaining constant level of refrigerant liquid necessary for proper work of the evaporator, or constant temperature of vapour superheating;

.2 stopping the delivery of liquid refrigerant into evaporators and any type of intermediate vessels, in case of compressor shut-down;

.3 stopping the compressor, shall the level of refrigerant liquid rise inadmissibly.

7.2.5 Plants incorporating "shell and tube" type evaporators shall be fitted with protective devices capable of:

.1 stopping the compressor, shall the circulation of the secondary refrigerant inside the evaporator be impeded, or cutting off this evaporator from the refrigerant system;

.2 stopping the compressor, shall the temperature of secondary refrigerant drop inadmissibly.

7.2.6 The refrigerating plants shall be provided with signal devices, which shall give general warnings at the refrigerating plant control station after operation of protective devices specified in **7.2.3** to **7.2.5**.

Provision shall be made at the local control station for decoding of the above signals.

7.2.7 Each space with equipment under refrigerant pressure shall be fitted with gas detection panel and refrigerant leakage alarm that comes into action in the following cases:

for Group I refrigerants (freons):

where the concentration of refrigerant in the working zone air is above the maximum allowable sanitary standard (3000 mg/m^3);

for Group I refrigerants (carbon dioxide): where the concentration of the refrigerant in the working zone is above the maximum allowable sanitary standard (9200 mg/m^3);

for Group II refrigerants (ammonia): where the concentration of refrigerant in the working zone air is above the maximum allowable sanitary standards (20 mg/m^3);

where the maximum allowable concentration of refrigerant (60 mg/m^3) in the space protected increases threefold. In this case, provision shall be made for automatic switching on the emergency ventilation, except for the refrigerated spaces;

where the concentration of 500 mg/m^3 is attained. In this case access to the space without individual protection outfit shall be prohibited.

Warning audible and visible alarms shall be mounted in the spaces protected and before entrance to these spaces. Warning signals shall be duplicated at the position where continuous watch is kept.

7.2.8 The system for temperature, humidity and atmosphere control inside the refrigerated spaces shall ensure accuracy in maintaining these parameters within the ranges consistent with the cargo transportation conditions.

7.2.9 When using the cascade refrigerating machines with carbon dioxide in the lower cascade branch the auxiliary (harbor) cooling unit of the lower cascade branch shall be automatically switched on in case of disconnecting the cascade refrigerating machines and to maintain the required temperature during the entire period of disconnecting the cascade refrigerating machine.

8. INSULATION

8.1 INSULATION OF THE REFRIGERATED SPACES

8.1.1 All steelwork of ship's hull inside the refrigerated cargo spaces shall be efficiently insulated.

The applied insulating materials shall be of a type approved by the Register and shall also comply with the requirements of the properly authorized Sanitary Inspection Authorities.

8.1.2 The insulating materials adopted for refrigerated cargo spaces shall have adequate resistance to adverse biological factors and shall be of the type that does not give off any odour.

8.1.3 The surfaces of the bulkheads and the inner bottom plating in way of fuel tanks shall be coated with oil-resistant and inodorous material.

The coating shall be applied before the insulation of these surfaces is arranged.

8.1.4 Care shall be taken to prevent the insulation from infiltration with water, or, alternatively, suitable means for drying it during service as well as protective measures against damage by rodents shall be provided.

8.1.5 The insulation of refrigerated cargo spaces shall be covered with suitable lining or other protective coating. In places where insulation linings may be crushed by cargo, they shall be suitably protected.

8.1.6 The insulation in freezing apparatus shall comply with the requirements of **8.1.2**, **8.1.4**, **8.1.5**.

8.2 INSULATION OF PIPING

8.2.1 Where pipes are laid through bulkheads and decks, no direct contact with surfaces they pierce is permitted to prevent heat exchange.

8.2.2 Provision shall be made for protecting the insulation of piping from dampness.

8.2.3 The insulating materials used for piping shall be non-combustible in accordance with **1.6.3.1**, Part VI "Fire Protection".

This requirement does not apply to insulation of piping arranged within the refrigerated cargo spaces and refrigerated storerooms.

8.2.4 Vapour barriers and adhesives used in conjunction with insulation as well as insulation of pipe valves need not satisfy the requirements of **8.2.3**, provided they are kept to the minimum quantity and their exposed surfaces have low flame spread characteristics in accordance with **1.6.3.5**, Part VI "Fire Protection".

9. REFRIGERATING PLANTS DESIGNED FOR COOLING OF CARGO IN THERMAL CONTAINERS

9.1 GENERAL PROVISIONS AND TECHNICAL REQUIREMENTS

9.1.1 The refrigerating plants designed to supply cooled air to the thermal containers and installed permanently on board ship are covered by the applicable requirements of this Part.

9.1.2 The refrigerating plants shall be capable of supplying cooled air within the required temperature range to the thermal containers with the cargo contained therein.

The degree of air circulation in the containers, devices for measuring and controlling temperature, maintaining required humidity, alarms to indicate maintenance of required parameters shall be consistent with transportation conditions of particular kinds of cargo.

The refrigerating capacity margin of the plant shall not be less than 20 % of the specified capacity.

9.1.3 If the purpose of a container is such that for carriage of cargo inside the container atmosphere control is required, its ventilation arrangements, insulation and alarm system shall meet the requirements of Part III "Thermal Containers" of the Rules for the Construction of Containers.

9.1.4 The atmosphere control system inside the thermal containers shall be capable of maintaining the required oxygen concentration in the containers.

9.1.5 The cooled air supplied to the thermal containers shall be sufficiently dry to avoid ice formation in flexible couplings.

9.1.6 The thermal containers carried on board ship shall comply with the requirements of Part III "Thermal Containers" of the Rules for the Construction of Containers and the Rules for Technical Supervision of Containers in Service.

Failure to meet these requirements cannot impede classification of the refrigerating plant.

10. ATMOSPHERE CONTROL SYSTEM

10.1 GENERAL PROVISIONS AND TECHNICAL REQUIREMENTS

10.1.1 To add a distinguishing mark CA (refer to **5.2.2.4**, Part I "Classification") to the character of classification of a refrigerating plant at least 50 % of the ship's total refrigerated cargo space volume shall meet the requirements for operation with controlled atmosphere.

10.1.2 Equipment, laying of piping shall meet the requirements of **2.1.1**, **2.5**, **4.1.1**, **5.1.1**, **6.2.1**, **7.2.1**.

10.1.3 Each refrigerated space served by the atmosphere control system shall be fitted with a safety device, which pressure set point and pressure relieving capacity shall be such that the pressure in the space shall not exceed 0,5 kPa (50 mm water column) and shall not be less than 0,2 kPa (20 mm water column).

10.1.4 Gas shall be discharged from the safety device through vertical ducts, whose outlets shall be located at least 2 m above the upper deck and within 4 m of the ventilation intakes of accommodation spaces.

10.1.5 Arrangements shall be provided to ensure that the inert gas cannot be delivered to the depressurized refrigerated spaces.

10.1.6 The inert gas used in the system shall not be hostile to the cargo carried, insulating and structural materials of the refrigerated spaces.

10.1.7 Alarm shall be provided to automatically giving audible and visual warning at least 60 s before the inert gas injection takes place. The alarm shall be interlocked with the inlet valve in such a way that the inlet valve cannot be opened unless the alarm signal has been given.

10.1.8 The refrigerated spaces with the controlled atmosphere shall be provided with an independent ventilation system with a capacity of at least 2 air changes per hour.

10.1.9 All spaces leading to the refrigerated spaces with controlled atmosphere and adjacent to them shall have an independent permanent ventilation system giving at least 6 air changes per hour.

10.1.10 The ventilation system serving the spaces specified in **10.1.8** and **10.1.9** shall be operated from outside the ventilated spaces.

10.1.11 All other spaces adjacent to the refrigerated spaces, other than those specified in **10.1.9** shall be arranged for ventilation by use of at least two portable ventilators provided on board, each of them being capable to give at least 2 air changes per hour.

10.1.12 The refrigerated spaces with controlled atmosphere shall be fitted with permanent devices providing O_2 volume content monitoring in the spaces before they are entered.

In addition, at least two portable O_2 analyzers shall be provided on board ship.

10.1.13 The supply and exhaust ducts of the atmosphere control system shall not pass through the accommodation and service spaces.

11. REFRIGERATING PLANTS DESIGNED FOR COOLING OF LIQUEFIED GAS

11.1 GENERAL

11.1.1 The refrigerating plants shall ensure maintenance of temperatures and pressures as may be required for the carriage of liquefied gas in bulk.

11.1.2 The refrigerating plants shall comply with the requirements of **4.2**, Part VI "Systems and Piping" of the Rules for the Classification and Construction of Gas Carriers, as well as the requirements of the present Part.

11.1.3 The minimum temperature the refrigerating plant is capable to maintain in the cargo tank shall be indicated in the Classification Certificate for the refrigerating plant.

12. REFRIGERATING PLANTS WITH ABSORPTION LITHIUM BROMIDE REFRIGERATING MACHINES

12.1 GENERAL

12.1.1 The requirements of this section apply to refrigerating plants with absorption lithium bromide refrigerating machines designed for work in the ship's air conditioning system.

12.1.2 Refrigerating plants with absorption lithium bromide refrigerating machines shall comply with requirements of **1.3.4.2**, **1.3.4.5**, **1.3.4.7** (only for protection systems), **1.3.4.8**, **2.1.2**, **3.1.1**, **3.1.6**, **5.1.1**, **7.1.2**, **7.2.2**, **13.2.6**.

12.1.3 The heating system for apparatus with absorption lithium bromide refrigerating machines (steam or hot water) shall comply with applicable requirements of Section **18**, Part VIII "Systems and Piping".

13. TESTS

13.1 TESTS AT THE MANUFACTURER'S

13.1.1 Tests of the refrigerating plant components listed in this Chapter shall be carried out in the presence of a surveyor to the Register.

13.1.2 Hydraulic tests for strength of the components working under the refrigerant pressure shall be carried out by a test pressure of not less than 1,5p in accordance with **2.2.1**.

Components working under the pressure of secondary refrigerant or water shall be tested by a hydraulic pressure of 1,5 times the working pressure, but not less than 0,4 MPa, whereas box structures shall be tested by a pressure equal to 1,5 times their working pressure.

13.1.3 Pneumatic leak tests of the components working under the refrigerant pressure shall be carried out at a test pressure of not less than the design pressure assumed according to **2.2.1**.

13.1.4 Equipment designed for operation under pressure of a refrigerant, which is below the atmospheric pressure, shall be subjected to vacuum-tight tests at a residual pressure of not more than 0,8 kPa.

13.1.5 Valves in assembly and automatic devices provided with shut-off facilities shall be subjected to a leak test by pneumatic pressure equal to the design pressure in accordance with **2.2.1**.

13.1.6 The machinery and equipment specified in **1.3.2** after assembling shall be tested in accordance with the requirements of **1.4**, Part IX "Machinery".

13.2 TESTING OF REFRIGERATING PLANT ON BOARD

13.2.1 To verify the fulfilment of the requirements of this Chapter, the refrigerating plant, after having been completely assembled on board, shall be tested and checked in operation under a programme approved by the Register.

13.2.2 The entire refrigerant system shall be subjected to pneumatic leak tests at a test pressure equal to the design one in accordance with **2.2.1**.

Pneumatic tests may be carried out using nitrogen, carbon dioxide or dried air.

Upon completion of leak test of the Group II refrigerant system, operation of the refrigerant emergency drain system shall be checked.

13.2.3 Upon completion of leak test, the Group I refrigerant system shall be tested for tightness by a vacuum test at a residual pressure of not more than 1 kPa.

13.2.4 After the system has been filled with refrigerant all joints and valves shall be checked for leak.

13.2.5 All pipes of secondary refrigerant and cooling water systems together with pertaining valves shall be subjected to leak tests under operational conditions.

13.2.6 The main and emergency ventilation, drainage, water-screen, remote machinery shutdown, safety devices, protective automatic equipment, refrigerant leak gas detection systems shall be checked in operation.

13.2.7 The refrigerating plant equipment shall be checked in operation under all operational conditions and along with that the fulfilment of the requirements of **2.3** and **7.2.8**, the work of the regulating automatic equipment and cooling facilities, defrosting efficiency shall be verified.

13.2.8 The refrigerating plant shall be tested at full design cooling load and specified refrigerant boiling and condensing temperatures. Where the tests are carried out at low outdoor temperatures, which differ from the specified ones, the simulation of additional cooling load may be required.

13.2.9 The calculation results of an averaged heat-transfer factor for refrigerated spaces shall be confirmed by insulation quality tests.

13.3 TESTING OF REFRIGERATING PLANT WITH ATMOSPHERE CONTROL

13.3.1 Air ducts to thermal containers shall be tested for distribution of cooled air by measuring the amount of air supplied to the flexible coupling of the container when the fan is running at full capacity.

Air flow (by amount of air) available at each thermal container shall not differ by more than ±5 % from the design one.

13.3.2 After cooled air ducts have been completely fitted onboard before installation of insulation, strength tests shall be carried out by air pressure of not less than 1,5 times the design pressure and also leak tests shall be carried out by a working pressure; the above tests may be combined.

14. SPARE PARTS

14.1 GENERAL

14.1.1 Each refrigerating plant shall be provided with spare parts carried on board to an extent that is not less than required by this Section.

14.1.2 The spare parts shall be secured in accessible positions marked and protected against corrosion in an effective way.

14.2 REQUIRED MINIMUM OF SPARE PARTS

14.2.1 Compressors, pumps and internal combustion engines driving the compressors shall be supplied with spare parts according to the provisions of Section **10**, Part VII "Machinery Installations".

Electric motors of compressors, pumps and fans shall be supplied with spare parts according to the provisions of Section **21**, Part XI "Electrical Equipment".

14.2.2 Apart from the requirements of **14.2.1**, the refrigerating plants shall be supplied with spare parts in accordance with Table 14.2.2.

Table 14.2.2

№	Spare parts	Quantity
1	Compressor piston with connecting rod complete, of each size used	1
2	Shaft seal[1] for compressor of each size used	1
3	Liner of compressor cylinder of each size used	1
4	Blades of rotary compressor of each size used	1 set[2]
5	Crankshaft bearings of piston compressor or rotor bearings of screw compressor	1 set[2]
6	Lubricating oil pump of piston, screw compressor	1
7	Filter elements of each type and size	1
8	Automatic monitoring and protective devices for refrigerating plant of each type	1
9	Fan impeller with shaft for refrigerated spaces and freezing apparatus of each size used	1
10	Control refrigerant expansion valve of each size used	1
11	Assorted cocks, valves of each size used	1
12	Gaskets and packings of each size used	1
13	Thermometers, pressure gauges and vacuum gauges of each size used	1
14	Safety valve springs of each size used	2
15	Leak detector	1
16	Hydrometer (only where the liquid secondary refrigerant is used)	1

[1] To be provided as spare parts are rapidly wearing parts of seals only if it is permitted by the seal design.
[2] Set for each compressor.

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